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Macroevolution of early tetrapods

By

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A dissertation submitted to the University of Bristol in accordance with the requirements of the degree of Doctor of Philosophy in the Faculty of Science.

December 2018

Word count: two hundred three thousand one hundred and twenty-seven

ABSTRACT

About 390 million years ago the transition from water to land paved the way for the success story of the most iconic clade of animals, the four-limbed tetrapods. The first half of the evolutionary history of Tetrapoda was characterised by major radiations, massive biotic crises, restructuring of vertebrate ecosystems, and ultimately the appearance of most modern tetrapod subclades. Previous macroevolutionary analyses of early tetrapods focused on smaller subclades, relied on imprecise stratigraphic data, did not incorporate phylogenetic relationships, and ignored the potential for heterogeneity in evolutionary rates.

Here I present the only comprehensive database (2,142 valid species) and associated supertrees spanning the first 200 million years of tetrapod evolution, with state-of-the-art alpha taxonomy and substage level stratigraphic resolution. Using this dataset and appropriate phylogenetic comparative methods I am able to show that rates of body size evolution were highly heterogeneous in terrestrial early tetrapods following the Simpsonian concept of quantum evolution (chapter 2). Unlike previously suggested, high rates of body size evolution were not responsible for the success of early tetrapod clades and were potentially a signal for stress. Similar to the rates of body size evolution, rates of the mandibular functional complex were also heterogeneous in early archosauromorphs (chapter 3). Despite the rate heterogeneity I find no evidence for positive phenotypic selection acting on the lower jaw of early archosauromorphs, consistent with a non-competitive model of replacement of faunas in the aftermath of the Permo-Triassic mass extinction event (PTME). Finally, I am able to show the complexity of speciation dynamics in early tetrapods prior to the PTME (chapter 4). ‘Amphibians’ were in decline tens of millions of years before the mass extinction, but amniotes were thriving up to the last moment indicating that without the PTME Palaeozoic terrestrial ecosystems probably would have persisted much longer into the Mesozoic.

DEDICATION AND ACKNOWLEDGEMENTS

I would like to thank my supervisors Michael Benton, Marcello Ruta, and Alexander Dunhill for their continuous support and encouragement. I would also like to thank Manabu Sakamoto, Chris Venditti, and Andrew Meade for their help with BayesTraits and MCMCglmm. Special thanks go to Suresh Singh for providing me with some of the data used herein and for suggesting several interesting collaborations.

Many thanks also to Graeme Lloyd and David Bapst for helpful discussions on time-scaling and to Emily Rayfield and Phil Anderson for help with functional measurements. Christian Kammerer, Jörg Fröbisch, Sterling Nesbitt, William Parker, Augustín Martinelli, Christian Sidor, Torsten Scheyer, Eric Buffetaut, Hans Hagdorn, Kenneth Angielczyk, Olivier Rieppel, Rainer Schoch, Angela Milner, Andrew Milner, Frederik Spindler, Jocelyn Falconnet, Blair McPhee, Timothy Smithson, Jason Pardo, Jason Anderson, Jozef Klembara, David Berman, Grzegorz Niedźwiedzki, Martín Ezcurra, David Button, Stephan Lautenschlager, Axel Hungerbühler, Fabio Marco Dalla Vecchia, Ralf Werneburg, Jörg Schneider, Pamela Gill, Paul Barrett, and Spencer Lucas are all thanked for help with alpha taxonomy and stratigraphy. I would also like to thank Mark Puttick, Max Stockdale, Ben Moon, and Tom Stubbs for their advice on various computational methods. Thanks to all members of the Bristol Palaeobiology Group for creating such an enjoyable working environment.

A big thanks to Mark Olenik for countless discussions on coding practice, mathematics, philosophy, and last but not least for cross-checking this thesis. Jorge Herrera-Flores, thank you for inviting me so often for dinner - the molletes were a pleasure.

Finally, I would like to thank my parents for always supporting me in this unusual career choice.

AUTHOR'S DECLARATION

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

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CHAPTER 1

INTRODUCTION

In the last 40 years the usage of phylogenetic comparative methods has become ubiquitous. Especially the last decade has been interesting due to the introduction of new methods that could account for heterogeneity in evolutionary rates. These new methods have often been applied to extant taxa, but rarely so to phylogenies including fossil species.

Mammals, amphibians, 'reptiles', and birds – the Tetrapoda – are a major component of today's terrestrial ecosystems. Their rise to dominance, however, was a bumpy road. More than once in its evolutionary history it seemed as if tetrapod life would face its final doom. Especially the first 200 million years in the evolution of tetrapods were characterised by major upheavals, among them the 'Mother of Mass Extinctions'. Given their eventful history, one would expect evolutionary rates to have varied substantially through time in early tetrapods. It stands to reason that early tetrapods could provide an exceptional opportunity to analyse long-debated macroevolutionary concepts such as 'quantum evolution', 'early bursts', competitive replacements, and long-term speciation slowdowns. Large-scale macroevolutionary (or rather mega-evolutionary; Simpson, 1944) analyses of early tetrapods appear therefore overdue. The aim of this project was to study macroevolutionary patterns of early tetrapods in a variable rates framework. This approach allowed me to test long-standing ideas on the success and demise of various tetrapod groups.

After defining the term 'early tetrapods' in the following paragraphs I give a short introduction to the evolutionary history of early tetrapods. This summary is by no means complete and focuses on key innovations and key events, especially mass extinctions, in the evolutionary history of early tetrapods. It is meant to provide a historical framework for the subsequent chapters and to emphasise the varied history of early tetrapods. Furthermore, a short introduction to some of the analytical methods used herein is provided as well.

1.1 Definition of 'early tetrapods'

The origin of the term 'tetrapods' is unclear (Clack and Milner, 2015). The vernacular German term 'Tetrapoden' was already used by Gegenbaur (1898) and Gegenbaur (1901) and the latinized form 'Tetrapoda' appeared later in the German (von Huene, 1913) and English literature (Goodrich, 1930). Older usage of 'Tetrapoda' is known (e.g., Haworth, 1825), even going back to Aristotle (Dana, 1863; Owen, 1859), but was very different from modern understanding of the term (Clack and Milner, 2015). Recently it has been suggested that Jaekel (1909) was the first to formally recognise Tetrapoda in the modern sense (Sues, 2019).

Historically, Tetrapoda has been understood as referring to all taxa with digitized limbs (Anderson, 2002b). The departure from the implicit apomorphy-based definition (= the first vertebrate with digits and all of its descendants; de Queiroz and Gauthier, 1990) in favour of node- or stem-based definitions has led to some confusion as to what the term actually means (Clack, 2012; Clack and Milner, 2015). The node-based 'crown-group' concept of Tetrapoda defines the clade as the group including the most recent common ancestor of extant amphibians and amniotes and all of its descendants (Gauthier et al., 1988), thereby excluding several Palaeozoic limbed vertebrates which previously have generally been considered 'tetrapods' (Anderson, 2002b). The stem-based 'total group' concept of Tetrapoda, defines the clade as all species that are more closely related to extant tetrapods than to either coelacants or lungfish, depending on the preferred topology (Clack and Milner, 2015). The total group concept used by Coates (1996) for the term Tetrapoda and by Ahlberg (1991a) for the term Tetrapodomorpha implies the inclusion of several non-digitized 'fish' in Tetrapoda (Anderson, 2002b; Clack and Milner, 2015). Using the term Tetrapodomorpha (Ahlberg, 1991a) for the total group definition and Neotetrapoda (Gaffney, 1979; Anderson, 2001) for the crown group definition can be useful (Clack and Milner, 2015), but does not clarify the meaning of Tetrapoda itself.

It is beyond the scope of this thesis to discuss the merits and drawbacks of the different definitions, which has already amply been done in the literature (e.g., Laurin, 1998; Anderson, 2001; Laurin, 2002; Anderson, 2002b; Laurin and Anderson, 2004; de Queiroz, 2007; Clack, 2012; Clack and Milner, 2015; see also usage in Coates et al., 2008). Here I adopt a pragmatic approach and consider Tetrapoda as the clade including all species included in the database of Benton et al. (2013c), their most recent common ancestor, and all of its descendants. The taxon content of this clade is therefore very similar to the 'tetrapod' concept of Clack (2012), and Clack and Milner (2015), who suggested to use the vernacular term 'tetrapod' to designate vertebrates with four legs that bear digits. The clade contains all the species described as 'basal tetrapods' or tetrapodomorphs (see comment of H.-D. Sues in Clack and Milner, 2015, p. V) in Clack and Milner (2015). The major difference between tetrapods *sensu* Benton et al. (2013c) and tetrapods *sensu* Clack and Milner (2015) is that the former also include a few species (*Livoniana multidentata*, *Tiktaalik roseae*, *Elpistostege watsoni*) as tetrapods, that are "basal to stem-tetrapods" according to Clack and Milner (2015, p. 13). The term 'early tetrapods' used herein follows the usage of

Benton et al. (2013c) and designates all tetrapods that appeared between the origin of the clade in the Middle Devonian, about ~390 million years ago (Ma), and the end of the Early Jurassic, 174.1 Ma.

1.2 Evolutionary history of early tetrapods

1.2.1 The conquest of land

The first part of the evolution of early tetrapods was characterised by the conquest of land. Niedźwiedzki et al. (2010) described the oldest tetrapod trackways from the early Middle Devonian (Eifelian) of Poland. These tracks are 390–391 Myr old (Narkiewicz and Narkiewicz, 2015) and thus 14 Myr older than the oldest tetrapod body fossils, if the late Frasnian elginerpetids *Elginerpeton pancheni*, *Obruchevichthys gracilis*, and *Webererpeton sondalensis* (Vorobyeva, 1977; Ahlberg, 1991b, 1995, 1998; Ahlberg and Clack, 1998; Ahlberg et al., 2005a; Ahlberg, 2011; Clément and Lebedev, 2014) are considered the oldest tetrapods. If the late Givetian *Livoniana multidentata* (Ahlberg et al., 2000) is the oldest known tetrapod, as treated herein (see discussion above; see also Ahlberg, 2019), the age gap between the body fossils and the oldest footprints is reduced to 5–8 million years. Biomechanical analyses have shown, that these trackways could not be made by *Ichthyostega*-like tetrapods (Pierce et al., 2012), but their importance as first evidence for the move onto land of vertebrates remains. The next oldest tetrapod trackways are known from the middle–late Givetian (384.9 Ma) of Ireland (Stössel et al., 2016), much closer in age to *Livoniana multidentata*.

Devonian tetrapods were characterised by a combination of characters that are typically associated with an aquatic (e.g., presence of a lateral-line system, presence of gills, tail fin formed of bony fin rays) and terrestrial lifestyle (e.g., presence of a sacrum, increased size of ribcage and limb girdles, smaller tail fin) (Coates and Clack, 1990, 1991; Clack and Coates, 1995; Coates, 1996; Ahlberg et al., 2005b; Callier et al., 2009; Pierce et al., 2012; Sanchez et al., 2016; Ahlberg, 2019). Recently it has been suggested that some of these character combinations might have been due to early reversals to a secondarily aquatic condition (Ahlberg, 2019). Increases in eye size preceded terrestrialisation (MacIver et al., 2017) and the move onto land was potentially facilitated by an exaptation of the tetrapod tail (McInroe et al., 2016).

1.2.2 The Late Devonian Biodiversity Crisis and ‘Romer’s Gap’

Three of the ‘Big Five’ mass extinctions took place during the evolutionary history of early tetrapods. The ‘Late Devonian Biodiversity Crisis’ (Stigall, 2010) was characterised by three extinction events, the Taghanic event (385 Ma), the famous Kellwasser event (374 Ma), and the Hangenberg event (359 Ma) (Friedman and Sallan, 2012). Only the latter one led to a decrease in tetrapod diversity (Sallan and Coates, 2010, fig. 1; but consider the low apparent diversity of tetrapods during this time period – see Benton et al., 2013c). Devonian tetrapods mainly inhabited aquatic environments characterised by quick salinity changes such as deltas and estuaries and it has been suggested that their euryhaline nature helped them survive these crises (Goedert et al., 2018). By the end of the Devonian, the 'Age of Fishes' (Coates, 2009) had ended and the 'Age of Amphibians' had begun (Friedman and Sallan, 2012). Tetrapods might have been globally distributed by that time (Gess and Ahlberg, 2018).

Romer (1956b) recognised a major gap in the fossil record of early tetrapods spanning about 30 million years from the end of the Devonian to the end of the Visean, separating the (semi-)aquatic fish-like Devonian tetrapods from the fully terrestrial Carboniferous ones (Smithson et al., 2012). It is now clear that the aptly termed 'Romer's Gap' (Coates and Clack, 1995) was a mere articaft of collection failure (Smithson et al., 2012) and major collection efforts especially in the last two decades have helped closing this gap (Paton et al., 1999; Clack, 2002; Warren and Turner, 2004; Clack and Ahlberg, 2004; Smithson et al., 2012; Anderson et al., 2015; Clack et al., 2016; Smithson and Clack, 2018; Otoo et al., 2019; Chen et al., 2018).

1.2.3 Carboniferous diversification and CRC

Typical tetrapods of the early Carboniferous were the whatcheeriids, baphetoids, colosteids, and the Scottish taxon *Crassigyrinus scoticus* (Coates et al., 2008; Clack and Milner, 2015). Unlike the polydactylous Devonian forms (Coates and Clack, 1990; Coates, 1996), the predatory whatcheeriids were probably pentadactylous in a functional sense and better adapted to a terrestrial life (Lombard and Bolt, 1995; Clack, 2002; Clack and Finney, 2005). Most baphetoids, which are only known from cranial material, were probably crocodile-like piscivores (Clack and Milner, 2015), except for the spathicephalids which probably relied on suction feeding of small invertebrates (Beaumont and Smithson, 1998; Smithson et al., 2017). Colosteidae was a clade of aquatic predators with elongated body (Clack and Milner, 2015), whose maximum size and mode of life might have been similar to the extant Asian giant salamander (Godfrey, 1989). *Crassigyrinus scoticus* was a relatively large (~2 m body length) specialised aquatic predator with a massive skull and an eel-like body (Clack and Milner, 2015).

The Pennsylvanian was characterised by widespread tropical rainforests (the 'Coal Forests') across Europe, North America, and China (Cleal and Thomas, 2005; DiMichele et al., 2007). High oxygen levels (Ward et al., 2006; Glasspool and Scott, 2010) during this time were probably responsible for the size gigantism observed in insects (Harrison et al., 2010). The extensive coal swamps and new ecological opportunities allowed the water-dependant 'amphibian'-grade early tetrapods to further diversify (Coates et al., 2008; Carroll, 2009; Benton, 2015c). Temnospondyls, anthracosaurs, and lepospondyls all originated in the Mississippian but only started to dominate in the late Carboniferous (Coates et al., 2008), during which also the small terrestrial gephyrostegids appeared (Boy and Bandel, 1973; Klembara et al., 2014). Temnospondyls and lepospondyls represent the two most speciose clades of anamniote early tetrapods and one of the two clades probably gave rise to modern Lissamphibia (Ruta and Coates, 2007; Pardo et al., 2017b; Marjanović and Laurin, 2019). Similar to the heated debate on the origin of lissamphibians (Ruta and Coates, 2007; Sigurdsen and Green, 2011; Maddin and Anderson, 2012; Maddin et al., 2012; Pardo et al., 2017b; Vallin and Laurin, 2004; Marjanović and Laurin, 2008, 2009; Pyron, 2011; Marjanović and Laurin, 2013, 2019) it is unclear, whether the small but morphologically diverse lepospondyls with similarities to modern lizards and snakes (Coates et al., 2008) were monophyletic or not (Anderson, 2001, 2007; Huttenlocker et al., 2013; Pardo et al., 2017a; Marjanović and Laurin, 2019). The species number of Temnospondyli was even higher than that of lepospondyls and their body length ranged from 5 cm to 5 m, but they were less morphologically diverse, mainly represented by aquatic and amphibious predators, albeit several terrestrial temnospondyls are known as well (Schoch and Milner, 2000, 2014). Anthracosaurs included both large crocodile-like aquatic predators and smaller terrestrial taxa (Smithson, 2000; Coates et al., 2008).

Early tetrapods faced several big climate changes, with a prominent example at the end of the Carboniferous during which the climate changed from humid to semi-arid conditions (Montañez et al., 2007). This change during the late Moscovian-Kasimovian was coupled with a collapse of the Carboniferous tropical rainforests (CRC) that led to the extinction of 91% of 'amphibian' genera (Benton et al., 2013c; Sahney et al., 2010). The anamniote baphetids, colosteids, three 'lepospondyl' families, and the potential stem amniote families Gephyrostegidae, Anthracosauria, and Solenodonsauridae all went extinct (Sahney et al., 2010). Dendrerpetidae, a family of terrestrial salamander-like temnospondyls (Schoch and Milner, 2014), also became extinct (Sahney et al., 2010), but the mean diversity of Temnospondyli remained unchanged during the late Carboniferous and early Permian (Ruta and Benton, 2008). Amniotes, which had already appeared in the fossil record prior to the event in the late Bashkirian (Reisz and Müller, 2004; Benton et al., 2015), were less heavily affected (Benton et al., 2013c) and it was suggested that the rainforest collapse was accompanied by the acquisition of new feeding strategies (Sahney et al., 2010). Rather than representing a sudden 'collapse' (Sahney et al., 2010) the vegetational change might have been more gradual with a transition from wetlands to drylands spanning much of the late Pennsylvanian (Cleal et al., 2009; Dunne et al., 2018) and it has recently been suggested that the floral change was accompanied by increased cosmopolitanism (Dunne et al., 2018) rather than increased endemism (Sahney et al., 2010). This increase in biogeographic connectedness was mainly driven by amniotes which were not confined to wetland environments (Dunne et al., 2018). Another study found support for decreased dispersal and increased vicariance during the late Carboniferous (Brocklehurst et al., 2018). The apparent conflict with the results of Dunne et al. (2018) has been explained as a result of scale difference (Brocklehurst et al., 2018). Open landscapes facilitated dispersal (of amniotes) at a smaller regional scale (Dunne et al., 2018; Brocklehurst et al., 2018), but dispersal was reduced at continental scale due to orogenic activity and resulting mountain barriers (Brocklehurst et al., 2018). With the end of the Carboniferous rainforests, the dominance of 'amphibian'-grade tetrapods was shattered and amniotes took over as the dominant tetrapods during the Permian (Carroll, 1977, 2009; Sahney et al., 2010; Benton et al., 2013c; Dunne et al., 2018). Latest Carboniferous and Early Permian terrestrial ecosystems were already characterised by ‘pelycosaurian’-grade synapsids (Benson, 2012; Brocklehurst et al., 2013b).

1.2.4 Permian diversification and PTME

The Permian was characterised by the further diversification of early tetrapods before metazoan life was facing its largest crisis, the Permo-Triassic mass extinction event (PTME) (Erwin, 1994; Benton and Twitchett, 2003). Anthracosaurs and most lepospondyls had gone extinct by the end of the Early Permian (Smithson, 2000; Coates et al., 2008; Clack, 2012; Huttenlocker et al., 2013). The major anamniote clades of the Permian were the temnospondyls, the seymouriamorphs, the chroniosuchians, and the diadectomorphs (Klembara and Ruta, 2005; Coates et al., 2008; Buchwitz et al., 2012; Clack, 2012; Schoch and Milner, 2014; Liu and Bever, 2015). Temnospondyls diversified massively during the Permian (Schoch, 2013; Schoch and Milner, 2014), but experienced a diversity drop during the Middle and Late Permian (Ruta and Benton, 2008). Recent phylogenetic analyses recover seymouriamorphs, chroniosuchians, and diadectomorphs on the amniote stem (Klembara et al., 2014; Liu and Bever, 2015; Clack et al., 2016; Witzmann and Schoch, 2018). The widely distributed (North America, Europe, Asia) seymouriamorphs were a relatively small predatory clade with mainly aquatic juveniles and terrestrial adults (Laurin, 2000). Chroniosuchia was a clade of mainly amphibious to terrestrial crocodile-like tetrapods, that did not appear before the Middle Permian and managed to survive the PTME (Witzmann and Schoch, 2018). Diadectomorphs were terrestrial, relatively bulky tetrapods (Sues and Reisz, 1998) and one of the first herbivorous tetrapod lineages, the other being Captorhinidae and the synapsid families Edaphosauridae and Caseidae (Reisz and Fröbisch, 2014).

A recent study suggested the origination of many diapsid lineages in the Permian (Simões et al., 2018) but generally the fossil record of Diapsida was very poor during this time interval (Reisz et al., 2010; Ezcurra et al., 2014). Capthorinids had relatively few species compared to the other major amniote clades of the Permian, the synapsids and the parareptiles, but were very abundant during the early Permian (Modesto et al., 2018). Their total length ranged from 25 cm to 2.5 m (Reisz et al., 2011c) and shifts in the rates of body size evolution have been reported, which, however, did not coincide with the evolution of high-fibre herbivory in the clade (Brocklehurst, 2016).

Despite their moderate clade size, parareptiles were characterised by relatively high ecological and morphological diversity (Tsuji and Müller, 2009). Pareiasauria, a parareptilian subclade of relatively large and bulky herbivores, was a major component of Middle and Late Permian terrestrial faunas (Benton, 2016). Previous suggestions of a close phylogenetic relationship of modern turtles and pareiasaurs (Lee, 1993, 1995, 1996, 1997b) are now rejected by analyses based on molecular (Shen et al., 2011; Crawford et al., 2012; Chiari et al., 2012; Field et al., 2014;

Crawford et al., 2015) and fossil data (Lee, 2013; Bever et al., 2015; Schoch and Sues, 2015). It is now generally accepted that parareptiles became extinct at the end of the Triassic (Ruta et al., 2011; Tsuji, 2018; Zaher et al., 2019).

Synapsids were the dominant component of Permian terrestrial ecosystems, represented by the 'pelycosaur' grade (Romer and Price, 1940; Reisz, 1986; Benson, 2012; Reisz, 2014) during the Early Permian. The paraphyletic group of 'pelycosaurs' included large high-fiber herbivores (Caseidae, Edaphosauridae), small insectivores (Eothyrididae), and small (Varanopidae; but see their phylogenetic position in Ford and Benson, 2019) to large carnivores (Ophiacodontidae, Sphenacodontidae) (Romer and Price, 1940; Reisz, 1986, 2014). The most iconic 'pelycosaurs' were probably the sail-backed herbivorous *Edaphosaurus* and the top predator *Dimetrodon* whose sail might have had a thermoregulatory function (Haack, 1986).

During Olson's extinction (Sahney and Benton, 2008; Benton, 2012; Brocklehurst et al., 2013b, 2017), which some authors had considered a gap in the fossil record of early tetrapods (Lucas and Heckert, 2001; Lucas, 2001, 2004, 2006, 2013a, 2017), the typical 'pelycosaurian' fauna became extinct and was succeeded by Therapsida, the modern synapsids, in the Middle Permian. Temnospondyls experienced a significant drop in (phylogenetic) diversity (Ruta and Benton, 2008). A decrease in parareptilian diversity was only observed when phylogeny-corrected values were analysed (Ruta et al., 2011).

Therapsida were represented by the six subclades Biarmosuchia, Dinocephalia, Anomodontia, Gorgonopsia, Therocephalia, and Cynodontia (Rubidge and Sidor, 2001). Biarmosuchia, an early diverging branch of Therapsida (Liu et al., 2009), consisted of small- to medium-sized carnivores which partially resembled 'pelycosaurs' (Rubidge and Sidor, 2001; Sidor and Rubidge, 2006). The large dinocephalians included both carnivorous (Kammerer, 2011) and herbivorous forms (Rubidge and Sidor, 2001; Güven et al., 2013). The majority of anomodonts belongs to Dicynodontia, a highly successful clade of strict herbivores (Kammerer et al., 2011; Fröbisch, 2014a; Angielczyk et al., 2018). Anomodonts had a large range of body size (Fröbisch, 2014a) and were ecologically quite diverse including even arboreal taxa (Fröbisch and Reisz, 2011) and herbivorous species with sabre teeth (Cisneros et al., 2011). The sabre-toothed gorgonopsians were exclusively carnivorous (Kammerer, 2014b) and the top predators of Late Permian terrestrial ecosystems in southern Africa (Kammerer, 2015, 2016b) and Russia (Kammerer and Masyutin, 2018b). Therocephalians were an ecologically diverse clade of therapsids that exhibited several convergences with cynodonts (Huttenlocker, 2009) and included large carnivorous, small insectivorous, and small herbivorous taxa during different stages in their evolutionary history (Kammerer and Masyutin, 2018a). Cynodonts, which include modern mammals, first appeared in the Late Permian (Botha et al., 2007; Kammerer, 2016a), but mainly diversified in the Triassic into the primarily herbivorous Cynognathia and the carnivorous/insectivorous Probainognathia (Ruta et al., 2013).

The Capitanian ('end-Guadalupian') mass extinction event removed about 74–80% of the tetrapod genera in the Karoo Basin (Day et al., 2015a). Nearly all members of Dinocephalia went extinct (Day et al., 2018b). All early diverging, large pareiasaurs and the remaining members of Varanopidae became extinct marking the final extinction of 'pelycosaurs' (Day et al., 2015a). Dicynodonts and therocephalians were less heavily affected (Day et al., 2015a). Increased aridity might have been linked to the mass extinction event although the exact mechanism is still unclear (Rey et al., 2018).

The most likely trigger for the PTME was the large igneous province (LIP) volcanism of the Siberian Traps in Russia (Wignall, 2001; Benton and Twitchett, 2003; Payne and Clapham, 2012; Burgess and Bowring, 2015; Bond and Grasby, 2017; Broadley et al., 2018). The terrestrial mass extinctions were probably caused by acid rain, global warming, and massive soil erosion, all resulting directly or indirectly from the sulfate, carbon dioxide, and methan emissions of the Siberian Traps LIP volcanism (Benton and Newell, 2014). Perhaps to a lesser degree, increased aridity, wildfires, hypoxia, and a destroyed ozone layer might have also contributed to the extinction on land (Benton, 2018). The magnitude of the end-Permian event, the greatest mass extinction of all time (Erwin, 1990; Benton and Twitchett, 2003), is exemplified by the substantial amount time (8–9 Myr) that was necessary for ecosystems to fully recover (Chen and Benton, 2012). About ~81% of all marine species (Stanley, 2016) and 84 out of 95 tetrapod genera (89%) were lost during the end-Permian mass extinction (Benton et al., 2013c). Extinctions in sauropsids, therapsids, and temnospondyls were not random but phylogenetically clustered (Soul and Friedman, 2017). Indeed, palaeocommunities during the PTME were more locally stable due to selective extinction of smaller amniotes (Roopnarine and Angielczyk, 2015a). Terrestrial ecosystems were heavily remodelled: seymouriamorphs, capthorhinids, biarmosuchians, gorgonopsians, and pareiasaurs went completely extinct and dicynodonts and therocephalians took a massive hit in diversity (Benton and Newell, 2014; Viglietti et al., 2016). In the Russian South Urals basin only two tetrapod families managed to survive the PTME: a clade of small Parareptilia, the procolophonids, and the medium-sized dicynodontids (Benton et al., 2004). The typical disaster taxon with global distribution and large abundance in the immediate aftermath of the PTME was *Lystrosaurus* (Fröbisch, 2009; Irmis and Whiteside, 2012; Benton and Newell, 2014). Cynodonts (Ruta et al., 2013), archosauromorphs (Sookias et al., 2012b; Ezcurra and Butler, 2018), procolophonids (Ruta et al., 2011), and some temnospondyl families (Ruta and Benton, 2008) diversified during the (Early) Triassic.

1.2.5 Rise of Archosauromorpha and ETME

The Triassic is insofar interesting as it marks the origin of many modern clades, like Lepidosauria (Jones et al., 2013), Crocodyliformes (Irmis et al., 2013a), (basal) mammals (Lucas and Luo, 1993; Luo et al., 2002), and Testudines (Joyce et al., 2013). This exemplifies the importance of the evolutionary history of early tetrapods for modern ecosystems.

During the Triassic marine reptiles appeared for the first time and started to diversify (Rieppel, 2000; McGowan and Motani, 2003; Benton et al., 2013b; Motani et al., 2017). Archosauromorphs, which had already appeared in the Late Permian (Gottmann-Quesada and Sander, 2009), started to dominate terrestrial ecosystems in the aftermath of the PTME (Benton et al., 2004; Sookias et al., 2012b; Ezcurra and Butler, 2018). Initially, early archosauromorph clades such as the herbivorous rhynchosaurs (Schultz et al., 2016) and allokotosaurs (Sengupta et al., 2017), early archosauriform clades such as the large, predatory erythrosuchids (Ezcurra et al., 2019), the crocodile-like Proterochampsia (Trotteyn et al., 2013), and the archosaurian Pseudosuchia with herbivorous (Aetosauria; Parker, 2016) and hypercarnivorous members ('rauisuchid' Paracrocodylomorpha; Nesbitt et al., 2013c) were the major components of Triassic terrestrial ecosystems. The iconic dinosaurs might have appeared already in the Middle Triassic (Nesbitt et al., 2013d), but the so called 'dinosaur diversification event' happened only after the Carnian Pluvial Event (CPE) in the middle Carnian during which the climate switched from arid conditions to humid ones and then back again (Bernardi et al., 2018a). The rise of dinosaurs was initially explained by outcompeting other terrestrial tetrapods (Bakker, 1972), but this view has been superseded by an alternative opportunistic model, in which dinosaurs owe their success to three extinctions, namely the end-Permian, Carnian-Norian (extinction of all rhynchosaurs and nearly all dicynodonts), and the end-Triassic event (ETME) (Brusatte et al., 2008a; Benton et al., 2014a). Thus, rather than by a Red Queen model the initial success of dinosaurs can be explained by a Court Jester model (Benton, 2009), which emphasises the abiotic component of evolution.

During the fourth of the 'Big Five' mass extinctions at the Triassic-Jurassic boundary tetrapods experienced a loss of 41% of genera (Benton et al., 2013c). Several pseudosuchian clades such as the crocodilian-like phytosaurs (Stocker and Butler, 2013), the carnivorous and potentially facultative bipedal ornithosuchids (von Baczko and Ezcurra, 2013), and the 'rauisuchian' members of Paracrocodylomorpha (Nesbitt et al., 2013c) became extinct. This enabled the second diversification of dinosaurs in the Early Jurassic (Brusatte et al., 2008b). It has been suggested that ornithischians entered several of the ecological niches left vacant after the ETME (Butler et al., 2007). The mass extinction event has been linked to the central Atlantic magmatic province (CAMP) LIP volcanism (Deenen et al., 2010; Davies et al., 2017). Note, however, that some authors have suggested that the ETME was not a single event but a series of multiple extinction events in the Late Triassic (Lucas and Tanner, 2018).

1.3 Phylogenetic comparative methods

All organisms are phylogenetically related (Darwin, 1859; Theobald, 2010). The shared ancestry implies that trait data of species cannot be considered independent when attempting interspecific comparisons, thus violating statistical assumptions (Felsenstein, 1985). The closer the relationship, the smaller the variance in trait values between species. Recently it has been shown that not just species traits but also evolutionary rates can carry a phylogenetic signal (Sakamoto and Venditti, 2018). Realising that the non-independence of species trait values needed to be accounted for in statistical analyses sparked the development of phylogenetic comparative methods (Felsenstein, 1985). These are similar to linear modelling approaches (e.g., general linear models, regressions) widely applied in science but account for the effect of phylogeny (Freckleton, 2012). Generally these models assume that trait values evolve according to a model of Brownian motion (BM) (Felsenstein, 1985; Freckleton, 2012). In a BM model, when changing from one time interval to the next, trait values are drawn from a normal distribution with the mean zero and a variance σ^2 (Felsenstein, 1973; Cooper et al., 2016a). The changes that occur during time interval t are expected to have a mean of zero and a variance $\sigma^2 t$, i. e. the expected variance increases linearly with time (Felsenstein, 1973; Freckleton, 2012).

A generalised least squares (GLS) approach can be used to determine whether a (continuous) trait covaries with evolutionary divergence (Pagel, 1997). When studying a single trait the GLS approach runs a regression of the trait on the elapsed time from the root to the species (= total phylogenetic path length). The trait value of each species is treated to be predicted by the regression (Pagel, 1997). The log-likelihood of observing trait data assuming a BM model within a GLS framework is (Venditti et al., 2011; Freckleton, 2012):

$$L\left(\mu_y, \sigma_y | \mathbf{V}\right) = -\frac{1}{2}\left[n\log(2\pi) + \log\left|\sigma^2\mathbf{V}\right| + \left(\mathbf{Y} - \mu_y\mathbf{X}\right)'\left(\sigma^2\mathbf{V}\right)^{-1}\left(\mathbf{Y} - \mu_y\mathbf{X}\right)\right], \tag{1.1}$$

with $\sigma^2{}_y$ as the evolutionary rate of trait y per time t, μ_y as the state of y at the root, n as the number of species, $\mathbf{V}$ as the expected variance-covariance matrix (given by the phylogeny), $\mathbf{Y}$ as the trait matrix, and $\mathbf{X}$ as a matrix of 1s.

The maximum likelihood estimates of the mean/root parameter and the variance/rate parameter are (Freckleton, 2012):

$$\mu_y = \left(\mathbf{X}'\mathbf{V}^{-1}\mathbf{X}\right)^{-1}\left(\mathbf{X}'\mathbf{V}^{-1}\mathbf{Y}\right), \tag{1.2}$$

$$\sigma^2{}_y = \frac{1}{n}\left(\mathbf{Y} - \mu_y\mathbf{X}\right)'\mathbf{V}^{-1}\left(\mathbf{Y} - \mu_y\mathbf{X}\right), \tag{1.3}$$

with $\mathbf{V}^{-1}$ as the inverted variance-covariance matrix.

A fast (Felsenstein, 1973; Freckleton, 2012) but less flexible (Pennell and Harmon, 2013) alternative to the GLS approach is the independent contrasts (IC) method (Felsenstein, 1973, 1985). Despite the methodological difference both GLS and IC give identical likelihood and parameter estimates when fit to the same dataset (Garland and Ives, 2000; Freckleton, 2012). Both are implemented in BayesTraits (Venditti et al., 2011; Meade and Pagel, 2016).

The IC method can be outlined as follows (Freckleton, 2012). A pair of adjacent species i and j, with trait values y_i and y_j and terminal branch lengths v_i and v_j, is selected. The difference in trait values $u_{ij} = y_i - y_j$ is calculated, giving the contrast u_{ij} for the last common ancestor k of species i and j. Contrast u_{ij} has an expectation of zero and a variance $V_i = v_i + v_j$. Now, the mean of the two trait values y_i and y_j is weighted by the variance V_i and the calculated value $y_k = \left(\frac{1}{v_i} y_i + \frac{1}{v_j} y_j\right) / \left(\frac{1}{v_i} + \frac{1}{v_j}\right)$ is assigned to the common ancestor k. The two species i and j are removed. Ancestor k represents now a tip whose terminal branch length v_k is increased to $v_k + v_i v_j / \left(v_i + v_j\right)$ due to the error included in estimating the character state of k. This process is repeated until only the root node remains, which has a contrast of zero and a variance v_0.

When using the IC method, the log-likelihood of trait y can be calculated as follows (Freckleton, 2012):

$$L\left(\mu_y, \sigma_y^2 | \mathbf{V}, \mathbf{Y}\right) = -\frac{1}{2}\left(n\log(2\pi) + \sum_{i=0}^{n-1}\left[\log V_i + \frac{u_i^2}{\sigma_y^2 V_i}\right]\right). \tag{1.4}$$

The estimated ancestral state of the root y_0 corresponds to the mean μ_y and the variance/rate can be calculated as follows (Freckleton, 2012):

$$\sigma^2{}_y = \frac{1}{n}\sum_{i=0}^{n-1}\frac{u_i^2}{V_i}. \tag{1.5}$$

While the BM model remains the preferred null model for most analyses, other models such as the Early Burst (EB) model (Harmon et al., 2010; Puttick, 2018) and the Ornstein-Uhlenbeck (OU model (Hansen, 1997; Butler and King, 2004) have attracted attention. These models represent more generalised versions of the BM model. Especially the OU model, which allows for the attraction to an ‘optimal’ trait value during a random walk process and has sometimes been misinterpreted as representing ‘stabilising selection’ (Cooper et al., 2016a), has become popular in palaeobiologic macroevolutionary studies (Sookias et al., 2012b; Benson et al., 2014a,b; Ezcurra et al., 2016; Benson et al., 2018). The OU model is still actively developed (Beaulieu et al., 2012; Ingram and Mahler, 2013; Uyeda and Harmon, 2014; Khabbazian et al., 2016) but recent simulation studies have given reason for concern. These studies indicate that the OU model is often mistakenly favoured over more simple models and is sensitive to measurement error, small sample size, and time-scaling approaches (Ho and Ané, 2014; Silvestro et al., 2015; Cooper et al., 2016a,b; Halliday and Goswami, 2016). Care should be taken when employing an OU model (Cooper et al., 2016a,b).

A promising recent development are models that allow for variation in evolutionary rates and detection of rate heterogeneity without requiring a priori hypotheses (Eastman et al., 2011; Venditti et al., 2011; Rabosky, 2014; Rabosky et al., 2014; Duchen et al., 2017). The implementation of some (but not all!) of these models has been criticised (Moore et al., 2016; Rabosky et al., 2017; Meyer and Wiens, 2018; Rabosky, 2018) but this does not detract from the fact that rate heterogeneity is ubiquitous in phylogenetic comparative data and needs to be accounted for (Venditti et al., 2011; Baker et al., 2015, 2016; Cooney et al., 2017; Landis and

Schraiber, 2017; Felice and Goswami, 2018). In the case of BayesTraits (Venditti et al., 2011) the variable rates model (implemented in a GLS and independent contrast framework; Baker et al., 2016; Meade and Pagel, 2016) uses a homogeneous BM process but detects branches whose inferred variance of trait evolution deviates from the homogeneous rate process (Baker et al., 2016). These branches are then stretched or compressed until an optimal set of branch lengths has been found that accommodates a BM process. The scalars used to rescale the branch lengths correspond to the relative evolutionary rates (Baker et al., 2016). BM background rate and rate scalars are simultaneously estimated using a Bayesian reversible jump Markov Chain Monte Carlo algorithm (rjMCMC) (Venditti et al., 2011; Baker et al., 2016).

Another interesting approach in phylogenetic comparative methods is the use of so called generalised linear mixed models (GLMM; Hadfield, 2010). GLMMs offer the combined advantage of linear mixed models (which allow the incorporation of random effects) and generalised linear models (which allow the usage of non-normally distributed data) (Bolker et al., 2009). Unlike standard GLS approaches that require a normally distributed response variable (Pennell and Harmon, 2013), GLMMs are capable of handling poisson-distributed count data using appropriate link functions (Bolker et al., 2009). Phylogeny can be added as a random effect in the form of an inverse phylogenetic variance-covariance matrix (Hadfield, 2010; Sakamoto et al., 2016). The major advantage of this approach is definitely its high flexibility allowing for complex models (Pennell and Harmon, 2013), especially when coupled with a Markov chain Monte Carlo algorithm for parameter estimation (Bolker et al., 2009; Hadfield, 2010).

1.4 Overview of chapters

This project is the first truly mega-evolutionary (Simpson, 1944) comparative phylogenetic analysis of early tetrapods. The aims of this project are two-fold: (1) to provide an up-to-date database and associated supertrees that allow carrying out large-scale phylogenetic comparative analyses of early tetrapods and (2) to test previous hypotheses on the evolution of early tetrapods. Besides making previously 'hidden' quantitative and qualitative data on early tetrapods readily available, the database reflects the current alpha taxonomic consensus and offers a stratigraphic resolution at substage level for all valid early tetrapod species, which other databases such as the Paleobiology Database do not provide so far. The hypotheses that I test mainly focus on evolutionary rates in the wider sense. Unlike previous phylogenetic comparative studies of early tetrapods, which mainly focused on the 'mode' of evolution, the recovered results give a clearer picture of the 'tempo' of evolution, which already Simpson (1944) recognised as equally important in understanding macroevolution.

1.4.1 Chapter Two

In chapter two I test the hypothesis that high rates of body size evolution are linked to evolutionary success in terrestrial early tetrapods. I show that rates of body size evolution in terrestrial tetrapods were heterogeneous in the first 200 million years of their evolutionary history. Rates were highest during the Permo-Triassic mass extinction event. The recovered rate pattern follows the Simpsonian concept of 'quantum evolution' Simpson (1953) with quick burst in evolutionary rates followed by a nearly instantaneous return to baseline rates. Early burst pattern characterised by a peak in rates and a subsequent exponential decrease in rates played no major role in terrestrial early tetrapod evolution. Unlike previously suggested, I find no support for long-term success of terrestrial early tetrapod clades being linked to elevated rates of body size evolution. High rates of body size evolution often appear to be associated with stress rather than success.

1.4.2 Chapter Three

In chapter three I test the hypothesis that strong selective pressure on the feeding apparatus of early archosauromorphs and early dinosaurs was one of the reasons for the success of these clades in the Triassic and Early Jurassic. I am able to show that early archosauromorph mandibles experienced variable evolutionary rates but positive selection did not play a major role in the evolution of early archosauromorphs. This result is consistent with an opportunistic non-competitive replacement model which has often been invoked for the success of these clades. It also emphasises the need for quantitative tests of older hypotheses on early tetrapod evolution, which mainly relied on qualitative arguments and have become entrenched in the literature.

1.4.3 Chapter Four

Sakamoto et al. (2016) have recently shown that the net speciation of non-avian dinosaurs was in decline tens of millions of years prior to the K-Pg boundary. Here I test whether a similar pattern can be recovered for early tetrapods prior to the Permo-Triassic mass extinction event (PTME). I show that early tetrapods were, indeed, in decline prior to the PTME, but the pattern is complex. Anamniote 'amphibians' exhibited a negative net speciation 25 million years prior to the PTME. In amniotes, on the other hand, extinction rates never exceeded speciation rates prior to the PTME. This result stresses the importance of the PTME - without the mass extinction event, typical Palaeozoic amniotes would have continued to thrive and Archosauromorpha, the most successful members of terrestrial Mesozoic ecosystems, might have never risen to dominance.

CHAPTER 2

BODY SIZE EVOLUTION IN TERRESTRIAL EARLY TETRAPODS: QUANTUM EVOLUTION AND SLOW RATES AS A KEY TO SUCCESS

Rebecca Lakin helped in updating the alpha taxonomy of anamniote 'amphibians' with an estimated work contribution to 'amphibian' alpha taxonomy of 4%. All other data collection, analyses, and the text presented here are the candidate's own work. Estimate of total work carried out by the candidate: 99%.

2.1 Abstract

The body size of terrestrial early tetrapods spanned several orders of magnitude during the first half of their evolutionary history (~385 Ma to 174 Ma). I find overwhelming support for variable evolutionary rates of body size in early tetrapods. Many clades exhibited rate patterns akin to the Simpsonian concept of quantum evolution: quick bursts of evolution followed by an immediate decrease in evolutionary rates indicating the transition to a new adaptive zone. Overall, high rates of body size evolution do not seem to confer a long-term evolutionary advantage in early tetrapods. Temporal trends of evolutionary rates indicate that rates were the highest for the clade Tetrapoda during the Permo-Triassic mass extinction event (PTME). Archosauromorphs, which replaced temnospondyls, therapsids, and parareptiles as the dominant component of terrestrial ecosystems after the PTME, were significantly more likely to exhibit lower evolutionary rates than the less successful clades. Similarly, the more successful non-avian dinosaurs were more likely to have low evolutionary rates compared to pseudosuchians. These results call into question the general idea of clade success being linked to high evolutionary rates and resulting 'evolvability'. Rates of body size evolution in early tetrapods rather seem to be connected to stress than to success.

2.2 Introduction

Mammals, amphibians, ‘reptiles’, and birds, the Tetrapoda (= four-limbed vertebrates; Clack, 2012), dominate modern terrestrial ecosystems, are found at the top of most terrestrial and marine food chains, and feature some of the most iconic animals known to humankind (Small, 2011). Today’s ~30,000 living tetrapod species (Wiens, 2015) are the product of roughly 390 million years of evolution (Niedźwiedzki et al., 2010; Ahlberg, 2019) punctuated by multiple pulses of diversification (Alfaro et al., 2009). The first half of the evolutionary history of Tetrapoda laid the foundation for most modern tetrapod clades (Benton et al., 2013c). These 200 million years saw the colonisation of land in the Middle Devonian (Niedźwiedzki et al., 2010; Ahlberg et al., 2000; Benton et al., 2013c), the demise of many ‘amphibian’-grade taxa and the subsequent rise of amniotes due to the ‘Carboniferous rainforest collapse’ (CRC) (Sahney et al., 2010; Dunne et al., 2018), the establishment of terrestrial tetrapod ecosystems and the evolution of herbivory in terrestrial clades during the late Palaeozoic (Sues and Reisz, 1998; Reisz and Fröbisch, 2014), the Permo-Triassic mass extinction which lead to the destruction of therapsid and parareptile-dominated terrestrial ecosystems and their subsequent replacement by archosauromorphs (Benton et al., 2004; Roopnarine and Angielczyk, 2015b; Sookias et al., 2012b; Ezcurra and Butler, 2018), the ‘dinosaur diversification event’ (DDE) in the aftermath of the Carnian Pluvial Episode (CPE; Bernardi et al., 2018a), the end-Triassic mass extinction event (Dunhill and Wills, 2015; Allen et al., 2019), and the further radiation of dinosaurs in the Early Jurassic (Brusatte et al., 2008a,b, 2010c). The body mass of early tetrapods spanned more than five orders of magnitude (Modesto et al., 2015; McPhee et al., 2018) during this time period. Body size is a fundamental trait of all animals (Peters, 1983; Schmidt-Nielsen, 1984) that is linked to thermoregulation and feeding efficiency (Gearty et al., 2018), metabolic rate (Kleiber, 1947; Gillooly et al., 2001; Gearty et al., 2018), generation time (Pianka, 1970; Brown et al., 2018), population size (Damuth, 1981; White et al., 2007; Yeakel et al., 2018), fitness (Brown et al., 1993; Blanckenhorn, 2000), and home range size (Jetz et al., 2004).

Recent large-scale macroevolutionary studies of body size (Venditti et al., 2011; Landis and Schraiber, 2017; Clavel and Morlon, 2017) included only extant taxa or only a small number of fossil taxa (Baker et al., 2015). Studies including extinct tetrapods did not incorporate phylogenetic information (Heim et al., 2015; Sallan and Galimberti, 2015) or focused on smaller subclades of early tetrapods (Sookias et al., 2012b; Turner and Nesbitt, 2013; Huttenlocker, 2014; Brocklehurst, 2016; Brocklehurst and Brink, 2017; Brocklehurst and Fröbisch, 2018), often without accounting for potential rate heterogeneity (Sookias et al., 2012b; Huttenlocker, 2014). Furthermore, several studies focused on morphological rates of evolution explicitly or implicitly suggested that the long-term success of clades (Rabosky et al., 2013; Benson et al., 2014b; Lee et al., 2014; Wang and Lloyd, 2016; Fischer et al., 2016; Cooney et al., 2017) was related to rapid rates evolution, specifically also to rates of body size evolution (Rabosky et al., 2013; Benson et al., 2014b).

Here I present a comprehensive study of evolutionary rates of body size in early tetrapods *sensu* Benton et al. (2013c) including all valid tetrapod species from the Middle Devonian to the Early Jurassic (except for the marine clades Ichthyosauromorpha, Sauropterygia, and Thalattosauria; Motani, 2009; Kelley and Pyenson, 2015). Unlike previous analyses I account for heterogeneous rates and aim to answer the following questions: (1) Were the evolutionary rates of early tetrapods stable and homogeneous over a period of 200 million years or do we find evidence for variable rates?, (2) What patterns of evolutionary rates can we recover? Did early bursts of evolutionary rates play a role in the evolution of body size in early tetrapods?, (3) Did elevated evolutionary rates confer a (long-term) advantage to early tetrapod clades?

2.3 Methods

2.3.1 Database and supertree construction

The early tetrapod database (ETD) of Benton et al. (2013c) contains information on the alpha taxonomy, stratigraphic range (at substage-level), and the specimen completeness (using the categories 'scrap', 'skull', 'skeleton', and 'multiple skeletons') of all known tetrapod genera from the Middle Devonian (late Givetian) to the terminal Early Jurassic (late Toarcian). The ETD (Benton et al., 2013c,a) and its derivative (Benton, 2015b,a) also contains a qualitative index for body size (categories: 'small', 'medium', 'large'), the year of the first description of the genus, the name of the formation(s) associated with the first (FAD) and last appearance (LAD) of the genus in the fossil record, the country in which the first occurrence of the genus was found, and additional stratigraphic and geographic information on the tetrapod-bearing formations spanning the late Givetian to late Toarcian.

This database was updated by scanning all relevant journals and using an exhaustive Google Scholar Search to find all appropriate articles published between the year 2012 (end of year 2011) and the 28th September 2018. Older literature was only considered when deemed necessary and when younger references were not available. The database was brought from genus to species level and associated columns were updated as required. The main changes were related to alpha taxonomy, the stratigraphy of tetrapod-bearing formations and consequently also the stratigraphic ranges of the tetrapod species. The absolute ages associated with the stratigraphic ranges were based on the 2017 version of the International Chronostratigraphic Chart (Cohen et al., 2013; International Commission on Stratigraphy (ICS), 2017). Substage-level designation followed Benton et al. (2013c). Unless noted otherwise, changes in alpha taxonomy were only reported in a separate log-file (Appendix A) if non-trivial, i. e. synonymies and *nomina dubia* recognised in 2012 or afterwards were reported in the log-file but newly discovered species in the same time frame were not. The biogeographic information of the database was expanded to include all countries for which a tetrapod species was reported. A quantitative proxy for body size, femur length, was recorded for all tetrapod species except for the marine clades Sauropterygia, Ichthyosauromorpha, and Thalattosauria. Additional proxies for various tetrapod subclades were included where deemed necessary. These proxies include sagittal skull length (measured from the tip of the snout to the posterior end of the occipital condyle), basal skull length (measured from the tip of the snout to the posterior end of the quadrate), greatest skull length (measured from the tip of the snout to the posteriormost part of the skull), lower jaw length, humerus length, tibia length, and radius length.

Femur length is generally considered a good proxy for body mass in terrestrial tetrapods (Hurlburt, 1999; Christiansen and Fariña, 2004; Farlow et al., 2005; Carrano, 2006; Sookias et al., 2012b; Turner and Nesbitt, 2013) but the minimum diaphyseal circumferences of femur and humerus have been shown to represent a superior proxy for body mass in (quadrupedal) terrestrial tetrapods (Campione and Evans, 2012). The minimum diaphyseal circumference of the propodials has been successfully applied in macroevolutionary analyses of body size in non-avian dinosaurs (Benson et al., 2014b, 2018). For early tetrapods *sensu* Benton et al. (2013c), however, these measurements are often not available (Castanhinha et al., 2013; Modesto et al., 2015, Electronic Supplementary Material; Brocklehurst, 2016; Brocklehurst and Brink, 2017) and multiple studies continue to use femur length as a proxy for body size in tetrapods (Lee et al., 2014; Puttick et al., 2014; Persons and Currie, 2016; Young et al., 2016a; Clauss et al., 2017; Johnson et al., 2018; Ősi et al., 2018), especially in early tetrapods (Sookias et al., 2012b,a; Shelton et al., 2013; Mancuso et al., 2014; Zanno et al., 2015; Clauss et al., 2017; Codron et al., 2017).

Benson et al. (2014b) and Benson et al. (2018) used humeral and femoral diameters to estimate additional humeral and femoral minimum shaft circumferences within non-avian Dinosauria. The latter measurements were then used to estimate body mass using the equations of Campione and Evans (2012). Attempting to apply this approach to early tetrapods is problematic for two reasons: First of all, propodial minimum shaft circumferences are rarely reported in the literature for early tetrapod species. In fact, many descriptions of early tetrapods rarely report any skeletal measurements, especially postcranial ones, let alone provide a table of measurements as found in primary literature of dinosaurs (A. Elsler, pers. observ., 2018). Using propodial minimum shaft circumferences would therefore imply that the vast majority of data used to estimate body mass would be based itself on estimated data. This problem is even more pronounced in early tetrapods since some clades (therapsids, temnospondyls, and various other anamniote tetrapod clades) rarely preserve femora and even less so both propodials (see also subsection 2.3.3). Therefore it would be necessary to first estimate the femoral and humeral diameters, then use these estimated values to estimate the propodial circumferences, which would then finally be used to estimate body mass. Such a long chain of inference appears undesirable and the reliability of the estimated body masses would be questionable. But even if such an approach was accepted, it would face a second issue. Adult femur length within early tetrapods ranges from 3.3 mm (*Utaherpeton franklini*) to 1365 mm (*Barapasaurus tagorei*). Femoral and humeral diameters can be measured from figures or reconstructions of the respective limb elements in the literature. Obtaining skeletal dimensions by measuring published figures/reconstructions is generally viable as long as the provided scale bar is correct (Laurin, 2004). In the case of small tetrapods, however, the 'absolutely small size' (Clack, 2001, p. 85) increases the relative measurement error since measurement error is negatively correlated with trait size (Pankakoski et al., 1987; Yezerinac et al., 1992; Palmeirim, 1998; Blackwell et al., 2006; Muñoz-Muñoz and Perpiñán, 2010). Since propodial shaft diameters will generally be much smaller than the respective propodial lengths, they will be more affected by the increased measurement error. This is probably less problematic for the larger non-avian dinosaurs, but an important issue when considering early tetrapods which include many clades and grades (e.g., early diapsids, 'lepospondyls', Dissorophoidea) which are characterised by a rather small body size.

I therefore used femur length as a proxy for body size. Where possible only adult specimens were recorded in the database. As the ontogenetic status of specimens was often not reported in the literature I assumed that the largest specimen was closest to the adult size and recorded its measurements accordingly. Sometimes it was necessary to rescale measurements obtained from a smaller, more complete specimen using a larger, but less complete specimen. Since ontogenetic series are rarely known for terrestrial early tetrapods – exceptions are, e.g., *Microbrachis pelikani* (Olori, 2013), *Hovasaurus boulei* (Currie, 1981), and *Thadeosaurus colcanapi* (Currie and Carroll, 1984) – and many species are only represented by a few specimens, this rescaling process was carried out for most species under the assumption of isometric scaling (Hopkins, 2018). Skull and femur lengths are known to scale isometrically for at least some tetrapod clades (Gould, 1975; Currie, 2003; Olori, 2013) and isometric rescaling is commonly applied when generating skeletal reconstructions or size estimates for poorly known tetrapod species (e.g., Reisz et al., 1984; McGowan, 1996; McGowan and Motani, 1999; Schmitz et al., 2004; Porro et al., 2011b; Pierce et al., 2012; Ibrahim et al., 2014; Woodruff et al., 2018; Persons et al., 2019). Isometric rescaling has also been used in similar studies focused on body size employing phylogenetic comparative methods (Turner and Nesbitt, 2013; Benson et al., 2014b, 2017). The exact details of the rescaling process are recorded for each species in the database (see Supplementary Files). Sagittal skull lengths and/or femur lengths of 232 tetrapod species were rescaled. For 20 out of these 232 species it was necessary to use the specimen of a closely related taxon to carry out the rescaling. All other rescaled values are based on specimens belonging to the same taxon.

An informal supertree approach was taken to place all valid early tetrapod species (2142 species) in a phylogeny. I used all early tetrapod species as complete trees are preferable over pruned ones when doing the subsequent timescaling (Lloyd et al., 2016b; Sakamoto and Ruta, 2012). When selecting phylogenies for the supertree construction preference was given to recent analyses featuring taxon- and character-rich data matrices. Scaffold trees were generated for major clades and smaller subclades were grafted onto the scaffold trees using Mesquite 3.51 (Maddison and Maddison, 2018). Taxa, which have never been included in a phylogenetic analysis, were added based on alpha taxonomic opinion. Adding taxa based on taxonomies for subsequent phylogenetic comparative analyses is warranted if care is taken when placing the taxa (Soul and Friedman, 2015). Three different topologies for anamniote tetrapods ('traditional' Amphibia, 'polyphyletic 'Lepospondyli', and Lissamphibia 'lepospondyl' hypothesis (LH)) and two different topologies for archosauromorphs ('traditional' Archosauromorpha and Ornithoscelida hypothesis) were generated resulting in a total of six different tetrapod supertree topologies (for details see Appendix A).

2.3.2 Time-scaling

I generated 100 randomly resolved replicates for each of the six tetrapod supertree topologies. I dropped *Nyasasaurus parringtoni* from all supertree topologies using the Ornithoscelida hypothesis prior to time-scaling the trees due to the uncertain phylogenetic (Nesbitt et al., 2013d; Baron et al., 2017a; Langer et al., 2017b; Puttick et al., 2017b; Baron and Williams, 2018) and stratigraphic placement (Nesbitt et al., 2017; Butler et al., 2018) of the taxon and its unusual derived position within the Ornithoscelida topology (Baron et al., 2017a). The supertree topologies were subsequently time-scaled using the bin_cal3TimePaleoPhy function of the `paleotree` package (Bapst, 2012, 2013). The cal3 method is a probabilistic 'a posteriori' time-scaling (APT) approach (Lloyd et al., 2016b) which draws divergence times under a birth-death sampling model based on a priori known rates of branching, extinction, and sampling (Bapst, 2013; Bapst and Hopkins, 2017). An attempt was made to estimate the necessary rates from the stratigraphic information provided by the early tetrapod database following the approach of Lloyd et al. (2016a). The resulting instantaneous (per-capita) rate of sampling of 0.44 lineages per million years (lmy^{-1}) appeared too high for early tetrapods, which is not surprising as the task of calculating these rates is non-trivial (Bapst and Hopkins, 2017), especially for terrestrial tetrapods (Benson et al., 2018). According to Soul and Friedman (2017) the sampling rate of the majority of Palaeozoic and Mesozoic terrestrial vertebrate clades should be on the order of 0.01 lmy^{-1}. Indeed, for Devonian tetrapod genera the instantaneous sampling rate is reported to range from 0.042 to 0.18 lmy^{-1} (Bapst and Hopkins, 2017; Friedman and Brazeau, 2011). An instantaneous sampling rate of 0.018 lmy^{-1} has also been recovered for Dinosauria (Lloyd et al., 2016b; Lloyd et al., 2016a; D. Bapst in Benson et al., 2018). I therefore decided to obtain the instantaneous sampling rate from a uniform distribution bounded by the lowest (0.042 lmy^{-1}) and highest estimates (0.18 lmy^{-1}) reported in the literature (Bapst and Hopkins, 2017; Friedman and Brazeau, 2011). These sampling rate estimates were then used to calculate the extinction and origination rates as in Lloyd et al. (2016a). The time of observation was treated as uncertain and was randomly sampled between the first and last appearance times (dateTreatment: randObs), the step size of increments used in the function to set node ages was set to 0.001 (step.size = 0.001), and the probability of inferring ancestor-descendant relationships was set to 0 (anc.wt = 0). The cal3 algorithm tends to produce several zero-length branches (ZLBs; e.g., Puttick et al., 2017a) which can be problematic for some phylogenetic comparative methods. Reducing the step size leads to fewer zero-length branches but increases the calculation time and the memory footprint of the time-scaled trees in R (R Core Team, 2018): a single time-scaled tree requires about 600 MB (!) of RAM when using a step size of 0.0001. The step size was therefore not set to a value lower than 0.001. To overcome the problem of ZLBs I added 0.0001 Myr (= 100 yr) to all branches with a length of zero (see also Bapst, 2014; Bapst and Hopkins, 2017).

2.3.3 Femur length estimation

To increase the taxon sample size for subsequent analyses, femur length was estimated for the following tetrapod groups (Table 2.1; see also section 2.6) similar to the approach of Sookias et al. (2012b): 'basal' Tetrapoda (excluding Colosteidae, *Crassigyrinus scoticus*, Temnospondyli, the least inclusive clade containing *Eoherpeton watsoni* and *Westlothiana lizziae*, and Aïstopoda recovered in Pardo et al., 2017a), Colosteidae + *Crassigyrinus scoticus*, Edopoidea (= *Edops craigi* + Cochleosauridae including *Nigerpeton ricqlesi* and *Saharastega moradiensis*), Dvinosauria, Zatracheidae, Dissorophoidea (excluding Batrachia and Zatracheidae; see Marjanović and Laurin, 2019), Eryopidae, 'basal Stereospondylomorpha' (excluding *Prionosuchus plummeri* and Stereospondyli except for Lapillopsidae, *Uruyiella liminea*, and *Peltobatrachus pustulatus*), Rhinesuchidae + *Arachana nigra*, 'Lydekkerinidae' (= *Broomulus dutoiti*, *Limnoiketes paludinatans*, *Lydekkerina huxleyi*, *Chomatobatrachus halei*, *Luzocephalus blomi*, *Luzocephalus johanssoni*, *Luzocephalus kochi*, *Deltacephalus whitei*, *Lydekkerina panchetensis*, *Eolydekkerina magna*; Dias-da-Silva and Hewison, 2013), Capitosauria, Brachyopoidea (excluding *Eocaecilia micropodia* recovered in Marjanović and Laurin, 2019), Rhytidosteidae, Trematosauridae, Metoposauridae + *Callistomordax kugleri* + *Almasaurus habbazi*, Embolomeri, non-bystrowianid Chroniosuchia, Bystrowianidae, Seymouriamorpha, Diplocaulidae, the least inclusive 'lepospondyl' clade including *Asaphestera intermedia*, *Tuditanus punctulatus*, *Stegotretus agyrus*, *Cardiocephalus sternbergi* but excluding Batrachia and *Eocaecilia micropodia*, Varanopidae, Therapsida, Parareptilia (excluding the aquatic Mesosauridae), 'Captorhinomorpha' (= non-diapsid Eureptilia including Captorhinidae and 'Protorothyrididae' but excluding the 'lepospondyls' recovered in Pardo et al., 2017a), Lepidosauria, and Pan-Testudines.

No attempt was made to estimate femur lengths for aïstopods and adelogyrinids. Aïstopods were limbless tetrapods (Carroll, 1998a, p. 163; Caldwell, 2003; Clack, 2012, p. 279). Adelogyrinids might have had unossified limbs which were not preserved during fossilization (Carroll and Andrews, 1998, p. 160; Clack, 2012, p. 280). Using closely related taxa with preserved hindlimbs it would be possible to calculate femur lengths for both clades thereby obtaining a proxy of body size that is comparable to other tetrapods (without implying the actual presence of hindlimbs in aïstopods). The phylogenetic relationships of 'lepospondyls' and especially those of adelogyrinids and aïstopods, however, are unclear (Ruta and Coates, 2007; Pardo et al., 2017a; Marjanović and Laurin, 2019). Therefore, no attempt was made to estimate femur length for these clades.

TABLE 2.1. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the 'traditional' Amphibia & Archosauromorpha topologies. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations: N, sample size; I, Intercept; S, Slope; λ, phylogenetic signal parameter (Pagel, 1999); 'B.', 'Basal'; *Cras.*, *Crassigyrinus scoticus*; Stereospondylom., Stereospondylomorpha; *Ara.*, *Arachana nigra*, Dissorophoidea*, Dissorophoidea without Batrachia & Zatracheidae; Brachyopoidea*, Brachyopoidea without *Eocaecilia micropodia*; Metoposauridae*, Metoposauridae including *Callistomordax kugleri* and *Almasaurus habbazi*; Chroniosuchia*, Chroniosuchia without Bystrowianidae.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.95	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.64	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	>0.99	47	NA	-0.080	0.379	0.994	<0.001	1
Captorhinomorpha	0.57	10	NA	-0.089	0.506	0.910	<0.001	1
Pan-Testudines	0.55	5	NA	-1.242	0.007	1.690	<0.001	1
Lepidosauria	0.79	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.97	10	0.907	-0.108	0.632	0.886	<0.001	0
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.56	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.66	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.77	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.75	5	NA	-0.007	0.979	0.865	0.003	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.69	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	14	0.892	-0.109	0.378	0.892	<0.001	0

Both clades were relatively small. Aïstopods consist of 10 valid species, out of which only 7 are represented by non-juvenile sagittal skull lengths. Adelogyrinids consist of 4 (5 if *Acherontiscus caledoniae* is considered a member of adelogyrinids/adelospondyls; see, e.g., Ruta et al. (2003b); Ruta and Coates (2007); Marjanović and Laurin (2019)), out of which 3 (4 with *Acherontiscus caledoniae*; note, however, that *Acherontiscus caledoniae* might also be a juvenile; see Ruta et al., 2003b) are represented by non-juvenile sagittal skull lengths. Due to the small size of the clades their exclusion from the trait-based analyses is considered to have negligible effects on the results.

Juvenile specimens were excluded prior to model fitting. As discussed for non-avian dinosaurs (Hone et al., 2016), palaeontological studies of early tetrapods might be more likely to treat specimens as 'subadults' which in modern-day studies of extant species would be considered 'adults'. For this reason and to not further reduce the already small sample size of some subclades, I choose not to exclude subadults from my analyses.

Generalized least squares (GLS) regressions as implemented in the `nlme` package (Pinheiro et al., 2018) were used to estimate femur length from basal skull length (for Varanopidae) or sagittal skull length (for all other clades). Three types of correlation structures were generated using the corPagel function of the `ape` package (Paradis et al., 2004; Paradis and Schliep, 2019), (1) assuming no phylogenetic signal (Pagel's $\lambda = 0$; Pagel, 1999), (2) strong phylogenetic signal (= the phylogenetic variance-covariance matrix follows Brownian motion, i. e. Pagel's $\lambda = 1$), and (3) allowing the phylogenetic signal/Pagel's λ to be estimated (a similar approach was used by Benson et al., 2017, Appendix S1; Benson et al., 2018). Model fitting and parameter estimation for all three correlation structures was carried out using maximum likelihood and was run for all time-scaled trees. I selected the best model by comparing the mean Akaike information criterion corrected for finite sample sizes AICc (Akaike, 1974; Sugiura, 1978; Burnham and Anderson, 2002) calculated for all 100 time-scaled trees:

$$AIC_c = -2 * log - likelihood + 2 * K * \frac{n}{n - K - 1}$$

with n = number of species, K = number of parameters (Burnham and Anderson, 2002, p. 66).

Measurements were $\log_{10}$-transformed prior to model fitting. The parameters of the best model were then used to calculate femur lengths for each tetrapod species featuring a sagittal skull length (or basal skull length in the case of Varanopidae) but no femur length across all 100 trees. The mean of these 100 femur length estimates was calculated for each tree and was used in the subsequent analyses. Due to the small sample size and the resulting flat likelihood surface the estimation of Pagel's λ would fail for some trees and some tetrapod groups. In this case only the results obtained with the fixed λ parameter were further considered. AICc calculation is only possible for models in which the number of species n is at least equal or greater than the number of parameters K plus two (Motulsky and Christopoulos, 2003, p. 144):

$$n \geq K + 2$$

For $2 < n \leq 4$ only the results obtained for $\lambda = 0$ were further considered. Such small samples sizes are also reported and used in regression analyses for non-avian dinosaurs (Benson et al., 2014b, Supporting Information: Table S1). For some clades the sample size was very small with $n \leq 2$. For $n = 2$ the linear function specified by the two data points was used to estimate femur length. For $n = 1$ the ratio between sagittal skull length and femur length of the only available taxon was used to estimate femur length for the other members of the subclade.

This approach allowed me to obtain femur lengths for 1051 (1052 for the Lissamphibia LH topology) terrestrial early tetrapod species. Note, that the term 'terrestrial' is herein used to indicate all early tetrapod species that do not fall into the clades Ichthyosauromorpha, Sauropterygia, and Thalattosauria, i. e., it also includes clades for which a semi-aquatic to aquatic lifestyle has been proposed (e.g., Mesosauridae, Trematosauria, Tanystropheidae, Thalattosuchia; Motani, 2009; Kelley and Pyenson, 2015). The GLS approach provided 525 (526 for the Lissamphibia LH topology) additional femur lengths, i. e. about 50% of the complete sample was based on GLS estimates. The large number of femur estimates is to be expected for terrestrial early tetrapods: Sookias et al. (2012b), who estimated femur lengths for Therapsida using a similar regression approach, report that for 77% of their therapsid sample no femur lengths had been described.

2.3.4 Rate analysis

I employed phylogenetic comparative methods to analyse rates of evolution of body size in terrestrial early tetrapods.

Taxa that are added to phylogenetic trees based on taxonomic opinion only and whose position is randomly resolved can potentially bias trait-based downstream phylogenetic comparative analyses (Rabosky, 2015). I therefore excluded all taxa from the rates analyses which had been added based on taxonomic opinion and which were still part of polytomies after having pruned all the taxa for which no body size data was available. This left 990 (993 for the Lissamphibia LH topology) terrestrial early tetrapod species for which the rate analyses could be carried out.

I used BayesTraits V2.0.2 (`http://www.evolution.rdg.ac.uk/BayesTraitsV2.0.2.html`) (Venditti et al., 2011) to compare homogeneous and heterogeneous rates models of evolution and to estimate relative evolutionary rates. BayesTraits employs a reversible jump Markov Chain Monte Carlo algorithm (rjMCMC) to detect shifts in the rate of evolution of a continuous trait on a phylogenetic tree. The tree branch lengths are optimized to conform to a Brownian motion model of evolution by rescaling the lengths of branches whose inferred variance of trait evolution deviates from that expected of a homogeneous Brownian motion model. The calculated scalars indicate the amount of acceleration or deceleration relative to the background rate on the branch of interest (Venditti et al., 2011; Baker et al., 2016). I ran variable rates independent contrast models using the MCMC method with default priors for each timescaled tree. Each tree was run for 240,000,000 iterations and parameters were sampled every 20,000 iterations. 40,000,000 iterations were discarded as burn-in. I calculated the marginal likelihood of the models using the stepping stone sampler (Xie et al., 2011) implemented in BayesTraits. I sampled 1,000 stones and used 100,000 iterations per stone. Convergence was assessed using the R package `CODA` (Plummer et al., 2006). The smallest effective sample size (ESS) value across all 100 trees was >229. I used the Variable Rates Post Processor (Baker et al., 2016) to extract the final parameters results. Models were compared using a Bayes Factor (BF) test.

Rates results were summarized by calculating a strict consensus tree for all timescaled trees where the branch lengths had been replaced with the mean rate scalars calculated by BayesTraits. The consensus tree was computed using the R package `phytools` (Revell, 2012). I calculated the mean branch lengths for each set of trees, ignoring edges that were not present in all trees of a set. I then plotted the consensus tree colour-coded according to the mean (rescaled) branch lengths using `ggtree` (Yu et al., 2017). Phylogenetically corrected evolutionary rates through time (Venditti et al., 2011; Sakamoto and Venditti, 2018) for all trees were calculated using the Variable Rates Post Processor (Baker et al., 2016) with 1,000 time slices per tree. Mean phylogenetically corrected evolutionary rates through time were calculated for all terrestrial early tetrapods and for separate subclades (Figure 2.2; Figure 2.3) across all 100 trees. Evolutionary rates were plotted against time using `geoscale` (Bell, 2015), modified to include an updated version of the International Chronostratigraphic Chart (Cohen et al., 2013; International Commission on Stratigraphy (ICS), 2017). Evolutionary rates for Temnospondyli, Parareptilia, Therapsida, and Archosauromorpha were directly compared using a two-tailed generalized Wilcoxon test (= Brunner-Munzel Test; Brunner and Munzel, 2000) as implemented in the R package `lawstat` (Gastwirth et al., 2017). The same test was also applied to compare Pseudosuchia and Dinosauria. The generalized Wilcoxon test is similar to the commonly applied Mann-Whitney U test (Mann and Whitney, 1947) but is better suited to compare groups that have unequal variance and skewed distributions (Neubert and Brunner, 2007; Neuhäuser and Ruxton, 2009; Neuhäuser, 2010). Where necessary, p-values were adjusted for multiple comparisons using the Benjamini-Hochberg correction (Benjamini and Hochberg, 1995).

Analyses were repeated for all six different topologies (see section 2.6).

2.4 Results

My results show that heterogeneous evolutionary rates were ubiquitous in the evolution of terrestrial early tetrapods. Results and discussion presented here refer to the supertree topology based on the traditional 'Amphibia' and Archosauromorpha relationships (Figure 2.1), but patterns of body size evolution were consistent across all six supertree topologies (see section 2.6). A minimum Bayes factor of >43 indicates that there is 'very strong' evidence (Raftery, 1996; Meade and Pagel, 2016) for a heterogeneous rate model.

The earliest terrestrial tetrapod species (except for Colosteidae) exhibit relatively low evolutionary rates compared to the later diverging taxa. High evolutionary rates are found among various subclades of Temnospondyli, especially within Dissorophoidea and Stereospondylomorpha (Figure 2.1). Dissorophoids are characterised by very high rates (>32 and >51 times the background rate) recovered on the single branches leading to Olsoniformes and the non-olsoniform dissorophoids (= Amphibamiformes of Schoch (2019)). Exceptionally high rates are also found on single branches leading to subclades of Stereospondylomorpha and the branch leading to the clade Eryopiformes + *Palatinerpeton kraetschmeri*, but within Stereospondylomorpha also several tips and whole clades (e.g., Rhytidosteidae and 'lydekkerinid' species) experience high evolutionary rates. This pattern is less common within Dissorophoidea, which are mainly dominated by exceptional rate shifts on single branches.

Anthracosauria are also characterised by high evolutionary rates found in both the branch leading to the clade and within the clade itself, especially in later diverging taxa.

Except for a few tips with higher evolutionary rates Lepospondyli exhibit average rates compared to other tetrapods, about three times the background rate. Similar evolutionary rates but without any major rate shifts are encountered within Seymouriamorpha, Chroniosuchia, and Diadectomorpha.

Parareptilia exhibit slightly higher rates, with a major rate shift found on the branch leading to Pareiasauria. Within pareiasaurs and procolophonids rates are higher compared to the rest of parareptiles.

Similar to the results of Brocklehurst (2016) higher evolutionary rates are recovered for the later diverging members of Captorhinidae, but compared to other early tetrapod clades no major rate shifts are recovered.

Within diapsids, higher evolutionary rates are recovered for Pan-Testudines and the branch leading to Archosauromorpha. Archosauromorpha overall feature lower and relatively homogeneous rates compared to other amniote clades such as parareptiles and therapsids. High rates are only recovered for a few tips (e. g., *Euparkeria capensis*, *Herrerasaurus ischigualastensis*, a few aetosaur species) and the least inclusive clade of sauropodomorph species including *Efraasia minor*.

High evolutionary rates are less common in 'pelycosaurian' synapsids (mainly found in Caseasauria) and more common in various therapsid subclades, especially within anomodonts (including the branch leading to Anomodontia), therocephalians, and (to a lesser extent) cynodonts.

The evolutionary rates of terrestrial early tetrapods (Figure 2.2) were initially low with the 'baseline' level approximately corresponding to the background rate of a homogeneous Brownian motion model (Baker et al., 2016). They experienced a first major increase at the transition from the Devonian to the Carboniferous, driven by higher evolutionary rates in Colosteidae and the branch leading to anthracosaurs. Evolutionary rates decreased again during the middle Tournaisian to a level of about two times the background rate. Afterwards there

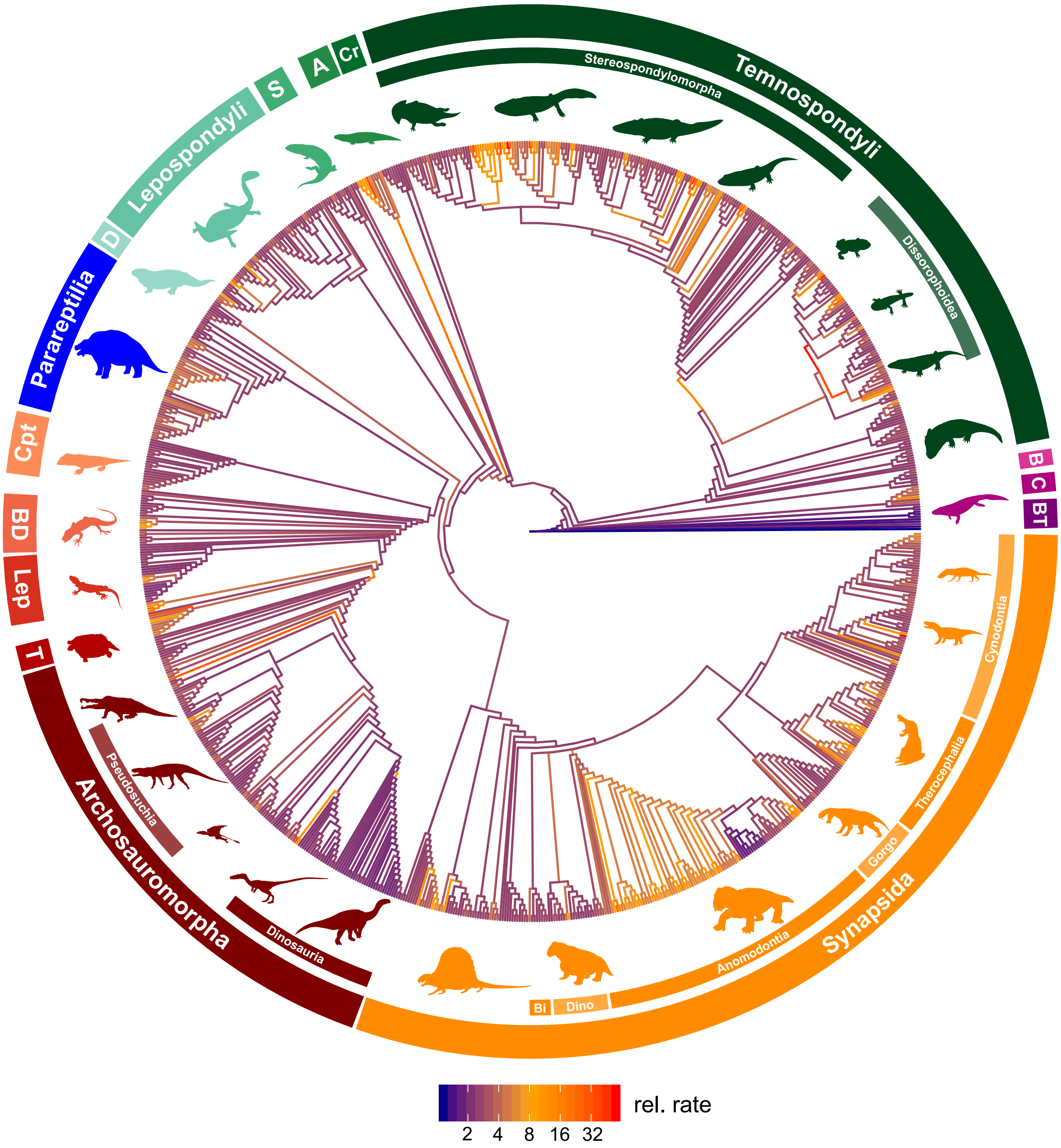

FIGURE 2.1. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the 'traditional' Amphibia and Archosauromorpha topologies (990 species). A, Anthracosauria; B, Baphetidae; BD, 'basal' Diapsida; Bi, Biarmosuchia; BT, 'basal' Tetrapoda; C, Colosteidae; Cpt, Captorhinidae; Cr, Chroniosuchia; D, Diadectomorpha; Dino, Dinocephalia; Lep, Lepidosauromorpha; Gorgo, Gorgonopsia; S, Seymouriamorpha; T, Pan-Testudines. For silhouettes see Figure 2.5.

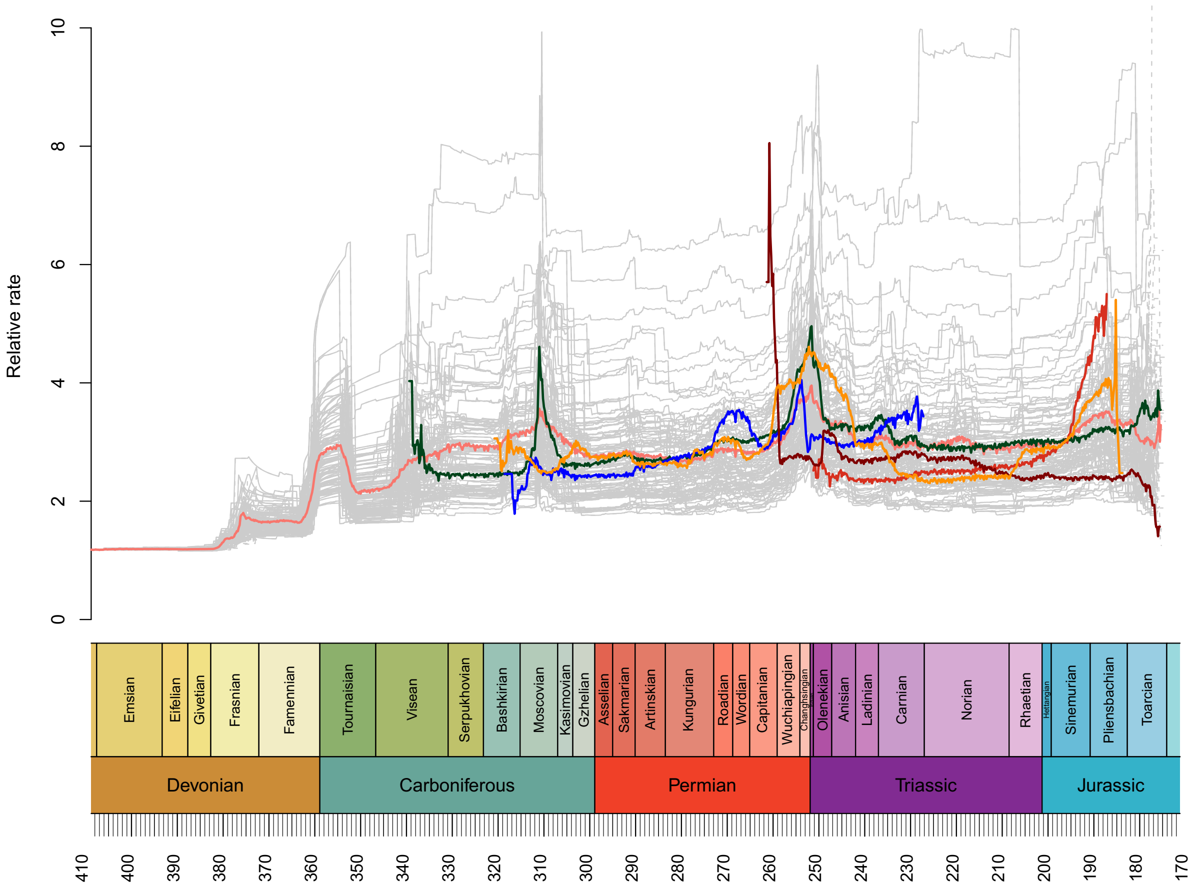

FIGURE 2.2. Mean rates of body size evolution through time based on the supertree of Figure 2.1. Grey lines represent the rates of Tetrapoda for each of the 100 timescaled trees, all other lines represent the mean across all 100 trees. Clades: ▬ Archosauromorpha, ▬ Lepidosauria, ▬ Parareptilia, ▬ Synapsida, ▬ Temnospondyli, ▬ Tetrapoda.

was a small but steady increase in evolutionary rates during the Carboniferous up to the Moscovian. During the Moscovian the terrestrial early tetrapods experienced a second peak in evolutionary rates which can be mainly related to higher evolutionary rates in temnospondyls and anthracosaurs. Due to the higher variability in evolutionary rates with rather low rates recovered for Parareptilia and Synapsida, this peak in evolutionary rates appears less pronounced than the middle Tournaisian one. The Moscovian peak in evolutionary rates was followed by a slight decline in rates which afterwards remained relatively stable for about 40 million years up to the end of the Capitanian. Note, that clades such as Parareptilia and (to a lesser extent) Synapsida already experienced an increase in evolutionary rates in the Middle Permian. The largest peak in evolutionary rates of terrestrial early tetrapods is found at the Permo-Triassic boundary (PTB). Similar to the Moscovian peak, different tetrapod clades reacted differently to the Permo-Triassic

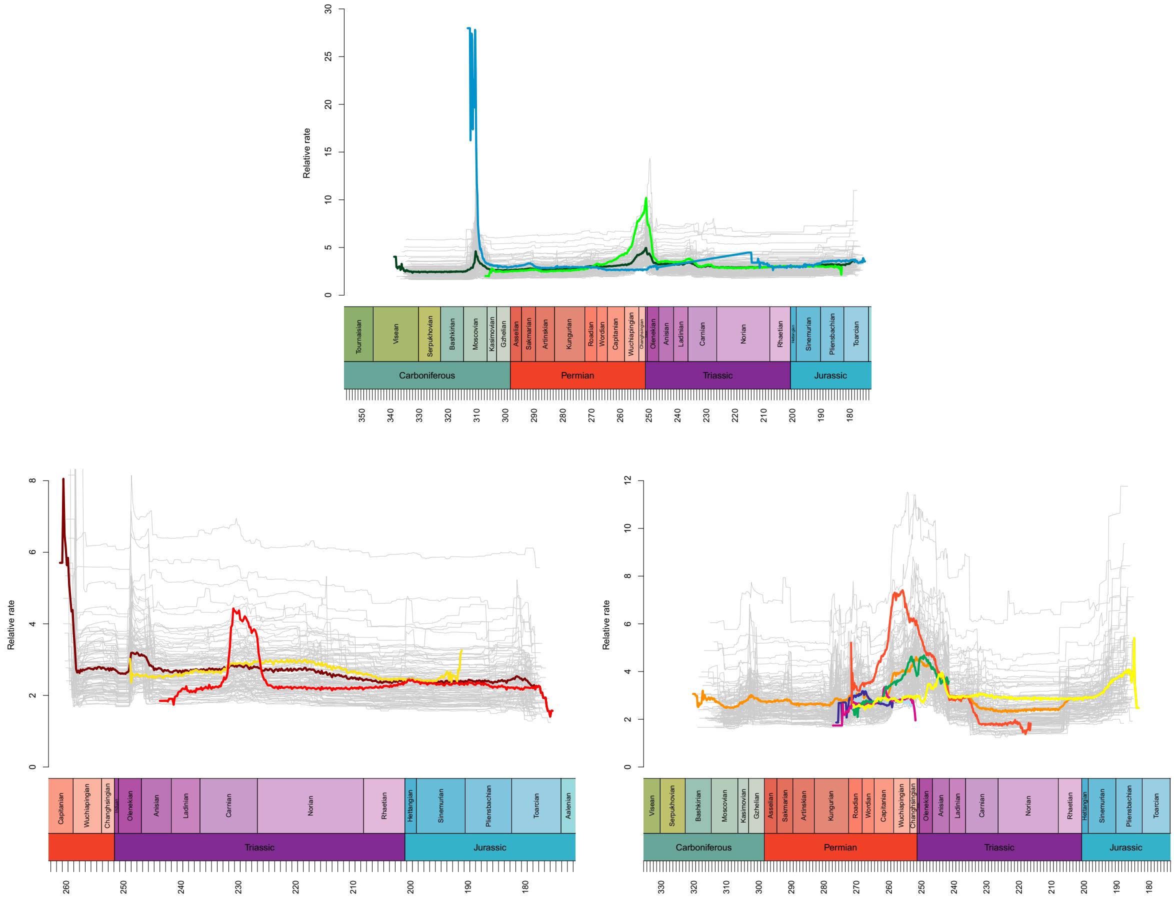

FIGURE 2.3. Mean rates of body size evolution through time for major subclades of Tetrapoda based on the supertree of Figure 2.1. Grey lines represent the rates of Temnospondyli (top), Archosauromorpha (bottom left), and Synapsida (bottom right) for each of the 100 timescaled trees, all other lines represent the mean across all 100 trees. Clades (**top**): ▬ Dissorophoidea, ▬ Stereospondylomorpha, ▬ Temnospondyli. Clades (**bottom left**): ▬ Archosauromorpha, ▬ Dinosauria, ▬ Pseudosuchia. Clades (**bottom right**): ▬ Anomodontia, ▬ Biarmosuchia, ▬ Cynodontia, ▬ Dinocephalia, ▬ Gorgonopsia, ▬ Synapsida, ▬ Therocephalia.

mass extinction event (PTME). Temnospondyli and Therapsida experienced exceptionally high evolutionary rates at the PTME, although the latter already saw an increase in evolutionary rates at the end of the Capitanian. The subsequent drop in evolutionary rates is much quicker in temnospondyls than in therapsids, which exhibit relatively high evolutionary rates until the end of the Anisian. Within Parareptilia the evolutionary rates peak before the PTME and drop during the mass extinction event. The early evolutionary history of Archosauromorpha is characterised by very high rates which already dropped at the begin of the Wuchiapingian, but

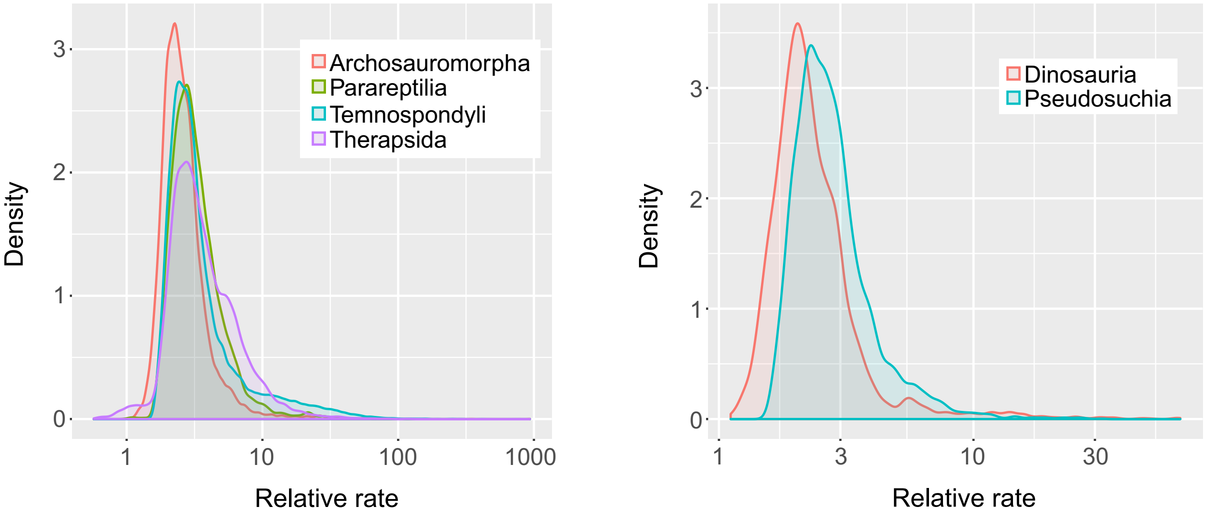

FIGURE 2.4. Distribution of relative evolutionary rates of major tetrapod clades based on the supertree of Figure 2.1.

the PTME appears to have no effect on this clade. Archosauromorphs did, however, experience a small rate increase in the aftermath of the PTME during the Olenekian. The evolutionary rates of terrestrial early Tetrapoda stabilised in the aftermath of the PTME and remained stable throughout much of the Triassic at a level around three times the original 'baseline' level. A minor increase in evolutionary rates is recorded at the begin of the Early Jurassic, but this is mainly driven by peaks in the evolutionary rates of Cynodontia and Lepidosauria. The evolutionary rates of Temnospondyli and Archosauromorpha remained stable for most of the Early Jurassic with archosauromorphs experiencing a sharp drop at the end of the Early Jurassic.

The earliest branches of Temnospondyli experienced relatively high evolutionary rates (about four times the background rate) compared to the rest of Tetrapoda in the Visean (Figure 2.2; Figure 2.3: top). Rates quickly declined and stabilised afterwards. The Moscovian peak was due to exceptionally high rates (nearly 30 times the background rate) in the early evolutionary history of Dissorophoidea. Rates plummeted to about three to four times the background rate in Dissorophoidea at the end of the Moscovian. Rates remained relatively stable in Temnospondyli and its two major subclades up to the end of the Permian. The peak at the PTME in Temnospondyli was largely an expression of the high evolutionary rates recovered for Stereospondylomorpha. Unlike Temnospondyli, however, evolutionary rates in Stereospondylomorpha started to rise in the Capitanian, and therefore earlier than in Temnospondyli. The subsequent evolutionary history of Temnospondyli was characterised by relatively stable evolutionary rates without any major jumps in rates.

Similar to Dissorophoidea, the clade Archosauromorpha had its highest rates at the begin of its evolutionary history, which was followed by a quick drop in rates (Figure 2.3: bottom left).

Rates remained stable for Archosauromorpha and its subclade Pseudosuchia for the rest of the Late Permian, Triassic, Early Jurassic except for a minor peak in the late Olenekian to early Anisian. Rates were on average slightly lower than the ones recovered for all of the terrestrial tetrapods. For much of their evolutionary history Dinosauria had even lower rates than the rest of Archosauromorpha. An exception was the late Carnian which saw a peak in evolutionary rates at about four times the background rate. This peak in evolutionary rates nearly perfectly coincides with the 'dinosaur diversification event' during the Carnian Pluvial Episode (Bernardi et al., 2018a).

The evolutionary rates of Synapsida (Figure 2.3: bottom right) remained stable throughout most of the history of the clade except for the PTME and the Capitanian ('end-Guadalupian') mass extinction event (Day et al., 2015a, 2018b). During both mass extinction events and their aftermath the evolutionary rates of therapsids were more than four times the size of the background rate. Especially anomodonts and therocephalians experienced high evolutionary rates during these mass extinction events. The evolutionary rates of anomodonts were more heavily affected by the Capitanian mass extinction event than therocephalians and evolutionary rates already started to drop prior to the PTME. This decrease in evolutionary rates in anomodonts continued for nearly 40 million years up into the Norian. Cynodonts showed a slight increase in evolutionary rates in the aftermath of the PTME during the Olenekian and Anisian before dropping back to its pre-PTME level. This was followed by a moderate increase in rates during the Early Jurassic.

A two-tailed generalized Wilcoxon test confirms that Archosauromorpha were significantly more likely to have lower rates than Temnospondyli, Parareptilia, and Therapsida (Figure 2.4; Table 2.2). Similarly Dinosauria were also characterised by a higher probability of lower rates than Pseudosuchia. Amniotes were also significantly ($p < 0.001$) more likely to exhibit lower rates than Temnospondyli, but the difference is rather small (relative effect size between 0.45 and 0.47, depending on the topology).

2.5 Discussion

I find overwhelming support (smallest Bayes factor > 43) for heterogeneous rates of body size evolution in terrestrial early tetrapods. This pattern holds irrespective of the chosen topology (section 2.6). Previous attempts in interpreting body size evolution within some clades of early tetrapods (e.g., Sookias et al., 2012b; Huttenlocker, 2014), that did not account for variable evolutionary rates, should therefore be viewed with caution.

I find no evidence for an 'early burst' (EB) type of evolution in early tetrapods with initially high evolutionary rates that were followed by an exponential decrease in rates. Instead evolutionary rates rose slowly after the appearance of the first tetrapods and remained stable throughout most of their history, except for three rate excursions. Sookias et al. (2012b) found support for an

TABLE 2.2. Results of the two-tailed generalized Wilcoxon test. Therapsida, Parareptilia, and Temnospondyli were compared with Archosauromorpha. Pseudosuchia was compared with Dinosauria. The null hypothesis for the relative effect size assumes P = 0.5 (Neuhäuser, 2010). The results are presented for all topologies. Abbreviations: d. f., degrees of freedom; Amph., 'traditional' Amphibia topology; P. Lepo., polyphyletic 'Lepospondyli' topology; Liss. LH, Lissamphibia LH topology; Archo., 'traditional' Archosauromorpha topology; Ornitho., Ornithoscelida topology.

Clade (= X)	Brunner-Munzel Test Statistic	d. f.	Sample estimate: P(X<Y)+.5*P(X=Y)	p-value
Amph. & Archo.				
Therapsida	-107.01	72595	0.300	<0.001
Parareptilia	-57.228	19764	0.330	<0.001
Temnospondyli	-82.217	62098	0.341	<0.001
Pseudosuchia	-48.085	19657	0.322	<0.001
Amph. & Ornitho.				
Therapsida	-97.095	71376	0.315	<0.001
Parareptilia	-50.076	20293	0.349	<0.001
Temnospondyli	-70.448	62433	0.362	<0.001
Pseudosuchia	-34.815	19836	0.366	<0.001
P. Lepo. & Archo.				
Therapsida	-111.44	74573	0.294	<0.001
Parareptilia	-60.637	19642	0.321	<0.001
Temnospondyli	-83.571	62006	0.339	<0.001
Pseudosuchia	-51.87	19563	0.310	<0.001
P. Lepo. & Ornitho.				
Therapsida	-103.62	74638	0.306	<0.001
Parareptilia	-58.305	20221	0.328	<0.001
Temnospondyli	-82.754	62857	0.340	<0.001
Pseudosuchia	-40.781	19430	0.345	<0.001
Liss. LH & Archo.				
Therapsida	-102.92	74943	0.307	<0.001
Parareptilia	-52.882	18765	0.339	<0.001
Temnospondyli	-79.278	65661	0.347	<0.001
Pseudosuchia	-39.002	20140	0.351	<0.001
Liss. LH & Ornitho.				
Therapsida	-94.578	72302	0.319	<0.001
Parareptilia	-47.16	19702	0.356	<0.001
Temnospondyli	-72.163	64090	0.358	<0.001
Pseudosuchia	-27.494	19989	0.392	<0.001

EB pattern in Therapsida and Cynodontia and Huttenlocker (2014) recovered the same pattern for Eutheriodontia (= Therocephalia + Cynodontia) and Cynodontia. I cannot confirm their results and instead recover quick bursts of evolution immediately followed by 'baseline' rates in various therapsid subclades. Some clades (e.g., Anomodontia) also show high evolutionary rates throughout their history. It is clear that an 'early burst' type of evolution played no major role in the evolution of body size of terrestrial early tetrapods. Similar analyses of body size evolution of Mammalia also found no evidence for EB (Venditti et al., 2011), support for which generally appears to be rare in comparative data (Harmon et al., 2010).

Several clades of terrestrial early tetrapods are characterised by an explosive increase (>5 to >50-fold of the background rate) of evolutionary rates on a single branch leading to monophyletic groups. Examples of such major bursts of evolution are found for olsoniform and non-olsoniform dissorophoids (= Amphibamiformes), the clade *Palatinerpeton kraetschmeri* + Eryopiformes (= Eryopidae + Stereospondylomorpha), Anthracosauria, Archosauromorpha, and (to a lesser extent) Anomodontia. Smaller subclades such as Rhytidosteidae, Capitosauroidea, Pareiasauria, and the least inclusive clade of Sauropodomorpha excluding *Saturnalia tupiniquim* show a similar pattern. These quick bursts in evolutionary rates are followed by a nearly instantaneous return to 'baseline' rates akin to the concept of 'quantum evolution' of Simpson (1953). Such lineages have experienced a jump in trait value in comparison to other clades (Baker et al., 2016) and have reached a new adaptive zone (Simpson, 1953). The clades experiencing short-term explosive increases in evolutionary rates entered a new ecological niche or a new environment (Baker et al., 2016).

Olsoniform dissorophoids were medium-sized land-dwelling animals, while the non-olsoniform dissorophoids were represented by both aquatic (Micromelerpetidae, Branchiosauridae) and terrestrial (Amphibamidae) members, characterised by a small body size (Schoch and Milner, 2014). Ontogenetic truncation has been interpreted as being responsible for the small size and paedomorphic appearance of the non-olsoniform dissorophoids (Pérez-Ben et al., 2018). Stereospondylomorpha (and Eryopidae) were generally larger than Dissorophoidea and mainly adapted to an aquatic lifestyle (Schoch and Milner, 2000, 2014).

Anthracosauria (= *Eoherpeton watsoni* + Embolomeri) was a small clade of aquatic Palaeozoic tetrapods, generally dominated by larger species but containing also relatively small ones (e.g., *Calligenethlon watsoni*), thus exhibiting a wide range of body sizes (Panchen, 1970; Smithson, 2000; Clack, 2012). This explains both the high rate on the branch leading to the clade and the high rates within the clade.

The body plan of Archosauromorpha was clearly distinct from that of the closely related Pan-Testudines and Choristodera and the average body size of archosauromorph species was larger than that of contemporaneous diapsid (Turner and Nesbitt, 2013) and therapsid species (Sookias et al., 2012b). The pattern recovered for Archosauromorpha is consistent with the results of Turner and Nesbitt (2013) for early Archosauriformes.

Pareiasauria were a herbivorous clade characterised by their large size in comparison to other parareptiles (Tsuji and Müller, 2009; Benton, 2016).

Anomodontia was the most speciose subclade of non-mammalian synapsids (Fröbisch, 2014a), characterised by a large body size range, a highly diverse ecology, and a cosmopolitan distribution (Fröbisch, 2009; Kammerer et al., 2011). Similar to Anthracosauria, the relatively high variability in body size explains again the prevalence of high rates in this clade.

Rhytidosteidae was a middle-sized (Warren, 2000), rather heterogeneous family of stereospondyls (Schoch, 2013), mainly restricted to the Early Triassic (Dias-da-Silva and Marsicano, 2011), whose phylogenetic affinities are still rather unclear (Dias-da-Silva and Marsicano, 2011; Schoch, 2013; Maganuco et al., 2014).

Capitosauroidea represents a clade of very large temnospondyls and were a major component of Mesozoic rivers, lakes and swamps (Schoch and Milner, 2000; Schoch, 2008b).

The least inclusive clade of Sauropodomorpha excluding *Saturnalia tupiniquim* was characterised by a very large body size compared to other members of the clade Sauropodomorpha (see also McPhee et al., 2018).

In a few cases (e.g., Anthracosauria, Pareiasauria, Pan-Testudines, Anomodontia, various smaller clades of Therocephalia and Stereospondylomorpha) all or most branches of a clade experience high evolutionary rates. As mentioned for anthracosaurs and anomodonts this pattern generally indicates greater variation in body size compared to other clades (Baker et al., 2016). Reduced body size variation could result in rate slowdowns, i. e. rates that are slower than the background rate of a homogeneous rate Brownian Motion model, which could represent evidence for stabilizing selection (Baker et al., 2016). I find no evidence for such rate decelerations in early tetrapods.

The evolutionary history of early tetrapods was characterised by quick bursts and immediate slowdowns. These peaks were associated with the invasion of new adaptive zones for several subclades of tetrapods and potential quick diversifications over short time periods (e.g., various subclades of temnospondyls, pareiasaurs, anomodonts, dinosaurs after the CPE). Additionally, however, peaks often appear to be associated with stress regimes. Both the end-Guadalupian mass extinction event (Day et al., 2015a, 2018b) and the PTME (Benton et al., 2004) were associated with high evolutionary rates. No such rate increases were observed for the end-Triassic mass extinction event of early tetrapods (Benton et al., 2013c; Dunhill and Wills, 2015; Allen et al., 2019), which might represent a protracted period of higher extinction rates or multiple mass extinction events rather than a single and quick mass extinction (Benton, 1986a, 1994b; Lucas and Tanner, 2018). The 'Carboniferous rainforest collapse' (CRC) (Sahney et al., 2010; Benton et al., 2013c) during the late Moscovian-Kasimovian might also be associated with the rate peak observed in terrestrial early tetrapods. Note, however, that this collapse might have been more gradual (Dunne et al., 2018) and that the observed peak in evolutionary rates appears to have occurred slightly before the major decline in 'amphibians' due to the CRC (Sahney et al., 2010;

Benton et al., 2013c).

High evolutionary rates have often been considered to indicate 'evolvability' and as partially responsible for the success of highly diverse clades such as birds and ray-finned fish (Rabosky et al., 2013; Benson et al., 2014b; Lee et al., 2014; Wang and Lloyd, 2016; Fischer et al., 2016; Cooney et al., 2017). Unexpectedly, high evolutionary rates of body size do not seem to confer long-term success in early tetrapods (Figure 2.4; Table 2.2). A good example is the clade Archosauromorpha which replaced the previously dominating temnospondyls, parareptiles, and therapsids (Benton et al., 2004; Brusatte et al., 2010a; Sookias et al., 2012b; Chen and Benton, 2012; Ezcurra and Butler, 2018) in terrestrial ecosystems during the Triassic. Temnospondyls, parareptiles, and therapsids are significantly more likely to have higher evolutionary rates than archosauromorphs.

This pattern is also found on a smaller scale. Dinosauria, which during the Late Triassic became more successful than the other major archosaurian subclade, the Pseudosuchia (Brusatte et al., 2008a), was more likely to have lower rates than the Pseudosuchia.

Similarly, during the Permian the dominant 'amphibians', which were mainly represented by Temnospondyli, were subsequently replaced by amniotes (Carroll, 2009; Sahney et al., 2010; Benton et al., 2013c; Dunne et al., 2018; Brocklehurst et al., 2013b). I do not attempt to further analyse the difference in evolutionary rates between 'amphibians' and amniotes, due to the uncertain relationships within non-amniote tetrapods (Marjanović and Laurin, 2019; Pardo et al., 2017a). I do note, however, that temnospondyls again were significantly more likely to exhibit higher evolutionary rates than amniotes albeit the difference is small.

Based on the recovered rate pattern there does not seem to be a clear-cut link between rates of body size evolution and metabolic rates. Temnospondyls and therapsids are both more likely to exhibit higher rates of body size evolution than archosauromorphs, but temnospondyls are generally considered to be ectothermic with rather low resting metabolic rates (Witzmann and Brainerd, 2017) while at least some clades of early therapsids were endothermic and had high resting metabolic rates (Rey et al., 2017; Olivier et al., 2017). Non-avian dinosaurs have been considered 'mesothermic' (Grady et al., 2014) and early archosaurosauromorphs might have also had high resting metabolic rates (Legendre et al., 2016). I did not test how rates of body size evolution were linked to feeding efficiency (Gearty et al., 2018) but for some clades it appears that higher rates of evolution are linked to changes in diet, particularly when the diet became herbivorous (e.g., pareiasaurs, several therapsid clades, sauropodomorphs; see also chapter 3).

Rates of morphological character change in early tetrapods decreased from the Devonian to the Permian (Ruta et al., 2006) but rates of body size evolution increased initially before reaching a plateau and remaining relatively stable except for the previously mentioned peaks. This indicates a decoupling of rates of morphological character evolution and rates of body size evolution. The decrease in rates of character evolution has been suggested to be caused by either increased intrinsic constraints (developmental or phylogenetic bottleneck) or increased ecological restrictions (Ruta et al., 2006). Both explanations are consistent with a scenario in which increased rates of evolution are not indicative of the success of a clade. Higher rates of body size evolution were also found in horse lineages characterised by low speciation rates (which would be consistent with the above scenario) but the difference between the pattern for low and high speciation rates lineages was not significant (Cantalapiedra et al., 2017).

These results indicate that high evolutionary rates of body size in early tetrapods were not associated with long-term success of a clade but rather a signal of stress. Quick bursts of evolution opened new adaptive zones but ultimately successful clades were generally associated with lower rates compared to less successful ones.

2.6 Supplementary Information

TABLE 2.3. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the 'traditional' Amphibia topology & the Ornithoscelida topology. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations as in Table 2.1.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.94	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.68	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	0.62	47	NA	-0.112	0.192	1.007	<0.001	1
Captorhinomorpha	0.58	10	NA	-0.105	0.426	0.921	<0.001	1
Pan-Testudines	0.56	5	NA	-1.265	0.010	1.700	<0.001	1
Lepidosauria	0.75	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.97	10	0.907	-0.108	0.632	0.886	<0.001	0
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.58	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.66	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.74	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.75	5	NA	0.046	0.710	0.846	<0.001	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.69	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	14	0.892	-0.109	0.378	0.892	<0.001	0

TABLE 2.4. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the polyphyletic 'Lepospondyli' topology & the 'traditional' Archosauromorpha topology. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations as in Table 2.1.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.97	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.67	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	0.54	47	NA	-0.109	0.244	1.001	<0.001	1
Captorhinomorpha	0.54	10	NA	-0.037	0.793	0.880	<0.001	1
Pan-Testudines	0.56	5	NA	-1.315	0.009	1.732	<0.001	1
Lepidosauria	0.75	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.70	8	0.978	-0.138	0.287	0.893	<0.001	0
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.58	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.68	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.74	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.75	5	NA	0.011	0.954	0.860	0.001	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.68	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	16	0.843	-0.074	0.586	0.850	<0.001	0

TABLE 2.5. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the polyphyletic 'Lepospondyli' topology & the Ornithoscelida topology. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations as in Table 2.1.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.96	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.64	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	>0.99	47	NA	-0.140	0.125	1.015	<0.001	1
Captorhinomorpha	0.54	10	NA	-0.089	0.483	0.908	<0.001	1
Pan-Testudines	0.57	5	NA	-1.218	0.008	1.674	<0.001	1
Lepidosauria	0.71	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.97	10	0.907	-0.108	0.632	0.886	<0.001	0
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.57	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.68	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.76	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.74	5	NA	0.021	0.896	0.857	0.001	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.69	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	16	0.843	-0.074	0.586	0.850	<0.001	0

TABLE 2.6. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the Lissamphibia LH topology & the 'traditional' Archosauromorpha topology. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations as in Table 2.1.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.95	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.64	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	>0.99	47	NA	-0.041	0.663	0.976	<0.001	1
Captorhinomorpha	0.56	10	NA	-0.104	0.403	0.921	<0.001	1
Pan-Testudines	0.55	5	NA	-1.406	0.005	1.786	<0.001	1
Lepidosauria	0.75	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.70	8	NA	-0.071	0.564	0.857	<0.001	1
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.63	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.67	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.76	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.76	5	NA	0.021	0.906	0.856	0.001	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.70	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	16	0.843	-0.074	0.586	0.850	<0.001	0

TABLE 2.7. Best regressions (based on AICc weight) to estimate femur length for various tetrapod clades using basal skull length (Varanopidae) and sagittal skull length (all other clades). The underlying supertree is based on the Lissamphibia LH topology & the Ornithoscelida topology. For regressions which include phylogenetic signal ($\lambda \neq 0$) only the results for a single tree are reported (the results for other trees can be found in the Supplementary Files). Abbreviations as in Table 2.1.

Clade	AICc weight	N	R^2	I	p-value (I)	S	p-value (S)	λ
Parareptilia	0.96	21	0.946	-0.240	0.054	1.070	<0.001	0
Varanopidae	0.66	5	0.989	0.193	0.130	0.811	<0.001	0
Therapsida	>0.99	47	NA	-0.116	0.194	1.009	<0.001	1
Captorhinomorpha	0.57	10	NA	-0.101	0.405	0.919	<0.001	1
Pan-Testudines	0.56	5	NA	-1.375	0.008	1.764	<0.001	1
Lepidosauria	0.75	6	0.853	0.169	0.555	0.851	0.008	0
'B.' Tetrapoda	0.70	8	NA	-0.0913	0.518	0.869	<0.001	1
Colosteidae & *Cras.*	NA	4	0.966	-1.189	0.084	1.295	0.017	0
Edopoidea	NA	2	NA	0.340	NA	0.670	NA	NA
Dvinosauria	0.58	5	0.972	-0.771	0.048	1.162	0.002	0
Zatracheidae	NA	1	NA	NA	NA	0.640	NA	NA
Dissorophoidea*	>0.99	31	0.967	-0.411	<0.001	1.079	<0.001	0
Eryopidae	NA	3	0.994	-0.837	0.168	1.229	0.048	0
'B.' Stereospondylom.	0.60	9	0.907	-0.066	0.790	0.870	<0.001	0
Rhinesuchidae & *Ara.*	NA	3	0.954	-0.290	0.667	0.899	0.138	0
'Lydekkerinidae'	NA	1	NA	NA	NA	0.776	NA	NA
Capitosauria	0.67	7	0.984	0.039	0.764	0.804	<0.001	0
Brachyopoidea*	NA	3	0.990	0.055	0.830	0.833	0.063	0
Rhytidosteidae	NA	1	NA	NA	NA	0.724	NA	NA
Trematosauridae	NA	1	NA	NA	NA	0.663	NA	NA
Metoposauridae*	0.74	6	0.990	-0.572	0.015	1.038	<0.001	0
Embolomeri	0.75	5	NA	0.047	0.754	0.846	<0.001	1
Chroniosuchia*	NA	1	NA	NA	NA	0.825	NA	NA
Bystrowianidae	NA	1	NA	NA	NA	0.910	NA	NA
Seymouriamorpha	0.69	6	0.932	-1.049	0.045	1.397	0.002	0
Diplocaulidae	NA	4	0.966	-0.592	0.126	1.080	0.017	0
'Lepospondyl' clade	>0.99	16	0.843	-0.074	0.586	0.850	<0.001	0

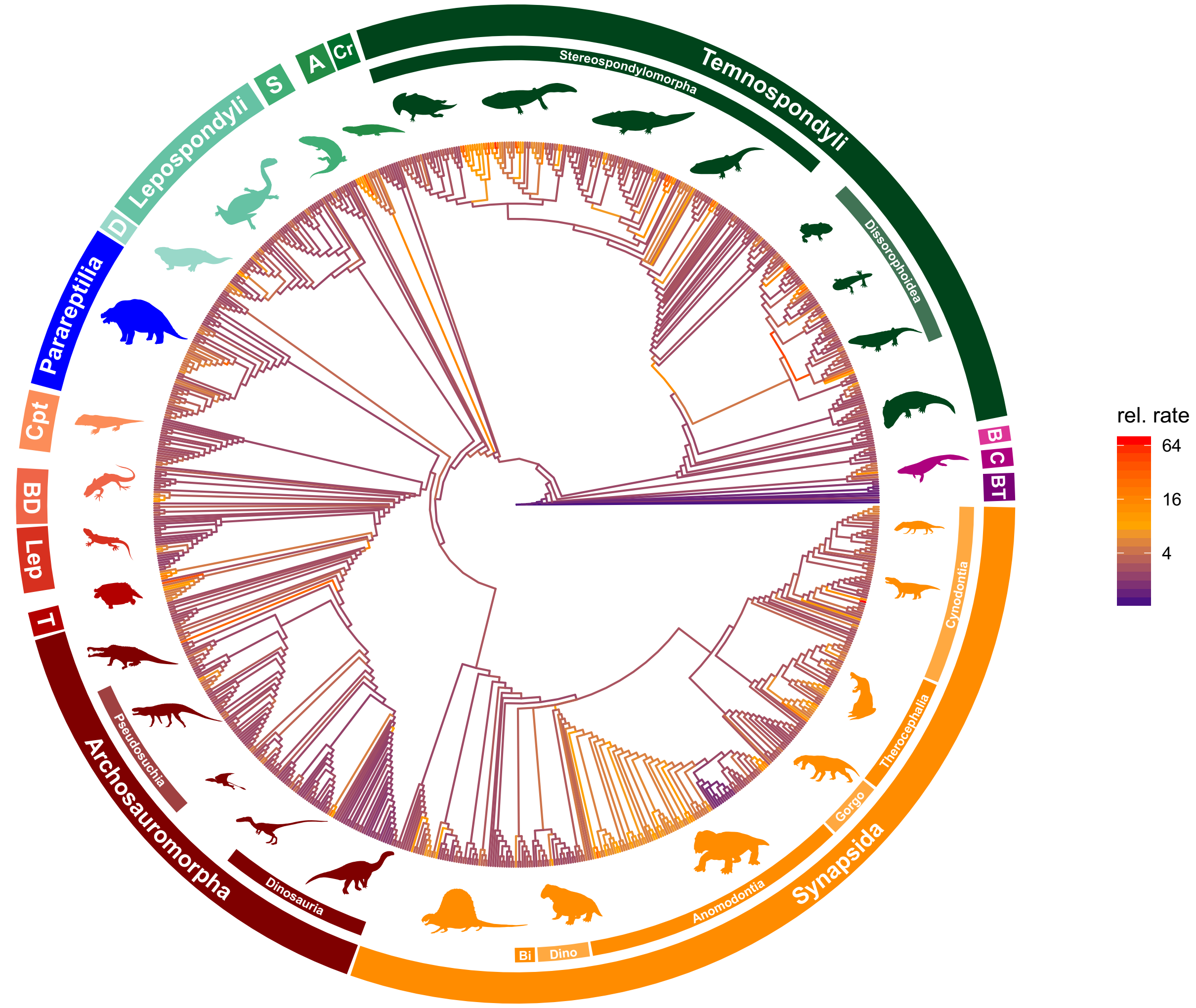

FIGURE 2.5. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the ‘traditional’ Amphibia and Ornithoscelida topologies (990 species). Abbreviations as in Figure 2.1. Silhouettes from `http://phylopic.org` (Steven Blackwood, Dmitry Bogdanov, Andrew A. Farke, Robert Gay, ‘Ghedo’, Chris Jennings, T. Michael Keesey, Brad McFeeters, Gareth Monger, Iain Reid, Roberto Díaz Sibaja, ‘Smokeybjb’, Nobu Tamura, Steven Traver, A. Verrière, Emily Willoughby, Mark Witton) and `https://commons.wikimedia.org` (Dmitry Bogdanov, Nobu Tamura).

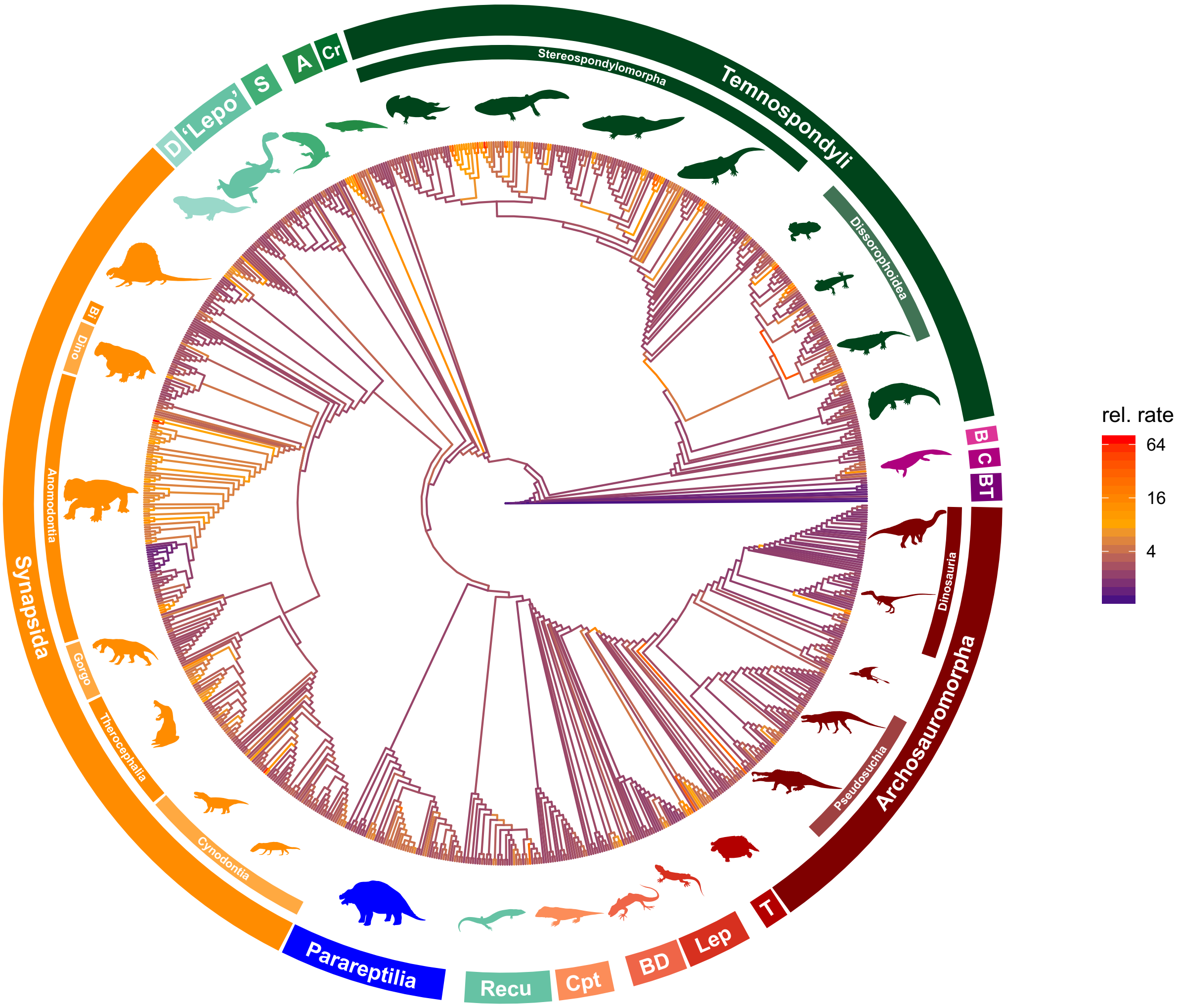

FIGURE 2.6. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the polyphyletic 'Lepospondyli' topology and the 'traditional' Archosauromorpha topology (990 species). 'Lepo', 'Lepospondyli'; Recu, Recumbirostra. Other abbreviations as in Figure 2.1. For silhouettes see Figure 2.5.

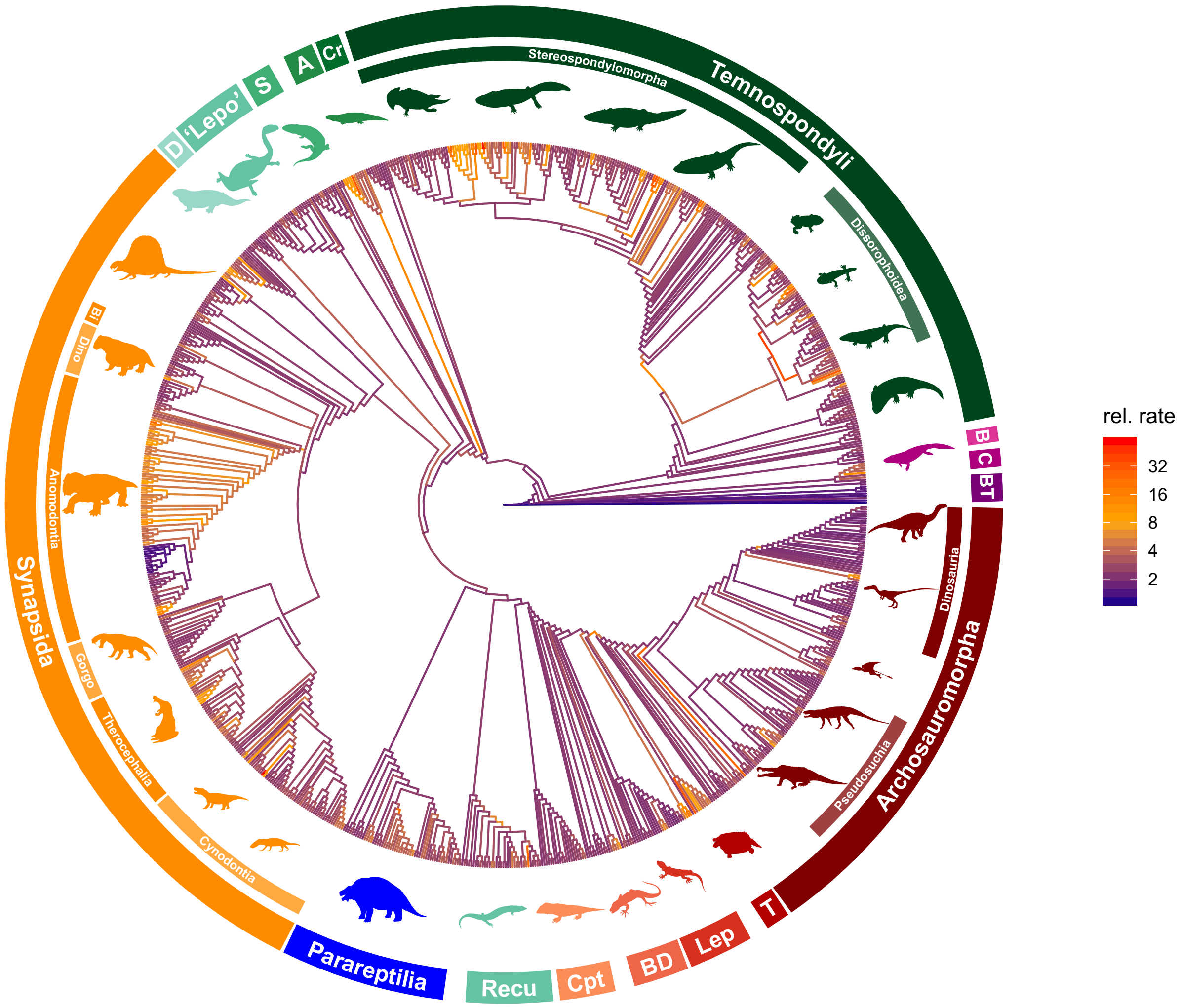

FIGURE 2.7. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the polyphyletic 'Lepospondyli' topology and the Ornithoscelida topology (990 species). 'Lepo', 'Lepospondyli'; Recu, Recumbirostra. Other abbreviations as in Figure 2.1. For silhouettes see Figure 2.5.

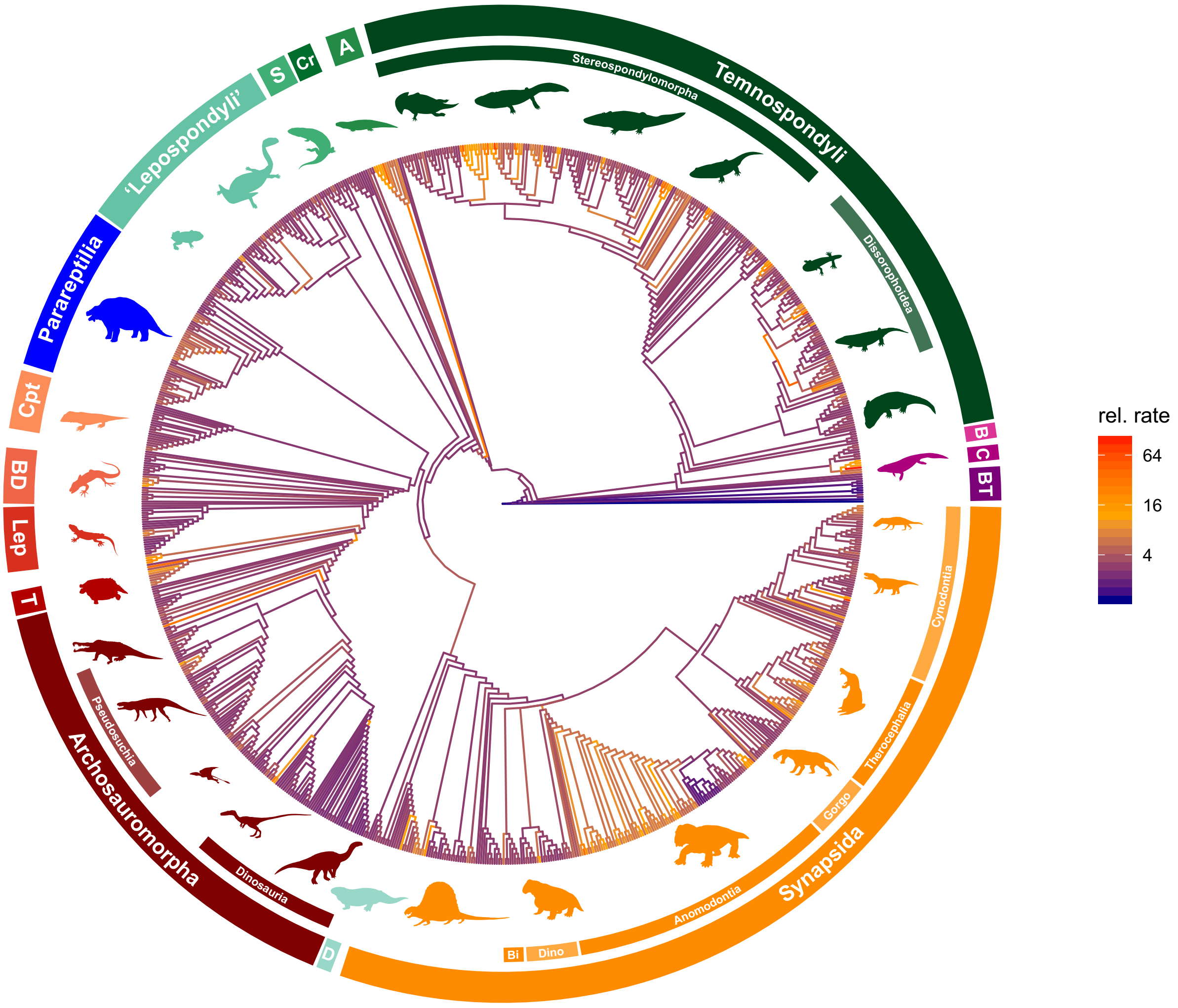

FIGURE 2.8. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the Lissamphibia LH topology and the 'traditional' Archosauromorpha topology (993 species). Abbreviations as in Figure 2.1. For silhouettes see Figure 2.5.

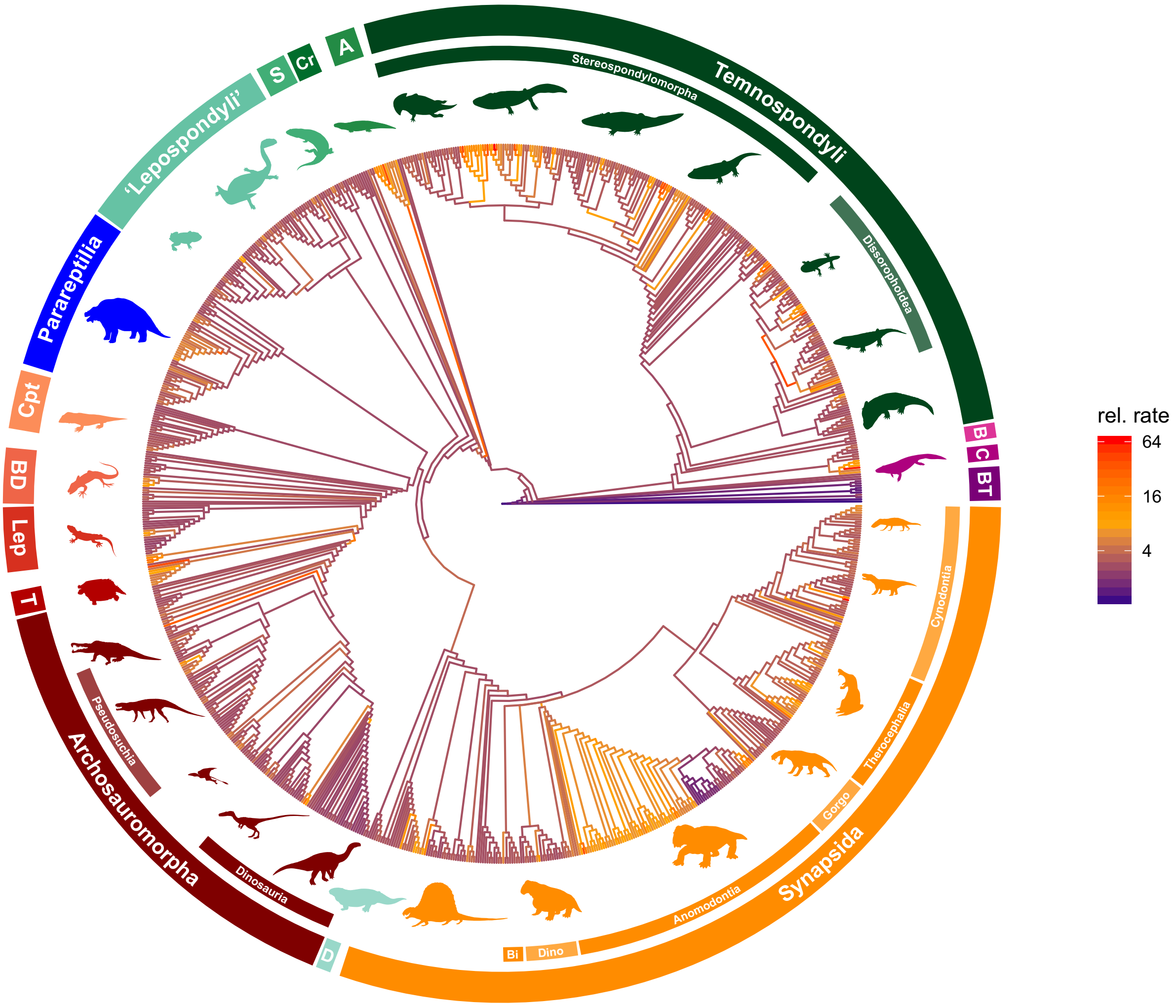

FIGURE 2.9. Relative rates of body size evolution in early tetrapods. Branches are coloured according to the mean relative evolutionary rate. The supertree is based on the Lissamphibia LH topology and the Ornithoscelida topology (993 species). Abbreviations as in Figure 2.1. For silhouettes see Figure 2.5.

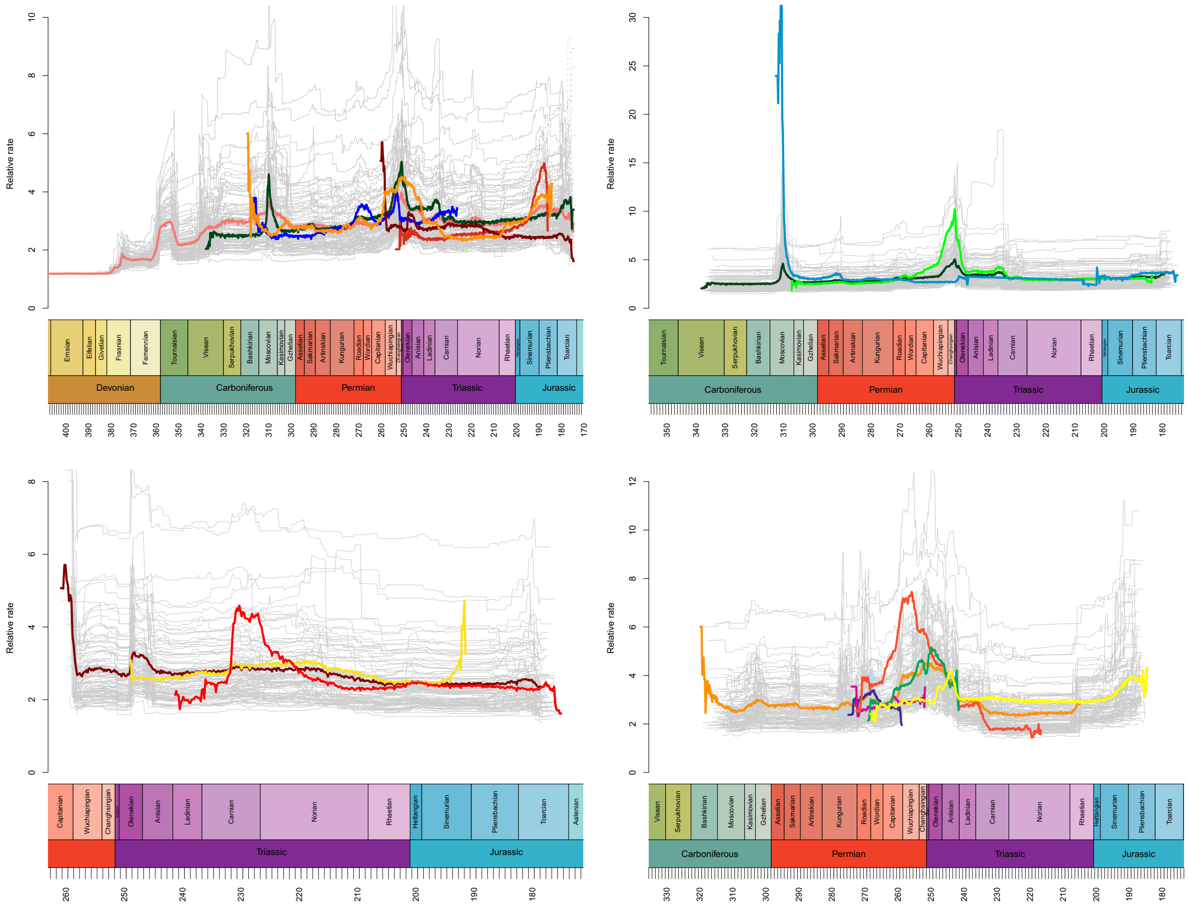

FIGURE 2.10. Mean rates of body size evolution through time for major subclades of Tetrapoda. The underlying supertree is based on the 'traditional' Amphibia and Ornithoscelida topologies. Clades coloured as in Figure 2.2 and Figure 2.3.

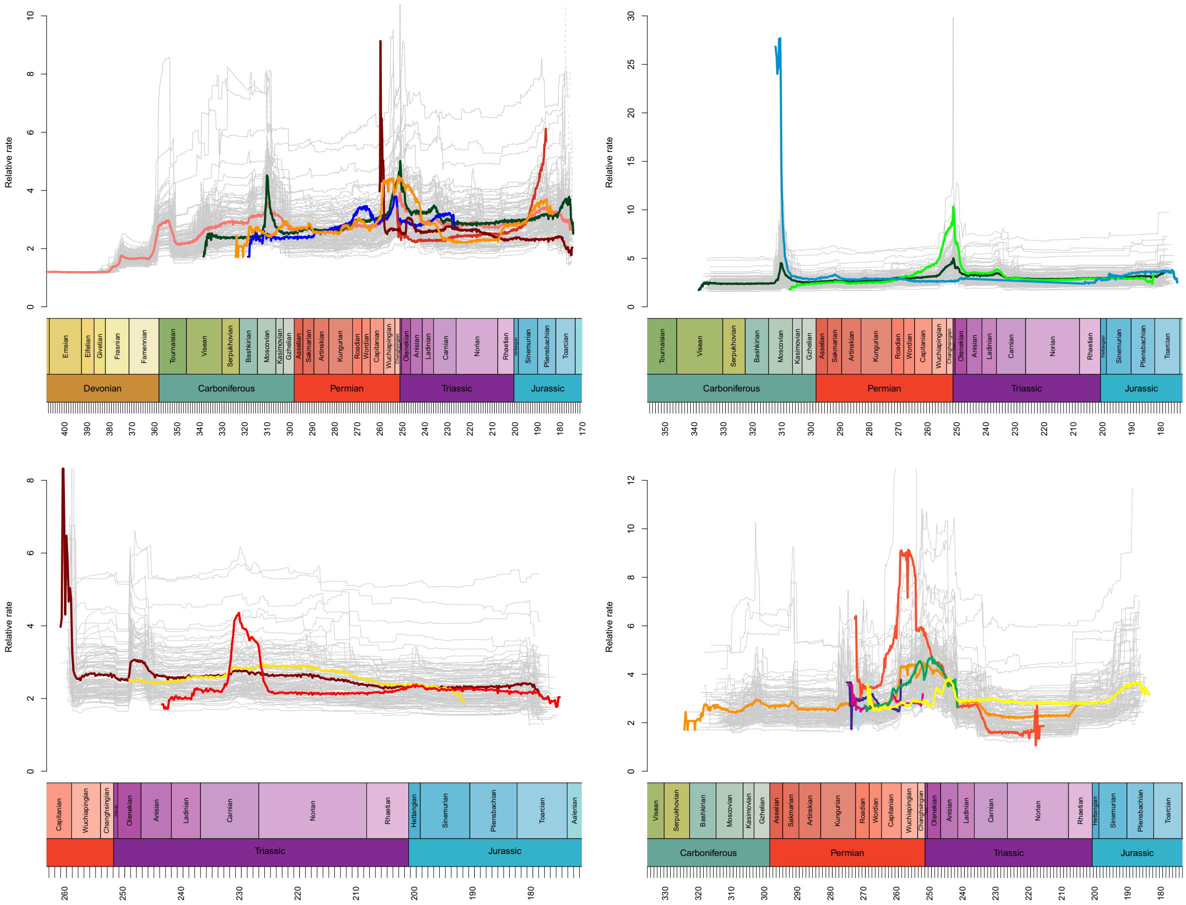

FIGURE 2.11. Mean rates of body size evolution through time for major subclades of Tetrapoda. The underlying supertree is based on the polyphyletic ‘Lepospondyli’ topology and the ‘traditional’ Archosauromorpha topology. Clades coloured as in Figure 2.2 and Figure 2.3.

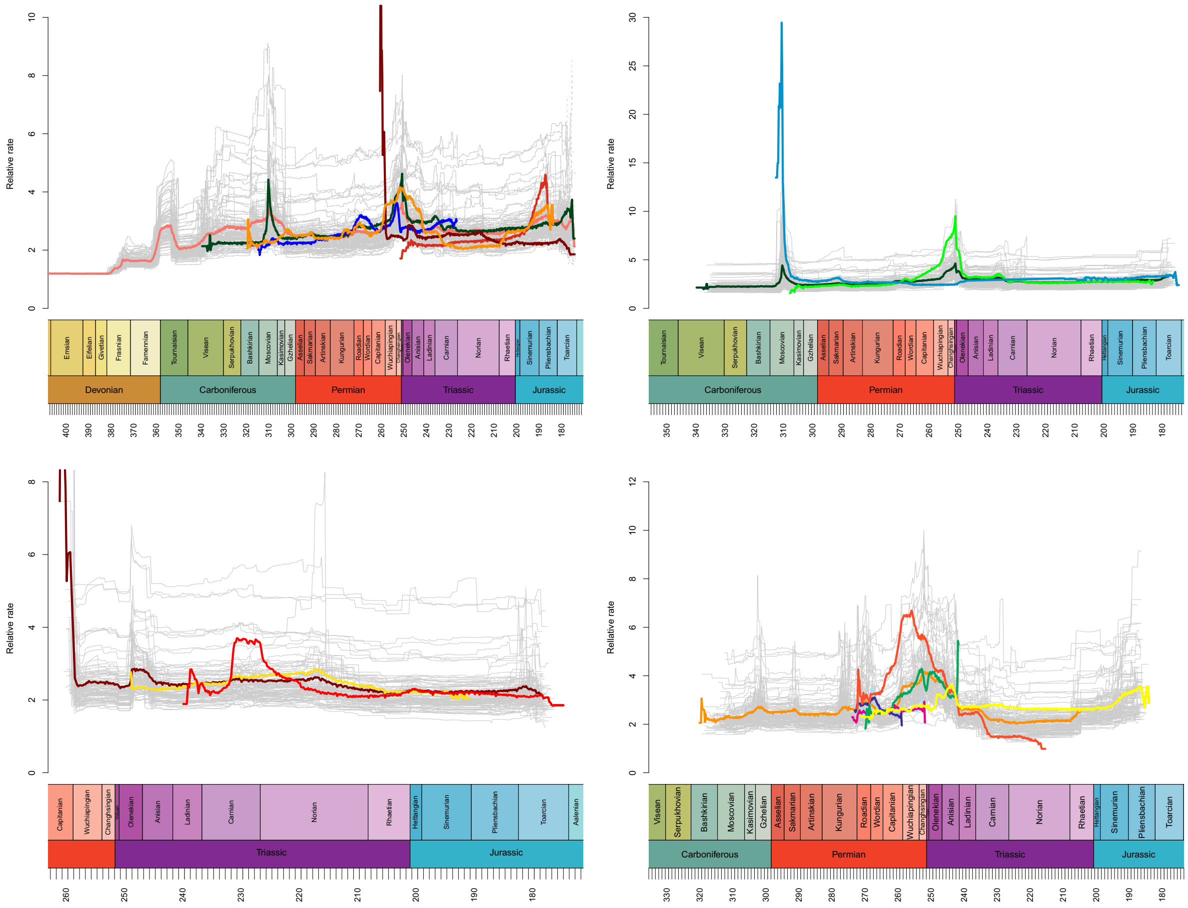

FIGURE 2.12. Mean rates of body size evolution through time for major subclades of Tetrapoda. The underlying supertree is based on the polyphyletic ‘Lepospondyli’ topology and the Ornithoscelida topology. Clades coloured as in Figure 2.2 and Figure 2.3.

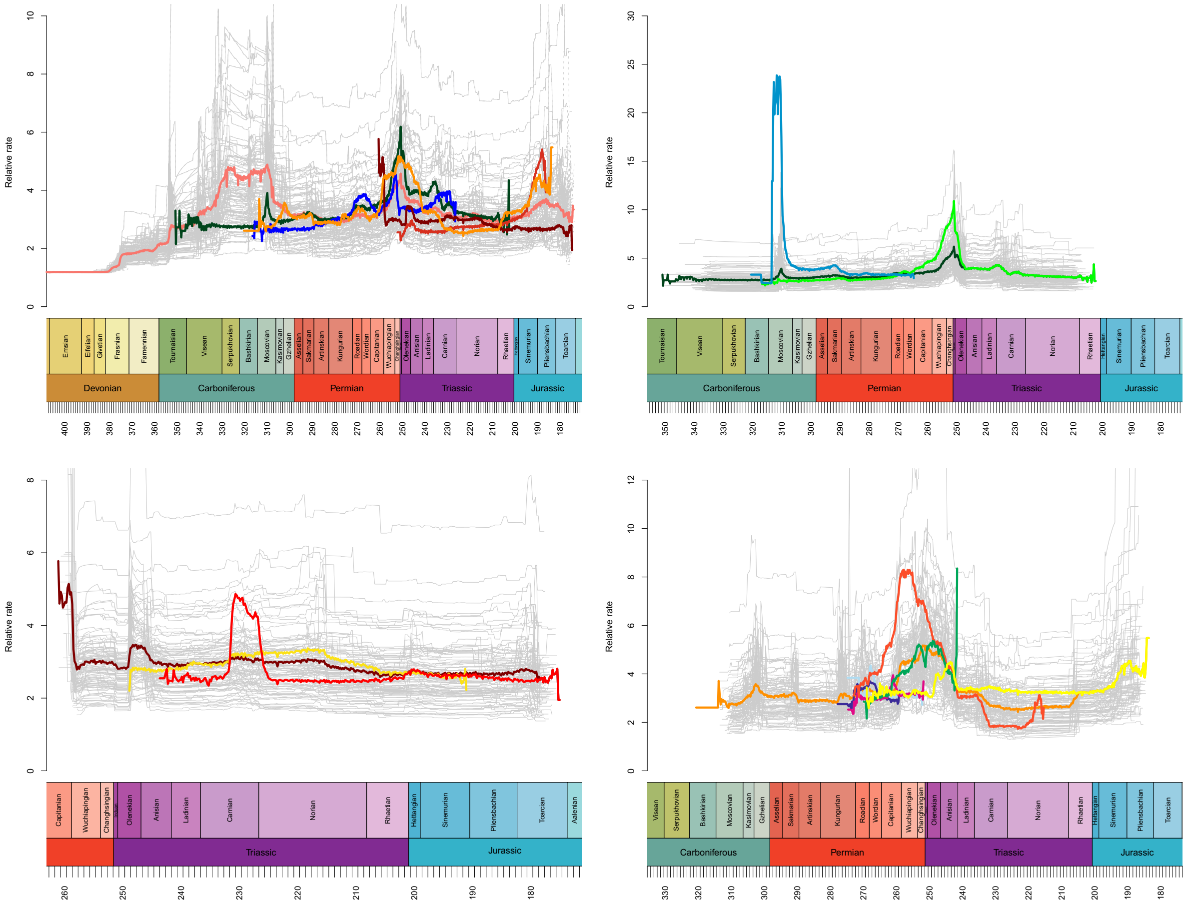

FIGURE 2.13. Mean rates of body size evolution through time for major subclades of Tetrapoda. The underlying supertree is based on the Lissamphibia LH topology and the ‘traditional’ Archosauromorpha topology. Clades coloured as in Figure 2.2 and Figure 2.3.

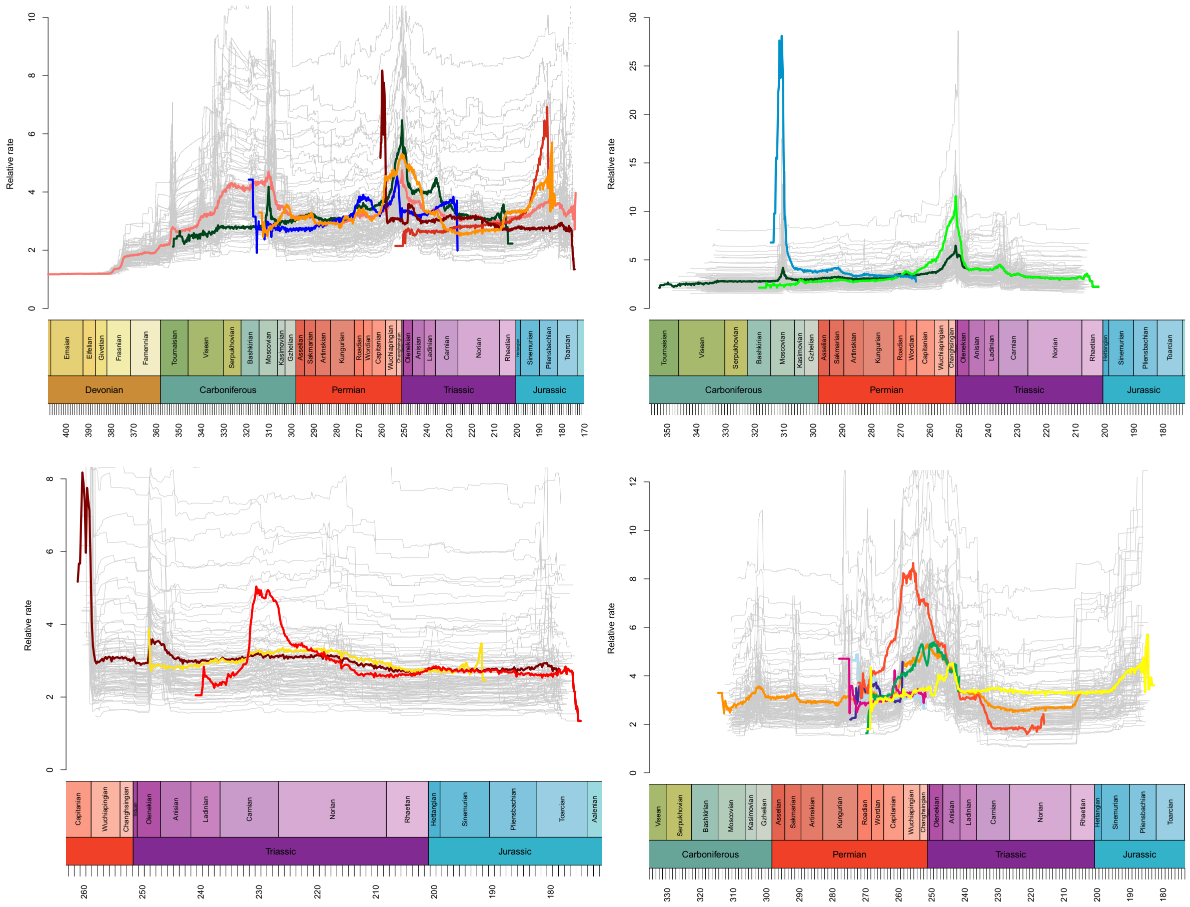

FIGURE 2.14. Mean rates of body size evolution through time for major subclades of Tetrapoda. The underlying supertree is based on the Lissamphibia LH topology and the Ornithoscelida topology. Clades coloured as in Figure 2.2 and Figure 2.3.

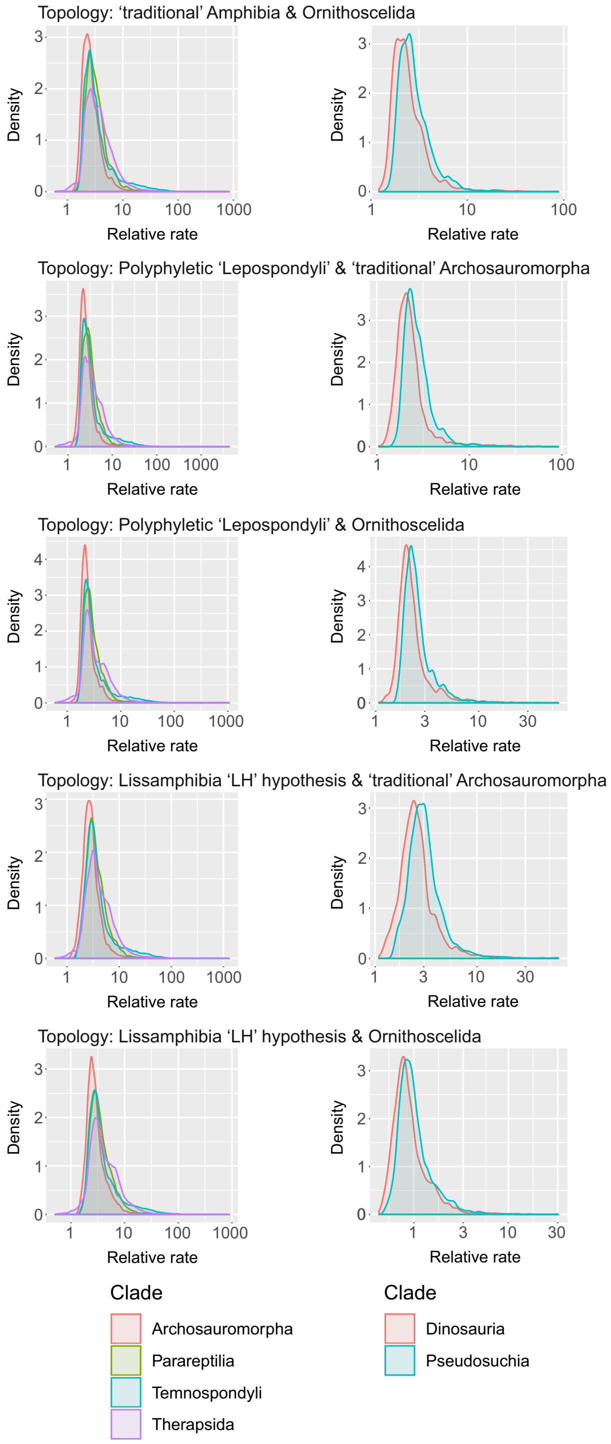

FIGURE 2.15. Distribution of relative evolutionary rates of major tetrapod clades under different topologies.

CHAPTER 3

NO EVIDENCE FOR POSITIVE PHENOTYPIC SELECTION OF FUNCTIONAL MANDIBULAR DISPARITY IN EARLY ARCHOSAUROMORPHS

Collection of early archosauromorph mandibles was mainly carried out by Suresh Singh. Measurement of functional characters and principal component analysis were also realised by Suresh Singh who generously made the PCA scores available for subsequent analysis. All other data collection, analyses, and the text presented here are the candidate's own work. Estimate of total work carried out by the candidate: 80%.

3.1 Abstract

The mandibles of archosauromorphs during their early evolutionary history (259.1 Ma to 174.1 Ma) were highly functionally disparate. I find very strong support for heterogeneous evolutionary rates of the mandibular functional complex of early archosauromorphs. Some herbivorous clades (hyperodapedontine rhynchosaurs, aetosaurs) exhibit high rates on single branches indicative of niche shifts. Absolute rates in sauropodomorphs and ornithischians are low compared to other herbivorous archosauromorph clades but higher compared to neotheropods. No drastic changes in evolutionary rates are recorded over time with a modest peak in rates at the Ladinian-Carnian boundary for early archosauromorphs. The evolutionary rates of early pseudosuchians always exceed the rates of early dinosaurs. Except for one taxon, *Ornithosuchus woodwardi*, I find no evidence for positive phenotypic selection acting on mandibular function in early archosauromorphs. Contrary to previous suggestions, strong selective pressure did not play a major role in the evolution of feeding adaptations of early archosauromorphs and early dinosaurs and was not responsible for their success. This result is consistent with an opportunistic non-competitive

replacement model for the success of these clades. Future studies will show whether this also applies to other traits considered responsible for the success of both early archosauromorphs and early dinosaurs.

3.2 Introduction

Archosauromorpha is the most successful clade of tetrapods represented by over 10,000 species of birds (Jetz et al., 2012; Wiens, 2015) and over 25 species of crocodiles (Grigg and Kirshner, 2015; Wiens, 2015) in today's ecosystems and featuring one of the most iconic group of animals, the non-avian dinosaurs, in its evolutionary history. Archosauromorphs are the only clade of tetrapods to have conquered both land (Brusatte et al., 2008a; Benson, 2018) and air in equally successful manner (Benson et al., 2014a; Navarro et al., 2018; Jetz et al., 2012) while also remaining a major component of marine faunas (Young et al., 2010; Stubbs and Benton, 2016; Foffa et al., 2018).

The early history of archosauromorphs, which originated in the middle-late Permian (Ezcurra et al., 2014; Ezcurra and Butler, 2018), was characterised by a series of events that ultimately led to their modern success. During the late Permian archosauromorphs were only a minor component of terrestrial ecosystems (Benton et al., 2004; Ezcurra and Butler, 2018) and it was only after the Permo-Triassic mass extinction event (PTME) when archosauromorphs started to dominate terrestrial ecosystems (Bakker, 1977; Benton et al., 2004; Sookias et al., 2012b; Ezcurra and Butler, 2018). After a climate oscillation in the mid Carnian, the so called Carnian Pluvial Event, dinosaurs diversified rapidly during the 'dinosaur diversification event' (Benton et al., 2018; Bernardi et al., 2018a) potentially preceded by the extinction of a few non-dinosaurian archosauromorph clades as part of the hypothesized Carnian-Norian extinction event (CNEE; Benton, 1986a; Benton, 1986c; Benton, 1993; Benton, 2004; Brusatte et al., 2008a; Benton et al., 2018; but see Irmis, 2011). The end-Triassic mass extinction event (ETME) saw the disappearance of several pseudosuchian clades and the establishment of non-avian dinosaurs as the dominant elements of Mesozoic terrestrial ecosystems (Benton, 1983a; Brusatte et al., 2008a). The replacement of the previously dominant typical Palaeozoic terrestrial fauna by early archosauromorphs during the Triassic and the rise of dinosaurs during the Late Triassic and Early Jurassic has been explained as the result of either competition (Bakker, 1972; Charig, 1980; Bonaparte, 1982; Bakker, 1986; see also Irmis, 2011; Padian, 2013; Griffin and Nesbitt, 2016) or opportunism (Benton, 1983a; Benton et al., 2004; Brusatte et al., 2008a; Sookias et al., 2012b; Ezcurra and Butler, 2018). Proponents of the first hypothesis argue that early archosauromorphs and early dinosaurs were biomechanically and physiologically 'superior' compared to their competitors which allowed the former to outcompete the latter (Bakker, 1972; Charig, 1980; Bonaparte, 1982; Bakker, 1986). Proponents of the second hypothesis relate the expansion of early archosauromorphs and early dinosaurs to the disappearance of the previously dominating clades, allowing early archosauromorphs and early dinosaurs to 'passively' enter the newly emptied niches (Benton, 1983a; Benton et al., 2004; Brusatte et al., 2008a; Sookias et al., 2012b; Ezcurra and Butler, 2018). As part of this debate it has been suggested that strong selective pressure led to the appearance of novel herbivore feeding adaptations in several early archosauromorph and early dinosaur clades (Charig, 1980; Zawiskie, 1986). These adaptations were invoked as one of the reasons for the success of early archosauromorphs and early dinosaurs (Charig, 1980; Zawiskie, 1986).

Recently a test for positive phenotypic selection has been proposed (Baker et al., 2016) which is inspired by a widely used test for detecting positive selection in molecular data (Yang, 2002, 2006) and relies on the consistent detection of major evolutionary rate increases for morphological data. Here I apply this test to a set of well-established functional measurements (Anderson et al., 2011, 2013; Stubbs et al., 2013; Button et al., 2014; MacLaren et al., 2017) taken from mandibles of early archosauromorphs ranging from the early Wuchiapingian to the late Toarcian (259.1 Ma to 174.1 Ma). The measured biomechanical traits are known to be closely related to feeding ecology (Anderson et al., 2011, 2013; Stubbs et al., 2013; Button et al., 2014; MacLaren et al., 2016, 2017). I test specifically whether (1) evolutionary rates of mandibular function were heterogeneous in early archosauromorphs and (2) whether there is any evidence for positive phenotypic selection acting on the functional properties of the early archosauromorph mandible. I compare the results with previous analyses of shape and biomechanical disparity in early archosauromorphs (Sakamoto, 2010; Brusatte et al., 2012; Foth and Rauhut, 2013; Stubbs et al., 2013; Foth et al., 2016; MacLaren et al., 2017; Ezcurra and Butler, 2018) and discuss the implications for hypotheses on the success of early archosauromorphs and early dinosaurs.

3.3 Methods

3.3.1 Data collection and supertree construction

The alphataxonomic framework and the stratigraphic range of the studied early archosauromorph taxa was based on the updated version of the Early Tetrapod Database ETD (Benton et al., 2013c,a) presented in chapter 2. The new ETD currently represents the largest up to date range-based database of early tetrapod species and the only one that provides stratigraphic ranges at substage-level resolution (Benton et al., 2013c; chapter 2). This increased temporal resolution relative to other databases allows for detecting within-stage patterns such as the mid-Carnian ‘dinosaur diversification event’ (Bernardi et al., 2018a) and is less prone to averaging effects (Benton, 2012).

162 mandible images of early archosauromorphs in lateral view were collected from published literature (Table 3.1). *Bergamodactylus wildi* has recently been argued to represent a junior synonym of *Carniadactylus rosenfeldi* (Dalla Vecchia, 2018; see Appendix A for further details) and was therefore excluded from further analyses leaving 161 mandible images. Data compilation was carried out at genus level except for genera which are particularly species-rich (*Hypero-*

dapedon: Mukherjee and Ray, 2014) or whose species alpha taxonomy is currently uncertain (*Dilophosaurus*; Wang et al., 2017a; Wang et al., 2017b). Most of the mandibles could directly be assigned to species thereby allowing me to use the stratigraphic range of the species in the subsequent phylogenetic comparative analyses. I assigned mandibles that were indeterminate at species level to the type species of the respective genus. Currently there are 439 valid species of early archosauromorphs, i. e. it was possible to find mandibles images for 37% of the known species diversity. The 439 species include 157 (36% of total diversity) pseudosuchians and 119 (27% of total diversity) dinosaurs, which represent the largest clades within early archosauromorphs. 60 (37% of all mandible images) mandibles images belong to pseudosuchians, 47 to dinosaurs (29% of all mandible images), i. e. the proportion of used mandible images reflects the proportion of the clades as part of the total diversity of early archosauromorphs.

Lower jaw biomechanical disparity was measured using eight functional characters extensively described in the literature (Anderson et al., 2011, 2013; Stubbs et al., 2013; Button et al., 2014; MacLaren et al., 2016, 2017): (1) primary anterior mechanical advantage (MA), (2) primary posterior MA, (3) opening MA, (4) maximum aspect ratio, (5) relative length of the tooth row, (6) relative length of the symphysis, (7) symphysis angle, (8) articulation offset. The mandible of jawed vertebrates can be modelled as a third-order lever (Barel, 1983; Westneat, 1994, 2003) with the articular joint acting as the fulcrum (point of rotation). The mandibular adductor muscles provide the input force that act about the articular joint and result in the output force at the biting tooth (Button et al., 2014). The mechanical advantage, the ratio between inlever and outlever, represents the proportion of input force that is converted to output force at the biting tooth and therefore provides a simple estimate for the efficiency of this system (Button et al., 2014). Taxa with weak and rapid bites have a low MA (Wainwright and Richard, 1995; Stubbs et al., 2013) and taxa with a strong bite force have a high MA. MA is known to correlate with diet in modern fish (Westneat, 1994; Wainwright and Richard, 1995) and is generally considered to increase in terrestrial herbivorous tetrapod lineages (Stayton, 2006). The outlever of the primary anterior MA is measured from the articular joint to the anterior-most tooth position, its inlever is measured from the articular joint to the centre of the adductor muscles insertion (Button et al., 2014; MacLaren et al., 2016). The primary anterior MA represents the lowest possible MA of the lower jaw along the toothrow (Button et al., 2014). The primary posterior MA represents the greatest possible MA of the lower jaw along the toothrow (Button et al., 2014) and differs from the primary anterior MA only in its outlever, which is measured from the articular joint to the posterior-most tooth position. The outlever of the opening MA is the same as the one used for calculating the primary posterior MA, its inlever is measured from the articular joint to the end of the retroarticular process (Stubbs et al., 2013). Opening MA is a proxy for the velocity during jaw opening (Westneat, 1994, 2003; Stubbs et al., 2013) with higher values indicating a lower velocity of jaw opening (Westneat, 2004; Stubbs et al., 2013). Opening MA is linked to feeding patterns and prey selection (Anderson and Westneat, 2007; Stubbs et al., 2013). The aspect ratio of the jaw is a proxy for the resistance to bending of the jaw and is given by the greatest depth of the mandible divided by its total length (Anderson et al., 2011; Button et al., 2014; MacLaren et al., 2016). The relative length of the tooth row represents the ratio of total tooth-row length and total mandibular length (Stubbs et al., 2013). A larger tooth row results in greater variation of potential bite force and speed (Anderson et al., 2011; Stubbs et al., 2013). The relative length of the tooth row also indicates the maximum jaw length available for prey capture (Stubbs et al., 2013). The relative length of the symphysis is the ratio between the long axis of the mandibular symphysis and total mandibular length and represents a proxy for symphysis robustness (MacLaren et al., 2016), which is known to affect food processing in modern herbivorous rhynchocephalians (Jones et al., 2012) and is of major importance in the mechanical response of modern crocodylians to biting, twisting, and shaking (Porro et al., 2011a; Walmsley et al., 2013). The symphysis angle, measured between the jaw line and a line parallel to the long axis of the mandibular symphysis, similarly also affects the capacity of a lower jaw to resist stress and strain (Daegling, 2001), with steeper angles resulting in increased resistance to transverse bending (Daegling, 2001; Anderson et al., 2011). The articulation offset is measured as the line perpendicular to the tangent of the mandibular tooth row which intersects the articular joint (Anderson et al., 2011; MacLaren et al., 2016). This line is then standardised by the total mandibular length. A small articulation offset indicates ‘scissor-like’ occlusion, which is typical of carnivorous taxa. A larger articulation offset allows all teeth to occlude simultaneously and is typical of herbivorous and durophagous taxa (Ramsay and Wilga, 2007; Stubbs et al., 2013).

These measurements, taken with ImageJ (Abràmoff et al., 2004; Schneider et al., 2012), therefore capture important biomechanical properties of the mandible related to feeding ecology and have been used in several studies to characterise mandibular function (Anderson et al., 2011, 2013; Stubbs et al., 2013; Button et al., 2014; MacLaren et al., 2017). They have been shown to better characterise ecological disparity than comparisons of overall shape (Wainwright, 2007; Anderson, 2009) and are therefore herein preferred over landmark-based morphometric analyses. To identify the significant axes of variation the matrix of all functional characters was subjected to a principal component analysis (PCA) using the R (R Core Team, 2018) package `FactoMineR` (Lê et al., 2008; Husson et al., 2018). Functional measurements and PC analysis were carried out by Suresh Singh who generously made the PCA scores available for subsequent analysis (Table 3.2).

An informal supertree approach was taken to place all valid archosauromorph species (439 species) in a phylogeny. I used all archosauromorph species as complete trees are preferable over pruned ones when doing the subsequent timescaling (Lloyd et al., 2016b; Sakamoto and Ruta, 2012). The most comprehensive currently available phylogeny of Archosauromorpha (Ezcurra et al., 2017) was used as the scaffold for the supertree and additional taxa were added using Mesquite 3.51 (Maddison and Maddison, 2018). I generated two different topologies to reflect the current uncertainty on dinosaur relationships. The first topology represents the previous consensus on dinosaur relationships (Bittencourt et al., 2015; Nesbitt and Ezcurra, 2015; Cabreira et al., 2016; Ezcurra, 2017; Müller et al., 2019, 2018b; Langer et al., 2017b), the second is based on the Ornithoscelida hypothesis (Baron et al., 2017a). The two topologies correspond to the archosauromorph topologies used in chapter 2 (for additional information on the supertree construction see Appendix A).

3.3.2 Time-scaling

I dropped *Nyasasaurus parringtoni* from the Ornithoscelida supertree topology prior to time-scaling the trees due to the uncertain phylogenetic (Nesbitt et al., 2013d; Baron et al., 2017a; Langer et al., 2017b; Puttick et al., 2017b; Baron and Williams, 2018) and stratigraphic placement (Nesbitt et al., 2017; Butler et al., 2018) of the taxon and its unusual derived position within the Ornithoscelida topology (Baron et al., 2017a). Polytomies were randomly resolved prior to timescaling.

I produced 100 timescaled tree for each topology using the current R implementation (available at: `http://www.graemetlloyd.com/pubdata/functions_7.r`) of the whole-tree extended Hedman algorithm (Lloyd et al., 2016b; Hedman, 2010). The Hedman algorithm is a probabilistic ‘a posteriori’ time-scaling (APT) approach (Lloyd et al., 2016b). It uses the ages of consecutive outgroups to a node (providing a set of uniform priors) to date the respective node in a Bayesian framework (Lloyd et al., 2016b; Hedman, 2010). Following Lloyd et al. (2016b) I set the absolute maximum bound t_0 conservatively to the base of the Cambrian (542 Ma) and opted for the “conservative approach” (Hedman, 2010) as modified by Lloyd et al. (2016b), thereby ignoring taxon ages that are younger than the ages of the preceding outgroup. I used the last appearance dates (LADs) of *Ichthyostega stensioi* (363.3 Ma), *Ymeria denticulata* (358.9 Ma), *Tulerpeton curtum* (358.9 Ma), *Ossirarus kierani* (350.8 Ma), *Casineria kiddi* (336.2 Ma), *Palaeomolgophis scoticus* (336.2 Ma), *Hylonomus lyelli* (315.2 Ma), *Anthracodromeus longipes* (307 Ma), *Petrolacosaurus kansensis* (303.7 Ma), *Orovenator mayorum* (286.8 Ma), *Lanthanolania ivakhnenkoi* (265.1 Ma), and *Eunotosaurus africanus* (259.1 Ma) as outgroup ages. Choice of outgroups and their absolute ages was based on the early tetrapod supertree and the updated ETD presented in chapter 2. I set the resolution parameter to 10,000. To account for uncertainty in taxon ages I created uniform distributions bounded by the first and last appearance date of each archosauromorph species from which I randomly sampled the tip ages. The available implementation of the Hedman algorithm (Lloyd et al., 2016b) is not capable of timescaling trees that include polytomies. For visualization purposes I therefore generated another unresolved timescaled tree for each topology using the minimum branch length (MBL) method (Laurin, 2004) as implemented in the timePaleoPhy function of the R package `paleotree` (Bapst, 2012). The minimum branch length was set to 0.5 Myr. The MBL timescaled tree was only used to provide a consensus tree that visualizes the results of the 100 trees timescaled using the Hedman method.

3.3.3 Rate analysis and test for positive phenotypic selection

I employed comparative phylogenetic methods to analyse evolutionary rates of mandibular biomechanical disparity and to determine the potential occurrence of positive phenotypic selection of mandibular function in early archosauromorphs.

I pruned the timescaled trees a posteriori to include only taxa with mandibular functional data. None of the taxa placed according to taxonomic opinion (see Appendix A) is part of a polytomy in the pruned trees. Problems related to randomly resolving polytomies (Rabosky and Hurlbert, 2015) therefore do not apply to this dataset. I used BayesTraits V2.0.2 (`http://www.evolution.rdg.ac.uk/BayesTraitsV2.0.2.html`) (Venditti et al., 2011) to estimate multivariate variable rates models for all five PCA scores, which represent 100% of the variation in the mandibular functional complex. I ran variable rates independent contrast models using the Markov chain Monte Carlo (MCMC) method with default priors for each timescaled tree. PC axes are per definitionem orthogonal (Cooney et al., 2017), but are evolutionarily correlated (Adams and Collyer, 2018; see also Felice and Goswami, 2018; Chira et al., 2018). I therefore allowed for correlation between the PC axes when running the multivariate variable rates models. Each tree was run for 110,000,000 iterations and parameters were sampled every 10,000 iterations. 10,000,000 iterations were discarded as burn-in. I calculated the marginal likelihood of the models using the stepping stone sampler (Xie et al., 2011) implemented in BayesTraits. I sampled 1000 stones and used 100,000 iterations per stone. Convergence was assessed using the R package CODA (Plummer et al., 2006). The smallest effective sample size (ESS) value across all 100 trees was >467. I used the Variable Rates Post Processor (`http://www.evolution.reading.ac.uk/VarRatesWebPP/`) (Baker et al., 2016) to extract the final parameters results. Models were compared using a Bayes Factor test.

I calculated a strict consensus tree for all timescaled trees in which the branch lengths had been replaced with the mean rate scalars calculated by BayesTraits. The consensus tree was computed using the R package `phytools` (Revell, 2012). I calculated the mean branch lengths for each set of trees, ignoring edges that were not present in all trees of a set. I then plotted the consensus tree colour-coded according to the mean rate scalars and with the original branch lengths replaced by the mean rate scalars using `ggtree` (Yu et al., 2017). Stretched and compressed branches on the consensus tree therefore directly reflect changes in the evolutionary rates of mandibular function.

I calculated phylogenetically corrected evolutionary rates through time (Venditti et al., 2011; Sakamoto and Venditti, 2018) for all trees using the Variable Rates Post Processor (Baker et al., 2016) with 1,000 time slices per tree. I then calculated the mean of the phylogenetically corrected evolutionary rates through time across all 100 trees for all early archosauromorphs and for the separate subclades Pseudosuchia and Dinosauria. I used the R package `geoscale` (Bell, 2015), modified to include an updated version of the International Chronostratigraphic Chart (Cohen et al., 2013; International Commission on Stratigraphy (ICS), 2017), to plot evolutionary rates against time.

Positive phenotypic selection sensu Baker et al. (2016) was defined on the basis of two criteria: (1) the ratio between the expected phenotypic variance on a single branch due to rate variation and the expected phenotypic variance given a Brownian motion background rate is larger than 2 (magnitude criterion), and (2) this ratio must be observed in more than 95% of the posterior distribution of rate scalars of the respective branch (certainty criterion) (Baker et al., 2016). Positive phenotypic selection is therefore detected on a branch if the rate scalar for this branch is >2 in >95% of the posterior distribution of rescaled trees output by BayesTraits. The definition is inspired by the ratio of the non-synonymous rate of nucleotide substitutions to the synonymous rate of nucleotide substitutions in protein-coding genes d_N/d_S, where positive selection is detected if the non-synonymous rate of substitution contributes to more than half of the genetic change observed on the branch of interest (Yang, 2002, 2006; Baker et al., 2016). This definition assumes that topology and branch lengths of a single phylogenetic tree are reliably for the studied clade (Baker et al., 2016). Since I ran the BayesTraits analyses over a set of trees, I added an additional criterion to detect positive phenotypic selection: (3) positive phenotypic selection is only detected if the magnitude criterion (1) and the certainty criterion (2) apply to all trees for the branch of interest. It could be argued that this criterion is overly conservative in detecting positive phenotypic selection. I therefore report the results for both a consensus tree which fits all three criteria and for the individual trees which only fit the first two criteria. I used the modal rate scalar for the magnitude criterion and the scaling frequency of a branch in the posterior distribution for the certainty criterion, both reported by the Variable Rates Post Processor (Baker et al., 2016). This approach is expected to give very similar results compared to the original definition (J. Baker, pers. comm., 2018; C. Venditti, pers. comm., 2018) and greatly reduces the memory footprint.

I repeated all analyses for both topologies (see Table 3.6).

3.4 Results

My results show that shifts in evolutionary rates of mandibular function of early archosauromorphs were common. Results and discussion presented here refer to the supertree topology based on the traditional Archosauromorpha relationships (Figure 3.1). A consistent pattern was recovered for the Ornithoscelida topology, albeit absolute rate values can differ between the two topologies (Table 3.6). A heterogeneous rate model is ‘very strongly’ (minimum Bayes factor >49; Raftery, 1996; Meade and Pagel, 2016) favoured for all 100 timescaled trees irrespective of the chosen topology.

Rate increases can be divided into two groups (Figure 3.1). The first group consists of terminal taxa characterised by exceptionally high evolutionary rates. Examples are *Vancleavea campi* (>8 times the background rate), *Aetosaurus ferratus* (>11 times the background rate), and

Ornithosuchus woodwardi (>21 times the background rate), and *Sanjuansaurus gordilloi* (>4 to 7 times the background rate, depending on the topology). Evolutionary rates over three times the background rate are also recovered for *Osmolskina czatkowicensis*, *Scleromochlus taylori*, and *Herrerasaurus ischigualastensis*. Terminal taxa with evolutionary rates higher than two times the background rate are more common in pseudosuchians (e.g., *Lotosaurus adentus*, *Lotosaurus adentus*, *Batrachotomus kupferzellensis*, *Hemiprotosuchus leali*) than in non-avian dinosaurs (e.g., *Coelophysis bauri*).

The second group of rate increases represents internal branches with very high evolutionary rates (Figure 3.1). Exceptionally high rates are found within rhynchosaurs on the branch leading to Hyperodapedontinae, including *Isalorhynchus genovefae*, *Teyumbaita sulcognathus*, and *Hyperodapedon* (>12 times the background rate). High rates are also found on the branch leading to the clade *Revueltosaurus callenderi* + Aetosauria (>2.8 times the background rate), the branch leading to Aetosauria (>4 times the background rate), the branch leading to the clade *Effigia okeeffeae* + *Lotosaurus adentus* (~3 times the background rate), the branch leading to the clade including all protosuchians except for *Orthosuchus* (>3 times the background rate), and the clade including the eopterosaurs *Carniadactylus rosenfeldi* + *Eudimorphodon ranzii* (>3 times the background rate).

Apart from the rate increases reported above, most of Archosauromorpha exhibit rates close to the background rate (Figure 3.1). A notable exception are theropod non-avian dinosaurs which are characterised by rates slower than the background rate, especially several neotheropods such as *Dilophosaurus sinensis*, *Dilophosaurus wetherilli*, *Liliensternus liliensterni*, *Zupaysaurus rougieri*, *Panguraptor lufengensis*, and *Megapnosaurus kayentakatae* whose rates are about 0.6 times the background rate. Sauropodomorpha (and the dinosauromorph Silesauridae) do not show remarkable rate increases but are also far from exhibiting the low rates recovered for the neotheropods.

The baseline rate of evolution of the mandibular functional complex in early archosauromorphs was close to the background rate of a Brownian motion model at the origin of the clade (Figure 3.2). No early burst with subsequent exponential deceleration of evolutionary rates or quick burst in evolutionary with an immediate decline afterwards (as observed for body size in early archosauromorphs; see chapter 2) was found. Instead, rates rose in a relatively gradual fashion through the Early and Middle Triassic before reaching a peak at the beginning of the Carnian, slightly below two times the background rate. Afterwards evolutionary rates decreased over an extended period of time, spanning more than 25 million years, before reaching another plateau at the begin of the Rhaetian, now slightly below the background rate. Rates remained basically stable throughout the rest of the Late Triassic and the Early Jurassic. The two big mass extinction events of this time period, the PTME and the ETME, either had no effect at all (ETME) or only a very minor one (PTME) on the evolutionary rates. Given the relatively small number of taxa present during the PTME this result should not be overinterpreted but the missing impact

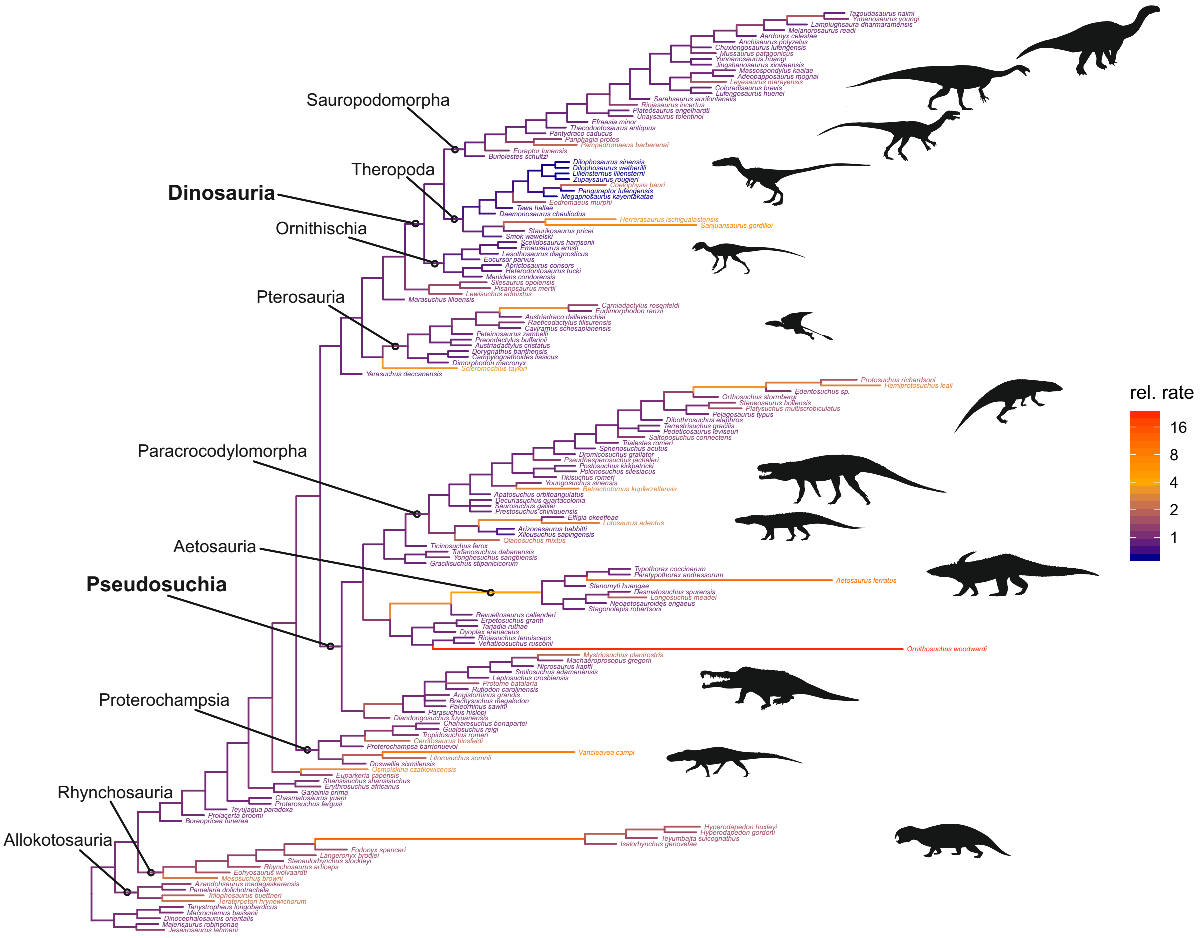

FIGURE 3.1. Relative rates of mandibular functional evolution in early archosauromorphs. Original branch lengths are replaced by the mean rate scalars (shorter branches indicate lower rates, longer branches indicate higher rates) and branches are also coloured according to the mean relative evolutionary rate. The supertree is based on the 'traditional' Archosauromorpha topology. Silhouettes from `http://phylopic.org` (Dmitry Bogdanov, Robert Gay, Scott Hartman, T. Michael Keesey, Bruno Navarro, Iain Reid, 'Smokeybjb', Nobu Tamura, Steven Traver, Emily Willoughby, Mark Witton).

of the ETME, despite a clearly larger sample size, is remarkable.

The minor peak around the PTME (Figure 3.2) is mainly due to elevated rates in *Osmolskina czatkowicensis* and some branches belonging to Pseudosuchia (Paracrocodylomorpha) and Rhynchosauria due to extended ghost lineages (Figure 3.1). Similar to the clade Archosauromorpha, Pseudosuchia exhibit a peak in evolutionary rates (slightly more than two-fold the background rate) at the Ladinian-Carnian boundary (Figure 3.2). This rate peak in Pseudosuchia is mainly driven by the high rates recovered for some paracrocodylomorph taxa and the internal branches

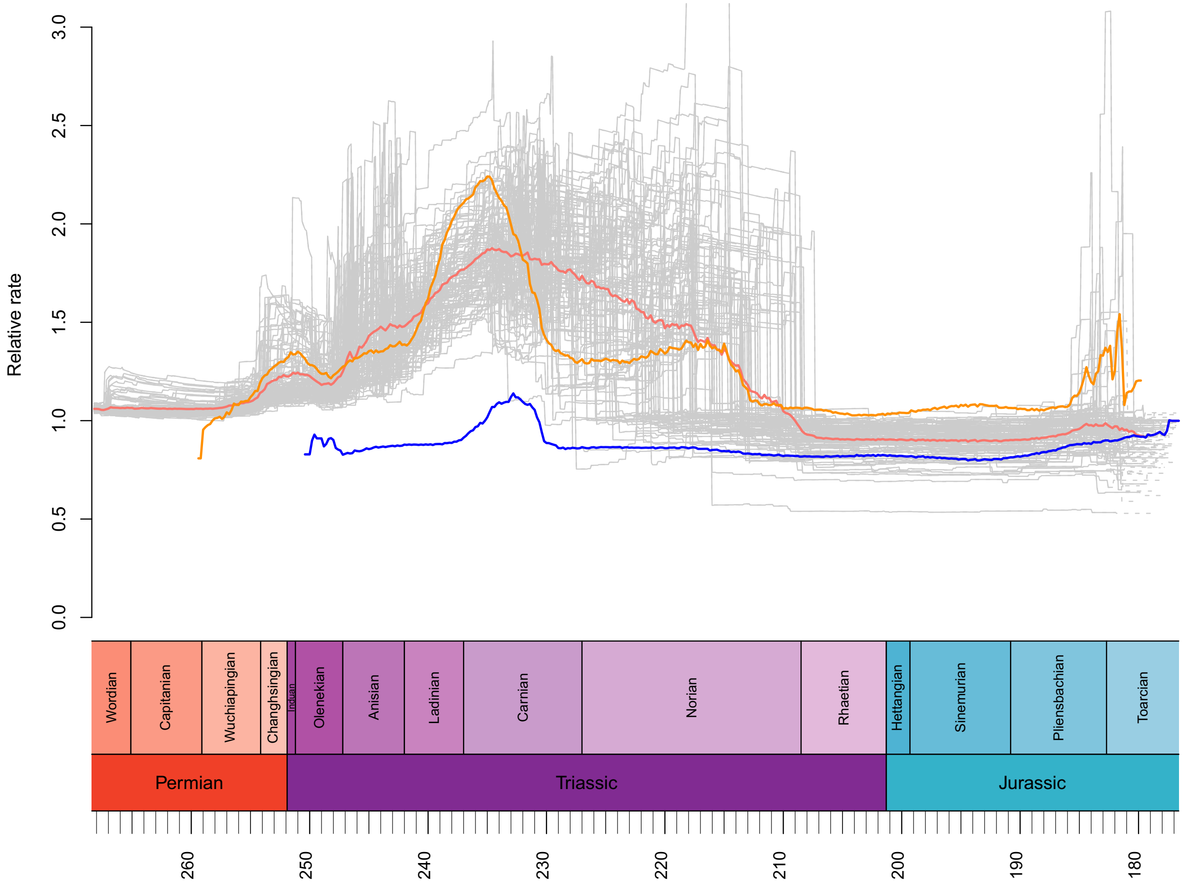

FIGURE 3.2. Mean rates of mandibular functional evolution through time based on the 'traditional' Archosauromorpha topology. Grey lines represent the rates of Archosauromorpha for each of the 100 timescaled trees, all other lines represent the mean across all 100 trees. Clades: ▬ Archosauromorpha, ▬ Dinosauria, ▬ Pseudosuchia.

leading to the clade Aetosauria (Figure 3.1). Unlike Archosauromorpha, however, the evolutionary rates decrease much faster in Pseudosuchia, reaching a plateau in the later half of the Carnian at about 1.3 times the background rate (Figure 3.1). Rates remain then relatively stable within Pseudosuchia up to end of the middle Norian. Rates subsequently fall to about the level of the background rate and only see a short increase in the Pliensbachian due to the higher rates of members of Thalattosuchia.

The evolutionary rates of non-avian dinosaurs remain essentially stable through time with a small peak during the middle Carnian (Figure 3.1), although this peak seems to precede the 'dinosaur diversification event' after the Carnian Pluvial Episode (Bernardi et al., 2018a). Notably, evolutionary rates of non-avian dinosaurs are always lower than those of their pseudosuchian counterparts and also lower compared to the clade Archosauromorpha, except for the end of the

Early Jurassic where the rate signal in Archosauromorpha is identical to the dinosaurian one.

Despite the evidence for multiple rate shifts in early Archosauromorpha positive phenotypic selection did not play a major role during the evolution of the mandibular functional complex (Figure 3.3). Only the taxon *Ornithosuchus woodwardi* exhibits positive phenotypic selection. A comparison of all 100 timescaled trees (Figure 3.4) reveals that this result is not due to the stricter criteria used herein in defining positive phenotypic selection compared to the original definition of Baker et al. (2016). Some of these trees also support positive phenotypic selection in other taxa such as *Aetosaurus ferratus* (86 out of 100 trees; Ornithoscelida topology (OT): 89) and *Vancleavea campi* (54 out of 100 trees; OT: 59). In a small number of trees positive phenotypic selection is also supported for the taxa *Osmolskina czatkowicensis* (3 out of 100 trees; OT: 1), *Sanjuansaurus gordilloi* (11 out of 100 trees; OT: 1), *Herrerasaurus ischigualastensis* (2 out of 100 trees; OT: 1), *Pampadromaeus barberenai* (2 out of 100 trees; no support in OT), *Batrachotomus kupferzellensis* (1 out of 100 trees in both topologies), *Eohyosaurus wolvaardti* (1 out of 100 trees in both topologies), *Qianosuchus mixtus* (only OT: 2 out of 100 trees), *Hemiprotosuchus leali* (only OT: 1 out of 100 trees), and *Coelophysis bauri* (only OT: 3 out of 100 trees). Evidence for positive phenotypic selection on a branch leading to a clade is exceptionally rare. Only 6 of the 100 trees (OT: 8) support positive phenotypic selection for the branch leading to Hyperodapedontinae. All other internal branches did not experience positive phenotypic selection in any of the timescaled trees. It is therefore clear that positive phenotypic selection had no important role in the evolution of the mandibular functional complex in early archosauromorphs.

3.5 Discussion

The origin of early archosauromorphs was characterised by evolutionary rates of mandibular function close to the background rate without any evidence for an initial burst in rates (Figure 3.2). This pattern differs from rates of body size evolution of early archosauromorphs which have been shown to exhibit a peak in rates at the origin of the clade and a subsequent slowdown (Turner and Nesbitt, 2013; see also chapter 2). This indicates a decoupling of the evolutionary rates of body size and mandibular function in early archosauromorphs. Rates of general morphological character evolution of early archosauromorphs were low in the middle to late Permian, but reached a peak during the Induan and especially the Olenekian before plummeting to pre-PTME levels during the Ladinian to early Carnian (Ezcurra and Butler, 2018). This rate pattern again differs from the results obtained here for rates of mandibular function. Evolutionary rates of mandibular function increased slightly during the PTME but were already on the decline during the early Olenekian (Figure 3.2). Rates of mandibular function only started to rise again at the transition from the Olenekian to the Anisian and continued to increase for nearly 15 million years before reaching a peak in the early Carnian. Evolutionary rates of mandibular function in early archosauromorphs were therefore not only decoupled from rates of body size evolution

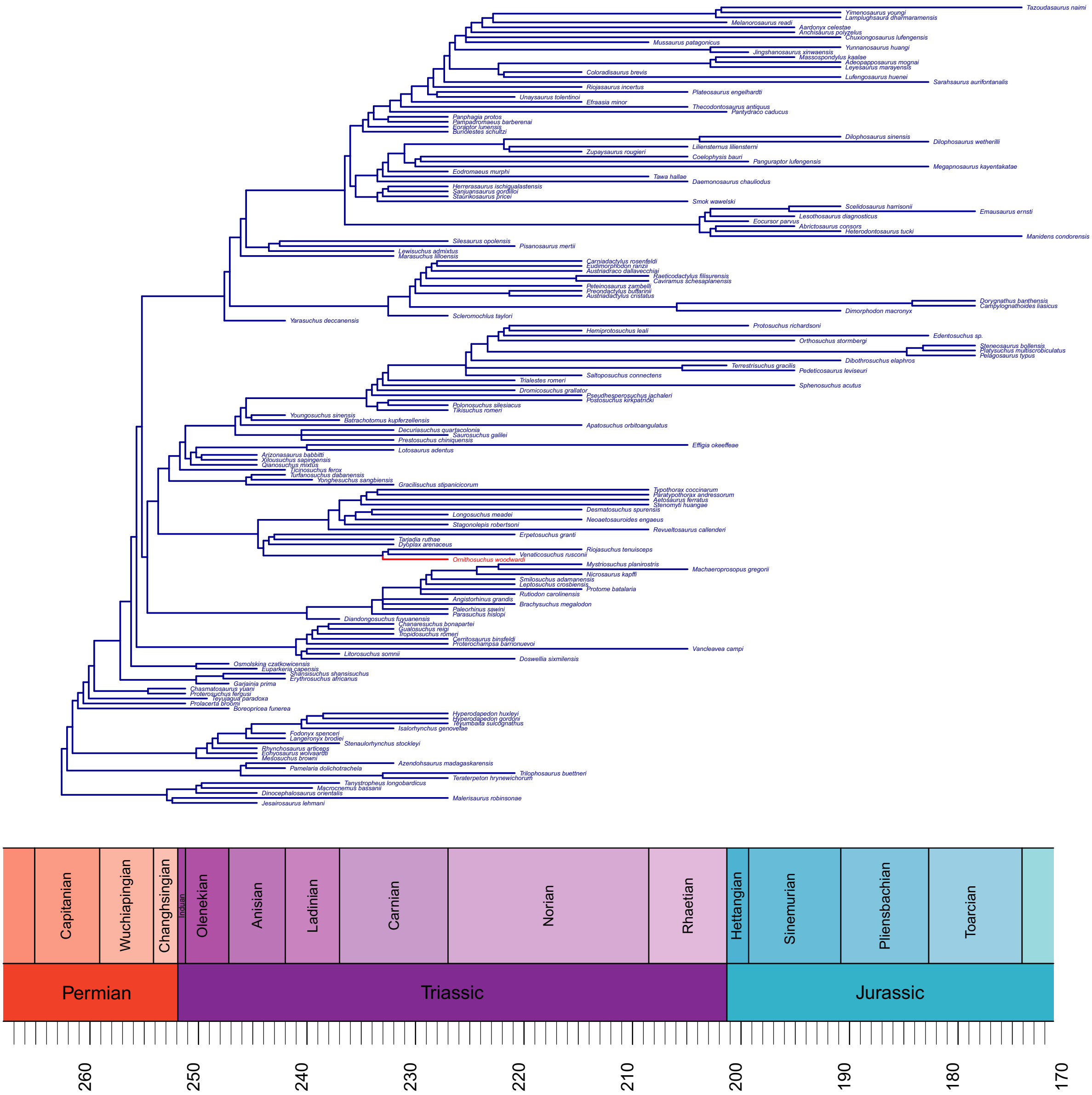

FIGURE 3.3. Positive phenotypic selection of mandibular function in early archosauromorphs based on the extended definition presented herein. Only branches coloured in red were subjected to positive phenotypic selection. For visualization purposes a MBL timescaled consensus tree is used. The supertree is based on the 'traditional' Archosauromorpha topology.

(Turner and Nesbitt, 2013; see also chapter 2) but also from rates of morphological character evolution. These results add to the complexity of the multiphase model of early archosauromorph diversification described by Ezcurra and Butler (2018). Early archosauromorphs started to diversify in the middle-late Permian while being characterised by low morphoskeletal (Ezcurra


Tree #1
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Tree #44
Tree #45
Tree #46
Tree #47
Tree #48
Tree #49
Tree #50

FIGURE 3.4. Positive phenotypic selection of mandibular function in early archosauromorphs in individual trees based on the definition of Baker et al. (2016). Only branches coloured in red were subjected to positive phenotypic selection. The supertrees are based on the 'traditional' Archosauromorpha topology.

and Butler, 2018) and cranial disparity (Foth et al., 2016). This origin of early archosauromorphs was coupled with a 'quantum shift' (Simpson, 1953) in body size evolution towards a new adaptive zone (see chapter 2). Archosauromorphs passed through the PTME relatively unscathed (Ezcurra and Butler, 2018) with minor changes in evolutionary rates of mandibular function. Only after entering the new body size niche would morphological disparity and rates of morphological character increase in the Olenekian (Ezcurra and Butler, 2018) but rates of the mandibular functional complex remained relatively low. And just after the peak in rates of morphological character evolution would rates of mandibular biomechanical disparity increase while rates of morphological character evolution were already decreasing again (Ezcurra and Butler, 2018). The temporal sequence of events, (1) 'high rates of body size evolution' - (2) 'high rates of morphological character evolution' - (3) 'high rates of the mandibular functional complex', might be causally linked but this requires further study.

Raw species and phylogenetic lineage richness of early archosauromorphs increased through the Early and Middle Triassic and reached their peak during the late Carnian, shortly after the evolutionary rates of the mandibular functional complex had reached their maximum. Both taxic and phylogenetic richness then decreased throughout the rest of the Triassic and the Early Jurassic, interrupted by some smaller diversity increases during the early to middle Norian and at the beginning of the Early Jurassic. Unlike the rates of the mandibular functional complex, which remained stable at a low level throughout the Rhaetian and most of the Early Jurassic, diversity counts continued to decrease during this time. Rates of functional diversity were therefore not directly coupled to diversity.

Biomechanical disparity in pseudosuchian mandibles has been reported to decrease from the Late Triassic to the Early Jurassic (Stubbs et al., 2013) but the ETME had no effect on mandibular biomechanical variation in herbivorous dinosaurs (MacLaren et al., 2017). Evolutionary rates of the morphofunctional complex of early pseudosuchians were also generally higher during the Late Triassic compared to the Early Jurassic (Figure 3.2). The high temporal resolution of the study presented herein reveals, however, that the drop in evolutionary rates happened long before the end of the Late Triassic and was therefore probably not related to the ETME. Similar to the biomechanical disparity pattern (MacLaren et al., 2017), evolutionary rates of mandibular function in early dinosaurs were also not affected by the ETME, which might not represent a single mass extinction event but multiple events or a protracted period of higher extinction rates (Benton, 1986a, 1994b; Lucas and Tanner, 2018).

The high evolutionary rates of mandibular function recovered on single internal branches followed by rate slowdowns in derived branches (Figure 3.1) are a typical example of transitions to new ecological niches or new environments (Baker et al., 2016; Venditti et al., 2011). In the case of rhynchosaurs and aetosaurs it represents the transition to a herbivorous diet and resulting changes in the mandibular morphology. The anterior region of the lower jaw of aetosaurs was edentulous and the articular joint was positioned below the tooth row. The mandibles of aetosaurs were optimised for a strong bite rather than quick jaw closure (Desojo and Vizcaíno, 2009). *Neoaetosauroides engaeus* slightly deviates from this pattern with an inferred faster jaw closure compared to other aetosaurs which has led to the suggestion of potential insectivory in this taxon (Desojo and Vizcaíno, 2009). Despite this difference, the evolutionary rate recovered for *Neoaetosauroides engaeus* does not deviate substantially from other aetosaurs. The curved maxillary tooth plate and dentary allowed a 'vise-like' occlusion (Stubbs et al., 2013) in rhynchosaurs, with the jaws near to full closure during the biting process, which guaranteed a higher mechanical advantage (Benton, 1983b). Hyperodapedontine rhynchosaurs were characterised by a mandible depth exceeding 25% of the total mandible length (leading to increased resistance to bending under dorso-ventral loads; Metzger et al., 2005; Anderson et al., 2011) and a dentary contributing to more than 50% of the lower jaw length (Mukherjee and Ray, 2014). Hyperodapedontinae, which were mainly restricted to the late Carnian (Langer et al., 2017a, 2018), are quite distinct compared to other rhynchosaurs (Mukherjee and Ray, 2014). Indeed, *Teyumbaita sulcognathus*, which together with *Hyperodapedon* forms the informal '*Hyperodapedon* clade', has been suggested to be another member of the genus *Hyperodapedon* (Langer et al., 2017a).

Early pterosaurs fed mainly on insects and were characterised by simple orthal movement of the jaws (Ősi, 2011). Unlike other early pterosaurs, *Eudimorphodon ranzii* and *Carniadactylus rosenfeldi* shared a triangular and pointed coronoid process (Dalla Vecchia, 2009a), had a jaw joint below the occlusal plane (also found in *Caviramus schesaplanensis*; Ősi, 2011), and were characterised by more complex oral food processing occupying an intermediate position between earlier dominantly insectivorous and later diverging dominantly piscivorous taxa (Ősi, 2011). The deeply positioned articular joint allowed for a faster jaw closure in these pterosaurs (Ősi, 2011).

Early narrow-snouted protosuchians were a terrestrial group of Crocodyliformes which was very different from the closely related longirostrine marine thalattosuchians (Ősi, 2014; Bronzati et al., 2015; Molnar et al., 2015; Wilberg, 2015b), which were characterised by rather low mechanical advantage (Ballell et al., 2019). Compared to other pseudosuchians, protosuchians occupied a distinct area in the biomechanical mandibular morphospace during the Early Jurassic (Stubbs et al., 2013) and contained both carnivores and omnivores (Ősi, 2014). *Orthosuchus stormbergi* differed from other early protosuchians in a rather shortened symphyseal region (Dollman et al., 2019) and a smaller depth of its mandible relative to the total length (Nash, 1975, fig. 35A; Sues et al., 1994, fig. 16.3B; Arcucci et al., 2004, fig. 3: 3; Nesbitt, 2011, fig. 12C; Dollman et al., 2019, fig. 3), the latter resulting in a decreased resistance to bending under dorso-ventral loads (Metzger et al., 2005; Anderson et al., 2011). Note, however, that the phylogenetic relationships of protosuchians are still relatively unclear (Wilberg, 2015b).

The mandible of *Lotosaurus adentus* and Shuvosauridae (herein represented by *Effigia okeeffeae*) differs substantially from the general pseudosuchian bauplan (Nesbitt et al., 2013c). It was modified to an edentulous beak that potentially supported a rhamphotheca and had a mandibular fenestra that exceeded 50% of the total length of the lower jaw (Nesbitt, 2011; Nesbitt et al., 2013c). Unlike most other members of Paracrocodylomorpha, generally regarded as carnivores, *Lotosaurus adentus* and shuvosaurids were probably herbivores, insectivores, or omnivores (Nesbitt et al., 2013c). Their remarkable convergence with the much younger Ornithomimidae has been noted (Nesbitt, 2007; Nesbitt et al., 2013c).

Higher evolutionary rates of mandibular function in herbivorous taxa appear to be a more general feature of tetrapod macroevolution since a similar pattern has also been recovered in other herbivorous early tetrapod clades (Diadectidae and Edaphosauridae; Anderson et al., 2013). Herein, it has been recovered for larger herbivorous archosauromorph clades such as rhynchosaurs and aetosaurs. Early dinosaurs are insofar interesting as they show generally lower evolutionary rates of mandibular function compared to the rest of Archosauromorpha. This is to be expected since early dinosaurs had rather simple jaws and feeding mechanisms (Barrett, 2014; Benson, 2018). Especially carnivorous (early) theropods were characterised by conservative cranial shape (Brusatte et al., 2012; Foth and Rauhut, 2013) and the evolution of biting performance in theropods generally followed a Brownion motion model of evolution (Sakamoto, 2010). These observations are consistent with the low evolutionary rates of mandibular function recovered here for several neotheropod taxa. These low rates could potentially indicate some form of stabilizing selection, evolutionary stasis, or a constraint acting on mandibular function in theropod dinosaurs (Baker et al., 2016). Rate decreases are generally rare in phylogenetic comparative data (Venditti et al., 2011; Baker et al., 2016; see also chapter 2), and the pattern recovered here for neotheropods appears to be an exception. Evolutionary rates of the mandibular functional complex are generally higher in herbivorous clades such as Sauropodomorpha and Ornithischia, which is again to be expected due to the their more complex feeding ecology (Barrett, 2014). These rates, however, are still low compared to other herbivorous archosauromorph clades (e.g., Rhynchosauria, Aetosauria) which is again to be expected, since the mandibles of early diverging members of Sauropodomorpha and Ornithischia were functionally and morphologically quite similar (MacLaren et al., 2017) and much less specialized than those of other early archosauromorph clades (Benton, 1984; Ezcurra et al., 2016) or later diverging members of Sauropodomorpha and Ornithischia (Barrett, 2014; MacLaren et al., 2017).

The high evolutionary rates of mandibular function observed for terminal taxa can be interpreted in a similar way to those seen on internal branches (Baker et al., 2016; Venditti et al., 2011). Since there is no evidence for widespread clade modifications affecting all branches of a monophyletic group (Baker et al., 2016) and since these rates are more prone to be affected by phylogenetic and stratigraphic uncertainty I refrain from interpreting high evolutionary rates observed on single terminal branches.

Considering the ‘very strong’ support for a heterogeneous rate model (Raftery, 1996; Meade and Pagel, 2016) and the clear evidence for multiple shifts towards high evolutionary rates it may appear unexpected that positive phenotypic selection played such a minor role during the evolution of the biomechanical properties of the early archosauromorph mandible (Figure 3.3; Figure 3.4). Baker et al. (2016) recovered support for multiple instances of positive phenotypic selection in six disparate datasets ranging from fruit diameter in angiosperm plants to semicircular ear canal radius in Mammalia and Brocklehurst and Brink (2017) found support for positive phenotypic selection towards increased body size in Carboniferous synapsids. Within paravian dinosaurs Baker et al. (2016) found positive phenotypic selection in relative forelimb proportions on the branch leading to Paraves and along 84% of the clade's branches. This pattern is in stark contrast to the results presented here for mandibular function which de-emphasize the role of positive phenotypic selection acting on the mandible in early archosauromorphs and underscore the idiosyncratic nature of paravian evolution in archosauromorph history (Lee et al., 2014; Puttick et al., 2014; Brusatte et al., 2014). Positive phenotypic selection is only recovered for *Ornithosuchus woodwardi*. Rather than being active apex predators (Walker, 1964) ornithosuchids were probably scavengers or preyed only on small animals as evidenced by their weak snout and their slow but powerful bite (von Baczko, 2018). The largest specimens of the Scottish *Ornithosuchus woodwardi* indicate a total body length of 2.2 m for this animal, similar to the body size of the other two ornithosuchids *Riojasuchus tenuisceps* and *Venaticosuchus rusconii*, only known from Argentina (von Baczko and Ezcurra, 2016). The fang-like dentary teeth of *Ornithosuchus woodwardi* were positioned more posteriorly relative to the respective dentary teeth of the other ornithosuchids (von Baczko and Ezcurra, 2013). The external mandibular fenestra of *Ornithosuchus woodwardi* was also smaller than that of the other ornithosuchids (von Baczko and Ezcurra, 2013). The sum of the moment arms of the adductor muscles of ornithosuchids resembled those of aetosaurs and was lowest in *Ornithosuchus woodwardi* (von Baczko, 2018). *Ornithosuchus woodwardi* is the oldest member of the clade, restricted to the late Carnian (von Baczko and Ezcurra, 2013; Langer et al., 2010). The stratigraphic range of *Venaticosuchus rusconii* extends from late Carnian to early Norian (von Baczko and Ezcurra, 2013; von Baczko et al., 2014; M. D. Ezcurra, pers. comm., 2018), while *Riojasuchus tenuisceps* only appeared in the middle Norian (von Baczko and Ezcurra, 2013; Kent et al., 2014). The differences in the mandibular biomechanical properties compared to other ornithosuchids, the timing of the first appearance, and the short stratigraphic range of *Ornithosuchus woodwardi* could explain the high evolutionary rates recovered for the taxon and therefore also the inferred positive phenotypic selection. I urge caution, however, when interpreting rate patterns of single terminal fossil taxa. Changes in the phylogenetic relationships and the stratigraphic assignment can change the recovered rate pattern. In fact, the phylogenetic position of Ornithosuchidae is still debated (von Baczko and Ezcurra, 2013; von Baczko et al., 2014; Lacerda et al., 2018) and the exact stratigraphic position of *Venaticosuchus rusconii* in the Ischigualasto Formation is unclear (Martínez et al., 2012; von Baczko and Ezcurra, 2013; von Baczko et al., 2014; Agnolín and Rozadilla, 2018; M. D. Ezcurra, pers. comm., 2018). Even if the biomechanical properties of the mandible of *Ornithosuchus woodwardi* were subjected to positive phenotypic selection, it is clear, that directional selection did not play a major role in the evolution of the mandibular functional complex of early archosauromorphs.

Strong directional selection of biomechanical properties of the mandible was therefore neither responsible for the success of early archosauromorphs in the aftermath of the PTME nor for the rise of early dinosaurs in the Late Triassic and Early Jurassic. This result agrees with an interpretation linking the rise of archosauromorphs in the early Mesozoic to a non-competitive replacement of the previously dominating therapsids and parareptiles (Bakker, 1977; Benton et al., 2004; Sookias et al., 2012b; Ezcurra and Butler, 2018) by entering the ecological niches cleared after the mass extinction event. ‘Superior’, and therefore strongly selected for, biomechanical properties of the mandible of early archosauromorphs were not responsible for their success. This also applies to early dinosaurs whose success compared to their pseudosuchian counterparts has been tied to historical contingency rather than competition or physiological ‘superiority’ (Benton, 1983a; Brusatte et al., 2008a). Non-competitive opportunistic replacement is compatible with a scenario in which positive phenotypic selection played a minor role. Due to the extinction of potential competitors in a series of events (PTME, CNEE, ETME) it was simply not ‘necessary’ for early archosauromorphs and early dinosaurs to experience strong directional selection to avoid competition (Hardin, 1960) for the already vacant niches. I emphasize here that the current study has only focused on mandibular biomechanical disparity. Future studies will show whether these observations also hold for traits involved in locomotion and thermoregulation, which have also been invoked as responsible for the success of early archosauromorphs and early dinosaurs (Bakker, 1972; Charig, 1980; Bonaparte, 1982; Bakker, 1986).

The dichotomy of observing multiple instances of substantial rate increases but no evidence for positive phenotypic selection demands further discussion. A potential explanation could be that the criteria used by Baker et al. (2016) are too conservative to detect all instances of positive phenotypic selection. In the case of early archosaurmorphs it would be the certainty criterion that proves too restrictive, since several rate increases are, indeed, detected. This issue could be exacerbated by the binary nature of the definition of Baker et al. (2016), which only recognises positive phenotypic selection as absent or present, but does not specify the strength of positive phenotypic selection (although it could be argued that the deviation from the background rate of evolution provides the relevant index for this). Weaker forms of positive phenotypic selection therefore might not be detected when using the definition of Baker et al. (2016). Since Baker et al. (2016) were able to detect multiple instances of positive phenotypic selection using this definition in widely different datasets (e.g., in their Dinosauria dataset 84% of the paravian branches experienced positive phenotypic selection) this appears less likely. In fact, Baker et al. (2016) were even able to detect instances of positive phenotypic selection, which had not been predicted a priori. Such a result would not be expected if the applied definition was too conservative.

Alternatively, evolutionary theory can provide an explanation for recovering high rates without evidence for positive phenotypic selection. The dichotomy has been observed and explicitly noted by Baker et al. (2016) when analysing the evolutionary rates of snout-vent length in *Anolis* lizards. Baker et al. (2016) consider three possibilities in which quick bursts of phenotypic evolutionary rates are not necessarily due to positive selection: (1) a fundamental constraint restricting phenotypic change became relaxed which lead to a 'release' in the evolutionary rates, (2) phenotypic diversity was substantially reduced due to a founder event or a bottleneck leading to a shift in mean phenotype even when rapid directional evolution was occurring, (3) the pace of life increased leading to higher rates of evolution. According to Baker et al. (2016), however, there is only weak support from empirical studies that conclusively links these explanations with increased rates of phenotypic evolution. Given my results, additional work on early archosauromorphs might prove fruitful in these regards.

It has been suggested that novel herbivore feeding adaptations were responsible for the success of several early archosauromorph (Charig, 1980) and early dinosaur clades (Zawiskie, 1986). Both Charig (1980) and Zawiskie (1986) advocated that these novel adaptations were a product of strong selective pressure. The change to herbivorous diet in allokotosaurs (Nesbitt et al., 2015), rhynchosaurs (Ezcurra et al., 2016), aetosaurs (Desojo et al., 2013; potentially also insectivorous; see Desojo and Vizcaíno, 2009; von Baczko et al., 2018), early sauropodomorphs and early ornithischians (MacLaren et al., 2017) is, indeed, generally associated with higher evolutionary rates of mandibular function indicating a shift to a new ecological niche (Baker et al., 2016). But I do not find any evidence for strong selective pressure in these clades. The success of early archosauromorphs and early dinosaurs was therefore either a result of sheer 'luck' (differential survival and non-competitive replacement; Benton, 1983a; Benton et al., 2004; Brusatte et al., 2008a; Sookias et al., 2012b; Ezcurra and Butler, 2018) or due to other traits not considered in this study such as erect stance and parasagittal gait, high growth and metabolic rates, and high intraspecific variation in postnatal development (Irmis, 2011; Padian, 2013; Griffin and Nesbitt, 2016).

3.6 Supplementary Information

Institutional abbreviations: AMNH, American Museum of Natural History, New York, USA; **BNM**, Bündner Naturmuseum, Chur, Switzerland; **BPI**, Bernard Price Institute for Paleontological Research, University of the Witwatersrand, Johannesburg, South Africa; **BSP**, Bayerische Staatssammlung für Paläontologie und Historische Geologie, München, Bavaria, Germany; **CA**, Colégio Anchieta, Porto Alegre, Brazil; **CAPPA/UFSM**, Centro de Apoio è Pesquisa Paleontológica da Quarta Colônia da Universidade Federal de Santa Maria, São João do Polêsine, Brazil; **CM**, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA; **CMY**, Chuxiong Museum, Chuxiong, Yunnan Province, China; **CPSGM**, Collections Paléontologiques du Service Géologique du Maroc, Rabat, Morocco; **CRILAR-Pv**, Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja, Paleontología de Vertebrados, Anillaco, La Rioja, Argentina; **DGM**, Divisão de Geologia e Mineralogia, Departamento Nacional da Produção Mineral, Rio de Janeiro, Brazil; **EXEMS**, Royal Albert Memorial Museum, Exeter, Devon, England, UK; **FMNH**, Field Museum, Chicago, Illinois, USA; **GHG**, Geological Survey, Pretoria, South Africa; **GR**, Ghost Ranch Ruth Hall Museum of Paleontology, Abiquiu, New Mexico, USA; **IGMPT**, Institut und Museum für Geologie und Paläontologie, Tübingen, Germany; **ISI/ISIR**, Geological Museum, Indian Statistical Institute, Calcutta, India; **IVPP**, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; **KM**, Kunming Museum, Kunming, Yunnan, China; **LFGT**, Bureau of Land and Resources of Lufeng County, Lufeng, Yunnan, China; **MACN**, Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Buenos Aires, Argentina; **MB**, Museum für Naturkunde der Humboldt Universität zu Berlin, Berlin, Germany; **MCSNB**, Museo Civico di Scienze Naturali Enrico Caffi, Bergamo, Italy; **MCZ**, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA; **MFSN**, Museo Friulano di Scienze Naturali, Udine, Italy; **MLP**, Museo de La Plata, La Plata, Argentina; **MNA**, Museum of Northern Arizona, Flagstaff, Arizona, USA; **MPEF**, Museo Paleontológico Egidio Feruglio, Trelew, Chubut, Argentina; **MPM**, Museo Regional Provincial Padre M. J. Molina, Rio Gallegos, Argentina; **MPUM**, Museo Paleontologico del Dipartimento di Scienze della Terra ‘A. Desio’ dell’Universitè degli Studi di Milano, Milano, Italy; **MSM**, Mesa Southwest Museum, Mesa, Arizona, USA; **MSNM**, Museo di Storia Naturale di Milano, Milano, Italy; **NGMJ**, Nanjing Geological Museum, Nanjing, China; **NHMUK/BMNH**, Natural History Museum, London, England, UK; **NM/NMQR**, National Museum, Bloemfontein, South Africa; **NMMNH**, New Mexico Museum of Natural History, Albuquerque, New Mexico, USA; **NMT**, National Museum of Tanzania, Dar es Salaam, Tanzania; **NSM**, Nova Scotia Museum of Natural History, Halifax, Nova Scotia, Canada; **NUGD**, Newwcastle University, Geology Department, Newcastle, England, UK; **PEFO**, Petrified Forest National Park Museum, Petrified Forest, Arizona, USA; **PIMUZ**, Paläontologisches Institut und Museum der Universität Zürich, Zurich, Switzerland; **PIN**, Palaeontological Institute, Russian Academy of Sciences, Moscow, Russia; **PULR**, Universidad Nacional de La Rioja, Paleontología, La Rioja, Argentina; **PVL**, Sección

Paleozoologia (vertebrados) del Instituto Miguel Lillo de la Universidád Nacionál de Tucumán, Tucumán, Provincia de Tucumán, Argentina; **PVSJ**, División de Paleontología de Vertebrados del Museo de Ciencias Naturales y Universidad Nacional de San Juan, San Juan, Argentina; **RC**, Rubidge Collection, Wellwood, Graaff-Reinet, South Africa; **SAM**, South African Museum, Cape Town, South Africa; **SGU**, Scientific Research Institute of Saratov State University, Saratov, Russia; **SGWG**, Sektion Geologie, Ernst-Moritz-Arndt Universität, Greifswald, Germany; **SMNS**, Staatliches Museum für Naturkunde in Stuttgart, Stuttgart, Germany; **TMM**, Vertebrate Paleontology Laboratory, Texas Natural Science Center, Austin, Texas, USA; **TTU/TTUP**, The Museum at Texas Tech University, Lubbock, Texas, USA; **UA**, Université d'Antananarivo, Antananarivo, Madagascar; **UCMP**, University of California (Berkeley) Museum of Paleontology, Berkeley, California, USA; **UFRGS**, Laboratório de Paleontologia de Vertebrados, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil; **UFSM**, Coleção de Paleontologia, Laboratório de Estratigrafia e Paleobiologia, Universidade Federal de Santa Maria, Brazil; **UH**, Urweltmuseum Hauff, Holzmaden, Baden-Württemberg, Germany; **ULBRA-PVT**, Universidade Luterana do Brasil, collection of Triassic Paleovertebrates, Canoas, Brazil; **UMMP**, University of Michigan, Museum of Paleontology, Ann Arbor, Michigan, USA; **UNC**, University of North Carolina, Chapel Hill, North Carolina, USA; **UNIPAMPA**, Laboratório de Paleobiologia, Universidade Federal do Pampa, São Gabriel, Brazil; **WARMS**, Warwick County Museum, Warwick, England, UK; **YPM**, Peabody Museum of Natural History, Yale University, New Haven, Connecticut, USA; **YX**, Yuxi Cultural Relic Administrative Institute, Yunnan Province, China; **ZMNH**, Zhejiang Museum of Natural History, Hangzhou, China; **ZPAL**, Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland.

TABLE 3.1. List of taxa and sources/specimens used in the study with associated references.

Taxon	Specimen/Source	Reference
Aardonyx celestae	Reconstruction based on multiple specimens	Yates et al. (2010, fig. 2b)
Abrictosaurus consors	Reconstruction based on NHMUK RU B54	Thulborn (1974, fig. 4)
Adeopapposaurus mognai	Reconstruction based on PVSJ568 and PVSJ610	Martínez (2009, fig. 5A)
Aetosaurus ferratus	Reconstruction based on SMNS 5770 (S-16)	von Baczko et al. (2014, fig. 4G)
Anchisaurus	Reconstruction based on YPM 1883	Yates (2010, text-fig. 1A)
Angistorhinus grandis	Reconstruction based on FMNH UC 631	Mehl (1915, fig. 3)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Apatosuchus orbitoangulatus	Reconstruction based on SMNS 12353b	von Huene (1932a, Tafel 1: fig. 5)
Arizonasaurus babbitti	Reconstruction based on MSM P4590	Nesbitt (2005, fig. 2B)
Austriadactylus cristatus	Reconstruction based on SMNS 56342	Ősi (2011, fig. 1D)
Austriadraco dallavecchiai	Drawing of BSP 1994 I 51	Kellner (2015, fig 2b)
Azendohsaurus madagaskarensis	Reconstruction based on UA-7-20-99-653	Flynn et al. (2010, text-fig. 13)
Batrachotomus kupferzellensis	Reconstruction based on SMNS 80260	Gower and Schoch (2009, fig. 8A)
Bergamodactylus wildi	Drawing of MPUM 6009	Kellner (2015, fig 5b)
Boreopricea funerea	Reconstruction based on PIN 3708/1	Benton and Allen (1997, text-fig. 4)
Brachysuchus megalodon	Photograph of UMMP 10336A	Case (1930, plate I: fig. 2)
Buriolestes schultzi	Photograph of ULBRA-PVT280	Cabreira et al. (2016, fig. 1J)
Campylognathoides liasicus	Reconstruction based on multiple specimens	Padian (2008a, text-fig. 10)
Carniadactylus rosenfeldi	Drawing of MPUM 6009	Dalla Vecchia (2009a, fig. 11B)
Caviramus schesaplanensis	Drawing of PIMUZ A/III 1225	Fröbisch and Fröbisch (2006, text-fig. 2B)
Cerritosaurus binsfeldi	Reconstruction based on CA s/n (formerly DGM 334-R)	Trotteyn et al. (2013, fig. 7)
Chanaresuchus bonapartei	Reconstruction based on PULR 07 and other specimens	Hungerbühler (2001, fig. 4d)
Chasmatosaurus yuani	Drawing of IVPP V 4067	Young (1978, fig. 3)
Chuxiongosaurus	Photograph of CMY LT9401	Lü et al. (2010a, 4B)
Coelophysis bauri	Drawing of AMNH 7224	Tykoski and Rowe (2004, fig. 3.2B)
Coloradisaurus	Reconstruction based on PVL 3967	Apaldetti et al. (2014, fig. 8A)
Daemonosaurus chauliodus	Drawing of CM 76821	Sues et al. (2011, fig. 1b)
Decuriasuchus quartacolonia	Reconstruction based on multiple specimens	de França et al. (2011, fig. 2f)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Desmatosuchus haplocerus	Photograph of TTUP 9024	Small (2002, fig. 1B)
Diandongosuchus fuyuanensis	Photograph of ZMNH M8770	Li et al. (2012, fig. 2A)
Dibothrosuchus elaphros	Drawing of IVPP V 7907	Wu and Chatterjee (1993, fig. 8A)
Dilophosaurus sinensis	Drawing of KM V8701	Hu (1993, fig. 1)
Dilophosaurus wetherilli	Reconstruction mainly based on UCMP 37303	Tykoski and Rowe (2004, fig. 3.2E)
Dimorphodon macronyx	Reconstruction based on YPM 9182	Padian (1983, fig. 6)
Dinocephalosaurus orientalis	Drawing of IVPP V13767	Li (2003, fig. 1)
Dorygnathus banthensis	Reconstruction based on SMNS 55886 and other specimens	Padian (2008b, text-fig. 18)
Doswellia sixmilensis	Reconstruction based on NMMNH P-61909	Heckert et al. (2012a, fig. 6B)
Dromicosuchus grallator	Reconstruction based on UNC 15574	Nesbitt (2011, fig. 19D)
Dyoplax arenaceus	Reconstruction based on SMNS 4760	Maisch et al. (2013, fig. 3)
Edentosuchus	Drawing of UCMP 97638	Sues et al. (1994, fig. 16.3B)
Effigia okeeffeae	Reconstruction based on AMNH FR 30587 and AMNH FR 30589	Nesbitt (2007)
Efraasia minor	Reconstruction based on SMNS 12216, SMNS 12684, and SMNS 12667	Yates (2003c, text-fig. 9A)
Emausaurus ernsti	Reconstruction based on SGWG 85	Haubold (1990, fig. 2)
Eocursor parvus	Photograph of SAM-PK-K8025	Butler (2010, fig. 5A)
Eodromaeus murphi	Reconstruction based on PVSJ 560, PVSJ 561, and PVSJ 562	Martínez et al. (2011, fig. 1B)
Eohyosaurus wolvaardti	Drawing of SAM-PK-K10159	Butler et al. (2015, fig. 2C)
Eoraptor	Reconstruction based on PVSJ 512	Sereno et al. (2012, fig. 40B)
Erpetosuchus granti	Reconstruction based on BMNH R3139	Benton and Walker (2002, fig. 2A)
Erythrosuchus africanus	Drawing of BPI 5207	Parrish (1992, fig. 6)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Eudimorphodon ranzii	Reconstruction based on MCSNB 2888	Nesbitt (2009, fig. II.8A)
Euparkeria capensis	Reconstruction based on multiple specimens	Ewer (1965, fig. 2a)
Fodonyx	Reconstruction based on EXEMS 60/1985.292	Benton (1990, fig. 28a)
Garjainia prima	Photograph of PIN 2394/5 (formerly SGU 104/3-43)	Gower and Sennikov (2000, fig. 8.4D)
Gracilisuchus stipanicicorum	Reconstruction based on multiple specimens	Romer (1972, fig. 5)
Gualosuchus reigi	Photograph of PULR 01 (formerly MLP 1964–XI–14–13)	Trotteyn et al. (2013, fig. 13a)
Hemiprotosuchus leali	Reconstruction based on PVL 3829	Arcucci et al. (2004, fig. 3.3)
Herrerasaurus ischigualastensis	Reconstruction based on PVSJ 407	Langer (2004, fig. 2.2E)
Heterodontosaurus tucki	Reconstruction based on multiple specimens	Norman et al. (2011, fig. 8B)
Hyperodapedon gordoni	Reconstruction based on NUGD A, NUGD B, BMNH R3153, BMNH R4782, and BMNH R4780	Benton (1983b, fig. 13b)
Hyperodapedon huxleyi	3D rendering of MACN-Pv 18185	Gentil and Ezcurra (2018, fig. 2.11)
Isalorhynchus genovefae	Reconstruction based on FMNH 9-8-98-525	Whatley (2005, fig. 1-10b)
Jesairosaurus lehmani	Reconstruction based on multiple specimens	Jalil (1997, fig. 2B)
Jingshanosaurus	Reconstruction based on LFGT-ZLJ0113 (field number: LV003)	Zhang and Yang (1994, fig. 10)
Lamplughsaura dharmaramensis	Reconstruction based on ISI R258 and ISI R259	Kutty et al. (2007, fig. 6.4)
Langeronyx brodiei	Reconstruction mainly based on WARMS Gz6097/BMNH R8495 and additional information from other specimens	Benton (1990, fig. 21a)
Leptosuchus crosbiensis	Photograph of UMMP 8855	Case (1924, plate XII: fig. 1)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Lesothosaurus diagnosticus	Reconstruction based on multiple specimens	Sereno (1991, fig. 13F)
Lewisuchus admixtus	Reconstruction based on PULR 01	Langer et al. (2013, fig. 3a)
Leyesaurus marayensis	Drawing of PVSJ 706	Apaldetti et al. (2011, fig. 3B)
Liliensternus liliensterni	Reconstruction based on MB.R. 2175	von Huene (1934, Tafel 13: fig. 13)
Litorosuchus somnii	Drawing of IVPP V 16978	Li et al. (2016a, fig. 2b)
Longosuchus meadei	Reconstruction based on TMM 31185-84B	Desojo et al. (2013, fig. 4h)
Lotosaurus	Photograph (no specimen number provided)	Brusatte et al. (2010c, fig. 7C)
Lufengosaurus	Drawing of IVPP V15	Barrett et al. (2005, fig. 6)
Machaeroprosopus gregorii	Reconstruction based on multiple specimens (mainly NMMNH P-4983, NMMNH P-31094, and NMMNH P-31095)	Spielmann and Lucas (2012, fig. 52C)
Macrocnemus bassanii	Reconstruction based on multiple specimens	Rieppel (1989, fig. 10)
Malerisaurus robinsonae	Reconstruction based mainly based on ISIR 150 and additions from ISIR 151	Chatterjee (1980, fig. 3)
Manidens condorensis	Reconstruction based on MPEF-PV 3211	Sereno (2012, fig. 81B)
Marasuchus lilloensis	Reconstruction based on PVL 3870 and PVL 3871	Sereno and Arcucci (1994, fig. 13)
Massospondylus kaalae	Drawing of SAM-PK-K1325	Barrett (2009a, fig. 7B)
Megapnosaurus kayentakatae	Reconstruction based on MNA V2623	Tykoski and Rowe (2004, fig. 3.2D)
Melanorosaurus	Reconstruction based on NM QR3314	Yates (2007b, text-fig. 6)
Mesosuchus browni	Drawing of SAM 5882	Dilkes (1998, fig. 7a)
Mussaurus patagonicus	Photograph of MPM-PV 1813/4	Pol and Powell (2007, fig. 1B)
Mystriosuchus planirostris	Drawing of SMNS 9134	Hungerbühler (2001, fig. 3a)
Neoaetosauroides engaeus	Reconstruction based on PVL 3525	Desojo and Báez (2007, text-fig. 4B)
Nicrosaurus kapffi	Drawing of NHMUK 42744	Hungerbühler (2001, fig. 3b)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Ornithosuchus	Reconstruction based on NHMUK PV R2409	Walker (1961, fig. 25)
Orthosuchus stormbergi	Reconstruction based on SAM-K409 and SAM-K4639	Nash (1975, fig. 7A)
Osmolskina czatkowicensis	Reconstruction based on multiple specimens	Borsuk-Białynicka and Evans (2009b, fig. 1B)
Paleorhinus	Reconstruction based on TTUP 9422	Simpson (1998, fig. 3.6A)
Pamelaria dolichotrachela	Drawing of ISIR 316/1	Sen (2003, fig. 6A)
Pampadromaeus barberenai	Reconstruction based on ULBRA-PVT016	Cabreira et al. (2011, fig. 2)
Panguraptor lufengensis	Photograph of LFGT-0103	You et al. (2014, fig. 2a)
Panphagia protos	Photograph of PVSJ 874	Martínez and Alcober (2009, fig. 4A)
Pantydraco caducus	Reconstruction based on NHMUK RU P24	Galton and Kermack (2010, fig. 3A)
Parasuchus hislopi	Reconstruction based on ISI R 42	von Baczko et al. (2014, fig. 4I)
Paratypothorax andressorum	Reconstruction based on SMNS 19002	Schoch and Desojo (2016, fig. 7A)
Pedeticosaurus leviseuri	Drawing of NMQR 606	Walker (1970, fig. 8)
Pelagosaurus typus	Reconstruction based on multiple specimens	Pierce and Benton (2006, fig. 2A)
Peteinosaurus zambelli	Reconstruction based on MCSNB 2886	Ősi (2011, fig. 1E)
Pisanosaurus mertii	Reconstruction based on PVL 2577	Bonaparte (1976, text-fig. 2D)
Plateosaurus engelhardti	Photograph of AMNH FARB 6810	Prieto-Márquez and Norell (2011, fig. 31A)
Platysuchus multiscrobiculatus	Drawing of UH 2	Mueller-Töwe (2006, fig. 4.8)
Polonosuchus silesiacus	Reconstruction based on ZPAL Ab III 563	Sulej (2005, fig. 3A)
Postosuchus kirkpatricki	Reconstruction based on TTUP 9000	Weinbaum (2011, fig. 1B)
Preondactylus buffarinii	Drawing of MFSN 1770	Dalla Vecchia (2013, fig. 8a)
Prestosuchus chiniquensis	Photograph of UFRGS-PV0629T	Mastrantonio (2010, fig. 72B)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Prolacerta broomi	Drawing of BP/1/471	Modesto and Sues (2004, fig. 3B)
Proterochampsa barrionuevoi	Reconstruction based on multiple specimens	Trotteyn et al. (2013, fig. 3)
Proterosuchus fergusi	Reconstruction based on BSP 1934 VIII 514, GHG 231, and RC 846	Ezcurra and Butler (2015a, fig. 12)
Protome batalaria	Drawing of PEFO 34034	Stocker (2012, fig. 9B)
Protosuchus richardsoni	Reconstruction based on MCZ 6727	Nesbitt (2011, fig. 19F)
Pseudhesperosuchus jachaleri	Photograph of PVL 3830	Irmis et al. (2013a, fig. 3b)
Qianosuchus mixtus	Photograph of IVPP V14300	Li et al. (2006, fig. 2A)
Raeticodactylus filisurensis	Reconstruction based on BNM 14524	Stecher (2008, fig. 6c)
Revueltosaurus callenderi	Reconstruction based on PEFO 34561	Nesbitt (2011, fig. 8H)
Rhynchosaurus articeps	Reconstruction based on BMNH R1236 and other specimens	Benton (1990, fig. 7b)
Riojasaurus	Reconstruction based on PULR 56	Bonaparte and Pumares (1995, fig. 3)
Riojasuchus tenuisceps	Photograph of PVL 3827	von Baczko and Desojo (2016, fig. 6A)
Rutiodon carolinensis	Reconstruction based on AMNH 1	Colbert (1947, fig. 7)
Saltoposuchus	Reconstruction based on NHMUK R7557 (= formerly BMNH P. 47/21 and counterpart BMNH P. 47/22)	Wu and Chatterjee (1993, fig. 16E)
Sanjuansaurus gordilloi	Photograph of PVSJ 407	Alcober and Martínez (2010, fig. 4B)
Sarahsaurus aurifontanalis	Drawing of MCZ 8893	Rowe et al. (2011, fig. 4a)
Saurosuchus galilei	Reconstruction based on PVSJ 32	Alcober (2000, fig. 11A)
Scelidosaurus harrisonii	Drawing of BMNH R.1111	Norman et al. (2007, fig. 2A)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Scleromochlus taylori	Reconstruction mainly based on BMNH R3556 with additional information from BMNH R3146A and BMNH R3146B, BMNH R3557, and BMNH R5589	Benton (1999, fig. 8c)
Shansisuchus shansisuchus	Drawing of IVPP V 2503	Parrish (1992, fig. 7)
Silesaurus opolensis	Reconstruction based on ZPAL Ab III/361 and ZPAL Ab III/437	Dzik (2003, fig. 6A)
Smilosuchus adamanensis	Reconstruction based on UCMP 7038/26699	Zeigler et al. (2002, p. 178)
Smok wawelski	Reconstruction based on ZPAL V.33/15, ZPAL V.16, ZPAL V.19, ZPAL V.20, ZPAL V.21, ZPAL V.22, ZPAL V.23, ZPAL V.24, ZPAL V.25, ZPAL V.26, ZPAL V.27	Niedźwiedzki et al. (2012, fig. 2A)
Sphenosuchus acutus	Reconstruction based on SAM-PK-3014	Sereno and Wild (1992, fig. 8A)
Stagonolepis robertsoni	Reconstruction based on multiple specimens	Walker (1961, fig. 6a)
Staurikosaurus pricei	Reconstruction based on MCZ 1669	Langer (2004, fig. 2.2K)
Stenaulorhynchus sp.	Drawing of IGMPT-317A	von Huene (1938, Tafel I: fig. 3)
Steneosaurus bollensis	Reconstruction based on BMNH 14781	Mueller-Töwe (2006, fig. 3.23)
Stenomyti huangae	Reconstruction based on multiple specimens	Small and Martz (2013, fig. 11a)
Tanystropheus longobardicus	Reconstruction based on MSNM BES SC 1018, MSNM BES SC 265, and PIMUZ T 2484	Nosotti (2007, fig. 49B)
Tarjadia ruthae	Reconstruction based on CRILAR-Pv 478, CRILAR-Pv 495, and MCZ 9319	Ezcurra et al. (2017, fig. 2a)
Tawa hallae	Photograph of GR 241	Nesbitt et al. (2009a, fig. 1B)
Tazoudasaurus naimi	Reconstruction based on CPSGM To1-275	Peyer and Allain (2010, fig. 4)
Teraterpeton hrynewichorum	Drawing of NSM 999GF041	Sues (2003, fig. 1)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Terrestrisuchus gracilis	Reconstruction based on NHMUK R7557 (= formerly BMNH P. 47/21 and counterpart BMNH P. 47/22)	Henderson and Weishampel (2002, text-fig. 5B)
Teyujagua paradoxa	(Interpretative) drawing of UNIPAMPA 653	Pinheiro et al. (2016, fig. 2B)
Teyumbaita sulcognathus	Drawing of UFRGS-PV-0232T	Montefeltro et al. (2010, fig. 9a)
Thecodontosaurus sp.	Reconstruction based on NHMUK RU P24	Galton and Upchurch (2004, fig. 12.3D)
Ticinosuchus	Reconstruction based on PIMUZ T2817	Benton (1986b, text-fig. 3a)
Tikisuchus romeri	Reconstruction based on ISI R 305	Chatterjee and Majumdar (1987, fig. 2.1)
Trialestes romeri	Reconstruction based on PVL 2561	Reig (1963, fig. 6)
Trilophosaurus buettneri	Reconstruction based on multiple specimens	Spielmann et al. (2008, fig. 22B)
Tropidosuchus romeri	Reconstruction based on PVL 4601	Arcucci (1990, fig. 1)
Turfanosuchus dabanensis	Reconstruction based on IVPP V3237	Wu and Russell (2001, fig. 2B)
Typothorax	Reconstruction based on TMM 31185-84b	Walker (1961, fig. 24c)
Unaysaurus tolentinoi	Reconstruction based on UFSM11069	Leal et al. (2004, fig. 2A)
Vancleavea campi	Drawing of GR 138	Nesbitt et al. (2009b, fig. 2)
Venaticosuchus rusconii	Photograph of PVL 2578	von Baczko et al. (2014, fig. 2B)
Xilousuchus sapingensis	Reconstruction based on IVPP V 6026	Nesbitt (2011, fig. 8J)
Yarasuchus	Reconstruction based on PVL 2052 and PVL 2059	Parker (2014, fig. 3.3)
Yimenosaurus	Reconstruction based on YX V8701	Galton and Upchurch (2004, fig. 12.4M)
Yonghesuchus sangbiensis	Reconstruction based on IVPP V 1237 and IVPP V 12379	Wu et al. (2001, fig. 4)
Youngosuchus sinensis	Drawing of IVPP V 3239 (mistakenly reported as IVPP V 4067 in the figure caption)	Parrish (1992, fig. 9)
Yunnanosaurus huangi	Drawing of NGMJ 004546	Young (1942, fig. 2)

Table 3.1 continued from previous page

Taxon	Specimen/Source	Reference
Zupaysaurus rougieri	Photograph of PULR 076	Ezcurra (2010, fig. 18C)

TABLE 3.2. List of PCA scores used in the study.

Taxon	PC1	PC2	PC3	PC4	PC5
Aardonyx celestae	0.930973274	-1.287241379	-0.435149562	0.302552869	0.359448466
Abrictosaurus consors	1.388687962	-1.201795871	1.029695663	-0.425874242	0.835924453
Adeopapposaurus mognai	0.59405433	-1.449613667	-0.218472711	0.393550649	-0.047797552
Aetosaurus ferratus	6.482784642	-0.756927984	3.899571839	-1.329687023	-1.376809479
Anchisaurus	0.814760124	-0.790177595	1.299916681	-1.720100924	0.51748077
Angistorhinus grandis	-2.379628524	0.164105968	1.814667926	1.363254671	0.638561524
Apatosuchus orbitoangulatus	0.077483918	-0.147962976	-0.603716741	-0.435101849	-0.041833283
Arizonasaurus babbitti	-0.208506293	-0.3200662	0.179428324	-0.360892461	-0.26495023
Austriadactylus cristatus	-1.962735147	-0.412261782	-0.360800099	0.708585781	-0.600191705
Austriadraco dallavecchiai	-0.582704287	-1.35374991	-0.030334745	0.535423766	0.879808154
Azendohsaurus madagaskarensis	-0.14983865	-3.05129567	-1.534974507	1.866996459	0.481623803
Batrachotomus kupferzellensis	-0.739779788	0.164392313	-0.225125788	-0.599054919	-2.647110145
Bergamodactylus wildi	-2.932760872	-0.85643481	1.237714947	1.449588538	0.879944206
Boreopricea funerea	0.013747986	0.000198289	0.150116408	-0.325556495	0.156176277
Brachysuchus megalodon	-1.052777346	0.94543471	1.058681089	0.652283318	-0.105166428
Buriolestes schultzi	-0.195585729	-1.298527161	-0.711643997	-0.823884146	0.671984896
Campylognathoides liasicus	-2.211616373	-0.069813124	1.482978551	-0.25120401	0.843598162
Carniadactylus rosenfeldi	-2.284026458	0.847366657	2.969235288	0.943670426	0.934436139
Caviramus schesaplanensis	-0.081084409	-0.800652031	-0.12276826	1.079118268	1.56270191
Cerritosaurus binsfeldi	0.457011056	0.293179268	-0.851626642	-0.597156369	2.430172666
Chanaresuchus bonapartei	-2.137454623	-0.567759215	-1.193088534	-0.288064217	-1.026222403
Chasmatosaurus yuani	-1.998113966	0.026486973	-0.539182235	-0.177437643	-0.979609046
Chuxiongosaurus	2.216062333	-1.093815654	-0.429408427	0.060846154	0.785770614

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Coelophysis bauri	-0.175391337	0.712856488	0.334078677	0.637997119	1.830877817
Coloradisaurus	0.36719944	-1.029999586	-0.933205522	0.18091676	0.64372878
Daemonosaurus chauliodus	0.325574949	-0.772301944	-0.523506043	-0.581723281	-0.335110978
Decuriasuchus quartacolonia	0.26952711	-0.846309572	-0.996017115	0.323934322	-0.379072087
Desmatosuchus haplocerus	2.147299254	0.03773446	-0.200349095	0.066110721	0.7069035
Diandongosuchus fuyuanensis	-1.191177626	1.402742672	0.924569725	-1.082408337	0.526121895
Dibothrosuchus elaphros	0.168214346	0.913435141	1.438493765	-1.253057864	-0.130990235
Dilophosaurus sinensis	0.651685883	0.0586841	-0.612977951	0.235121606	0.289002203
Dilophosaurus wetherilli	-1.068808421	-1.382181253	-0.393847209	-1.0831391	-0.567289169
Dimorphodon macronyx	-2.311667866	0.24414593	1.854446064	0.17811516	0.308387156
Dinocephalosaurus orientalis	-2.71145871	-0.88070419	0.790004827	0.597857821	-0.274700937
Dorygnathus banthensis	-2.258439602	0.728808482	0.040260458	0.673398161	1.726613037
Doswellia sixmilensis	-0.723972608	0.852587551	-0.21169036	1.570390933	0.221489663
Dromicosuchus grallator	-1.646397149	-0.131907522	0.345892981	-0.105085607	-0.781698351
Dyoplax arenaceus	-0.333455358	1.798385985	-0.250013252	-1.624409101	0.532185039
Edentosuchus	1.470997209	0.853249312	1.650415943	0.138079153	-1.049099154
Effigia okeeffeae	0.777129433	1.429655612	-1.315929116	-0.177033395	0.285526527
Efraasia minor	1.501293876	-1.005947431	-0.55498818	0.626012622	1.926779707
Emausaurus ernsti	0.175840441	-2.117003214	-0.061697878	0.557466081	-0.689306526
Eocursor parvus	0.197533357	-1.141235519	0.726271822	0.633538019	0.478899197
Eodromaeus murphi	0.848000415	-1.648777008	0.2762617	-0.634834876	-0.417789405
Eohyosaurus wolvaardti	1.422988571	0.203899207	0.338794414	-0.877783799	-1.017789567
Eoraptor	-0.717093137	-1.83028432	0.012031593	0.075137292	0.239555707
Erpetosuchus granti	-0.245559779	0.988591835	-1.147771403	-1.253663415	-0.47894825

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Erythrosuchus africanus	-0.183166527	0.384553116	-0.788644171	0.493846443	-0.719202873
Eudimorphodon ranzii	-2.148882046	0.502358783	1.719891709	0.097758286	1.015339955
Euparkeria capensis	-0.519337249	-0.709365831	-0.271830512	-0.339541338	-1.489387576
Fodonyx	1.28104525	-0.371299072	-0.10738667	0.777992849	-0.846435198
Garjainia prima	-0.239028549	-0.319493488	-0.860872256	0.049832613	-1.669582936
Gracilisuchus stipanicicorum	-0.510367717	0.91063193	0.692302391	-1.195706428	-0.10296671
Gualosuchus reigi	-1.456956206	-1.044239643	-1.067366086	-0.350023792	-0.197236157
Hemiprotosuchus leali	1.218350662	1.459385312	-0.737628221	-0.411337631	0.344091518
Herrerasaurus ischigualastensis	0.105913864	-0.575428192	0.738675658	-1.012553158	0.071763964
Heterodontosaurus tucki	2.852686833	-0.436236368	0.338411648	0.479700692	1.123312522
Hyperodapedon gordoni	2.60756492	0.066559953	1.522933332	2.478821907	-0.848832966
Hyperodapedon huxleyi	3.186336883	1.005567065	0.971202528	3.460232626	-2.430079492
Isalorhynchus genovefae	2.707429136	0.895009326	0.069982618	2.407237553	-1.991911334
Jesairosaurus lehmani	-1.159383954	1.120743864	-1.184985126	-0.186196781	1.379914616
Jingshanosaurus	0.582612605	-1.410691208	0.560212359	1.597728517	0.381708831
Lamplughsaura dharmaramensis	0.457335108	-0.184090371	-0.636425588	0.863545086	0.275710341
Langeronyx brodiei	1.130907092	0.790644711	-0.051655517	0.513483153	-0.272767739
Leptosuchus crosbiensis	-2.238145433	0.34927495	1.062830954	0.665899737	0.040661316
Lesothosaurus diagnosticus	0.470819607	-0.817853963	0.845299908	-0.529654669	0.401229874
Lewisuchus admixtus	-2.678555525	-1.096988526	-0.835378391	-0.124767549	0.043857769
Leyesaurus marayensis	1.203072149	-0.296523596	0.641546749	-2.257255124	0.717731361
Liliensternus liliensterni	-0.624253724	-0.907108217	-0.287213454	-0.376247597	0.061735674
Litorosuchus somnii	-2.100872736	-0.408118922	-1.474332425	0.208282195	-0.636803109
Longosuchus meadei	3.622807282	1.356828878	-0.728129538	0.556047113	1.318718942

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Lotosaurus	2.073534364	1.418350121	-2.483062199	-0.599671158	0.914193712
Lufengosaurus	1.462435336	-3.296047291	-1.733143906	0.73867071	0.763098246
Machaeroprosopus gregorii	-2.543624833	-0.778370504	0.98444037	2.677867149	-0.695956241
Macrocnemus bassanii	-2.353279567	-0.665922884	-0.659219179	0.651839816	-0.747270444
Malerisaurus robinsonae	-0.547957229	-0.262514164	-0.033743361	0.280443812	-0.515418912
Manidens condorensis	2.532518596	1.337939287	0.551139616	0.481859668	-0.964596092
Marasuchus lilloensis	-1.786978051	0.018861076	0.227954988	0.943707924	0.628051403
Massospondylus kaalae	1.198331453	0.190192905	0.607785627	1.214499296	0.900052447
Megapnosaurus kayentakatae	1.289231466	-0.822387114	-0.086799736	-1.087323713	0.44433698
Melanorosaurus	-1.085320006	-0.429007288	0.334270233	0.461291414	0.942500512
Mesosuchus browni	1.662576829	1.386345385	-1.404645227	0.006169843	0.876269797
Mussaurus patagonicus	2.287044072	-2.240773329	-1.236102504	-0.476877217	0.030028479
Mystriosuchus planirostris	-3.231540364	-0.406444575	2.428701156	0.723483777	0.530791566
Neoaetosauroides engaeus	3.533412186	0.476325653	-0.449469064	-0.400271366	0.991071288
Nicrosaurus kapffi	-1.679987478	-0.189983588	0.220181505	1.168780404	0.082960675
Ornithosuchus	3.939559065	-2.296366612	5.062504118	-2.120962353	-1.525661317
Orthosuchus stormbergi	-1.68968446	0.031456772	-2.392827417	-1.102683084	-1.517422996
Osmolskina czatkowicensis	-0.114656063	1.51915474	0.498541422	-0.725471179	-0.359659782
Paleorhinus	-1.859869226	1.049741999	0.925299278	0.598037272	-0.387375575
Pamelaria dolichotrachela	0.440638941	-1.202874781	-1.341342977	-0.142618828	-0.318047133
Pampadromaeus barberenai	-0.068163183	-0.770915598	-1.946517679	-0.642482854	0.395467317
Panguraptor lufengensis	0.024723419	-0.801160029	-0.038654662	-0.950126732	-0.122402338
Panphagia protos	-0.434912239	-1.716908276	-1.193398452	-0.264861598	-0.049389503
Pantydraco caducus	0.44773749	0.15791732	0.490166188	-1.57900474	1.209574277

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Parasuchus hislopi	-3.15766662	0.230245211	0.391367932	1.003996041	0.144749693
Paratypothorax andressorum	2.258963994	1.542089729	0.422567563	0.158474546	1.460666706
Pedeticosaurus leviseuri	-0.700021108	0.771126799	-0.295107122	-0.76296945	-1.132137855
Pelagosaurus typus	-3.012800034	0.24404218	2.505246804	-1.009181327	0.730364361
Peteinosaurus zambelli	-1.729277411	0.261180084	0.925069046	-0.579221167	-0.21002244
Pisanosaurus mertii	2.188273755	-1.214227405	0.832307521	-0.147795156	-0.625920241
Plateosaurus engelhardti	0.278571554	-0.653041722	-1.235321515	0.587546411	0.68428205
Platysuchus multiscrobiculatus	-2.27334833	2.751869808	0.75650247	-1.421410034	0.412577274
Polonosuchus silesiacus	-0.273519392	0.986434495	0.725236386	0.105700071	-0.394680583
Postosuchus kirkpatricki	1.119186268	0.60850145	0.006922063	0.616701552	-0.315578747
Preondactylus buffarinii	-2.114744479	-0.474502261	-0.708359285	0.32774366	-0.340421229
Prestosuchus chiniquensis	1.134827072	0.27940898	-0.382850985	-0.077111473	-1.012570982
Prolacerta broomi	-0.562516526	0.154184928	0.209699619	-0.828236587	0.967916677
Proterochampsa barrionuevoi	-1.752168088	0.401972779	-0.122479684	-1.763168163	-0.960225987
Proterosuchus fergusi	-0.779393473	0.262652891	-0.646194442	-0.469844755	-1.331627446
Protome batalaria	-2.270668156	0.168360505	-1.591727605	0.60980766	-0.213256508
Protosuchus richardsoni	1.496322903	1.158359392	1.882768114	0.189439616	-0.338089414
Pseudhesperosuchus jachaleri	-0.476513719	2.162589531	0.46746499	0.134482856	2.113389789
Qianosuchus mixtus	0.010396575	-0.708743215	-1.329181444	0.461900995	0.270168078
Raeticodactylus filisurensis	1.229152707	-0.139096185	0.305316944	2.250633203	0.899515363
Revueltosaurus callenderi	1.114551061	0.440848335	0.143519908	0.745905703	-0.266462665
Rhynchosaurus articeps	1.963096444	-0.873631727	0.284589973	0.44318175	-0.590245242
Riojasaurus	0.108899561	-0.078690832	-1.221319951	1.025103213	-0.247386057
Riojasuchus tenuisceps	1.49468596	0.673506079	-1.559425988	-0.267517091	-0.174070782

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Rutiodon carolinensis	-2.44128764	0.879117423	0.607062602	1.500009063	-0.129562996
Saltoposuchus	-2.002709467	-0.276618874	0.537514625	-1.50654907	-0.647086941
Sanjuansaurus gordilloi	0.786923448	-0.213210094	-1.132385978	-0.193843721	-1.608428823
Sarahsaurus aurifontanalis	0.608272989	-3.114720895	-0.140279918	0.721758669	0.907530329
Saurosuchus galilei	0.579015736	0.310434022	-0.038011656	0.036582804	0.200291573
Scelidosaurus harrisonii	1.094052612	-1.085239433	0.998524855	0.945631955	-0.071860896
Scleromochlus taylori	-0.12619666	1.207616801	-1.160336543	-0.183693539	1.748026754
Shansisuchus shansisuchus	-0.468119275	0.018633453	-0.879134852	-0.622425046	-1.536505331
Silesaurus opolensis	0.392188012	0.929485505	-0.325366415	-1.639938395	-0.023071809
Smilosuchus adamanensis	-2.438979223	-0.307658644	1.417946757	1.208920212	0.05467738
Smok wawelski	-0.07690148	0.669876389	0.725976424	-0.677116045	-0.84347084
Sphenosuchus acutus	-0.14178115	1.073543196	-0.092616403	-0.038316901	-0.364865716
Stagonolepis robertsoni	2.261622204	1.022038981	-0.115646691	-1.092817517	-0.301683714
Staurikosaurus pricei	0.01009007	0.201433647	-0.280628875	-0.754732075	-0.932920522
Stenaulorhynchus sp.	0.731377189	0.478326801	0.373517642	0.36357138	-1.245691469
Steneosaurus bollensis	-1.859175884	1.408692739	1.470505512	-1.389608546	1.417227362
Stenomyti huangae	3.433374718	1.079323234	0.169076089	-1.151775244	1.070081497
Tanystropheus longobardicus	-0.271660027	-1.178401678	-0.341613761	0.250581882	0.93900813
Tarjadia ruthae	-0.538262814	0.436017063	-0.560967772	-0.594474688	-1.603548504
Tawa hallae	-0.978620852	-1.044913712	0.67383662	-1.190876252	-0.165958991
Tazoudasaurus naimi	-1.052951687	1.509593354	-0.801791328	1.475284555	-0.411711709
Teraterpeton hrynewichorum	-0.447176892	0.340697842	-1.066065715	-1.605814566	1.552253465
Terrestrisuchus gracilis	-1.894945711	-0.297413823	0.554286727	-1.413064054	-0.307695507
Teyujagua paradoxa	-0.255455959	-0.165023847	-0.828476272	0.354617414	-0.839729193

Table 3.2 continued from previous page

Taxon	PC1	PC2	PC3	PC4	PC5
Teyumbaita sulcognathus	1.573237	1.316091416	0.611156674	2.365398177	-0.313043506
Thecodontosaurus sp.	0.894581797	0.084640319	-0.557537228	-0.253934335	0.985174266
Ticinosuchus	-1.446795748	0.564662559	-0.166241954	-0.394393915	-0.539690522
Tikisuchus romeri	-0.127972233	0.767098799	-0.545015908	0.241932169	-1.936669915
Trialestes romeri	-0.711909971	1.017126741	-0.604181782	-1.013927941	-1.035010991
Trilophosaurus buettneri	2.201212506	-0.626170699	0.510164113	1.118126584	0.403384238
Tropidosuchus romeri	-1.466350802	-1.527607572	-1.46413696	-1.586462504	-0.615575268
Turfanosuchus dabanensis	-0.979199277	0.671316128	0.196767053	-0.851156125	-0.273299461
Typothorax	3.914992825	0.63231695	-0.539326619	0.246309104	1.325162255
Unaysaurus tolentinoi	0.418687359	-1.084458194	-0.210654682	-0.463988272	1.232707403
Vancleavea campi	1.121606539	5.364182193	-1.352091182	1.50028537	-0.515720218
Venaticosuchus rusconii	1.813899551	0.817670069	-1.024159555	-0.464948589	0.036904024
Xilousuchus sapingensis	-0.103877669	-0.329991689	0.15336013	-0.414453803	-0.247771513
Yarasuchus	-0.368986915	1.19720511	0.267529077	-0.486759881	0.001556077
Yimenosaurus	0.058095403	2.265757286	-1.777142204	1.100545783	-0.069942996
Yonghesuchus sangbiensis	-0.093008983	-0.606431155	0.997395191	-0.496939495	0.517222069
Youngosuchus sinensis	0.528280587	0.523087312	-0.212399027	-0.717931842	-0.307160327
Yunnanosaurus huangi	0.617303178	0.784772894	-0.78946553	-0.604394665	-0.332078854
Zupaysaurus rougieri	-0.10329602	-1.060261822	-0.88429994	-0.523594729	-0.660368405

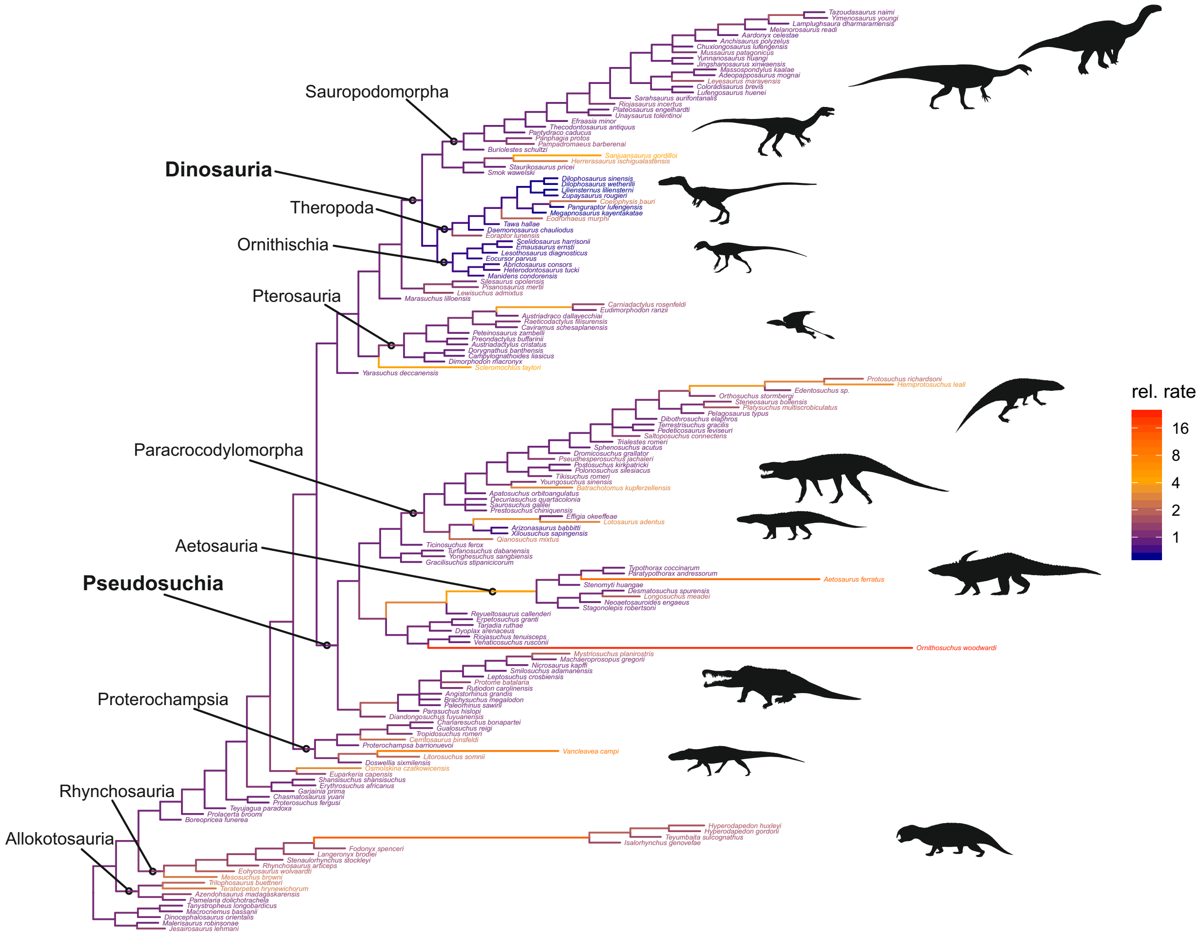

FIGURE 3.5. Relative rates of mandibular functional evolution in early archosauromorphs. Original branch lengths are replaced by the mean rate scalars (shorter branches indicate lower rates, longer branches indicate higher rates) and branches are also coloured according to the mean relative evolutionary rate. The supertree is based on the Ornithoscelida topology. Silhouettes from `http://phylopic.org` (Dmitry Bogdanov, Robert Gay, Scott Hartman, T. Michael Keesey, Bruno Navarro, Iain Reid, 'Smokeybjb', Nobu Tamura, Steven Traver, Emily Willoughby, Mark Witton).

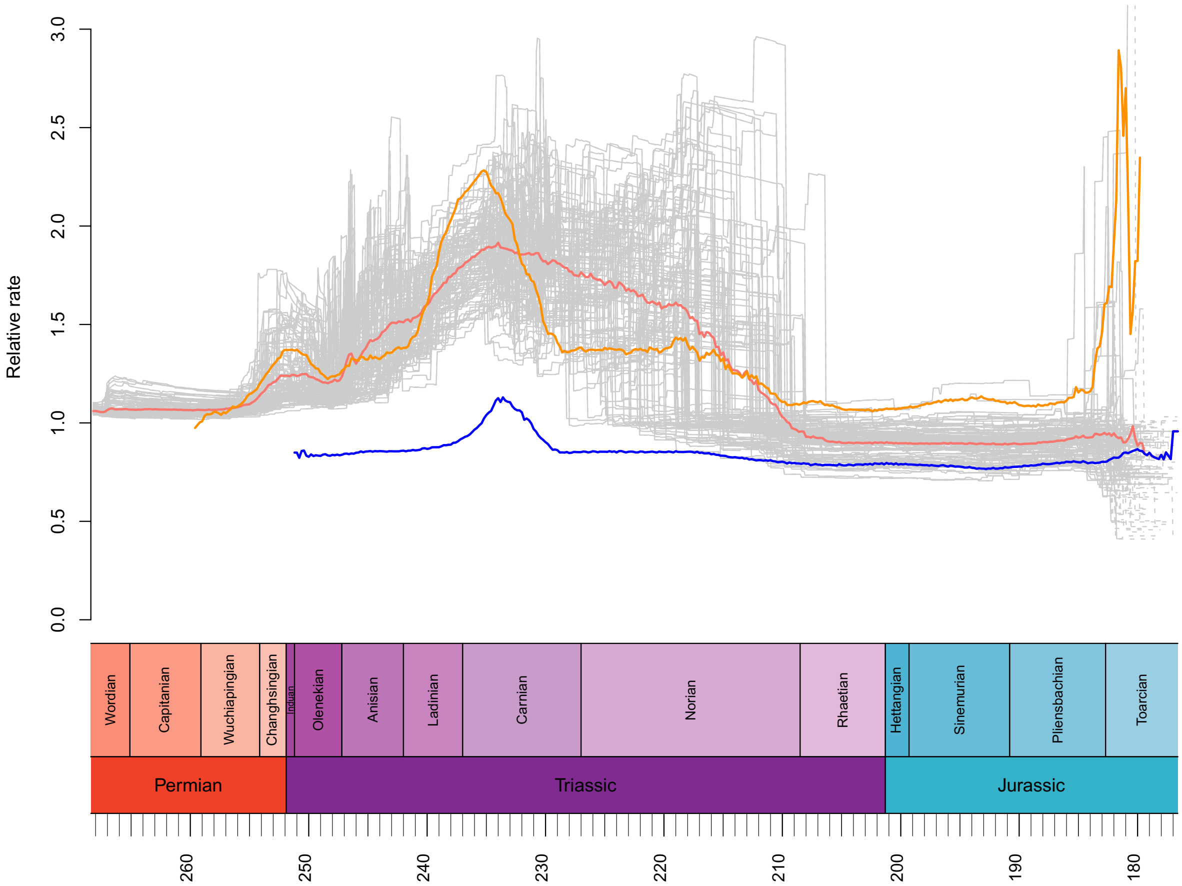

FIGURE 3.6. Mean rates of mandibular functional evolution through time based on the Ornithoscelida topology. Grey lines represent the rates of Archosauromorpha for each of the 100 timescaled trees, all other lines represent the mean across all 100 trees. Clades: ▬ Archosauromorpha, ▬ Dinosauria, ▬ Pseudosuchia.

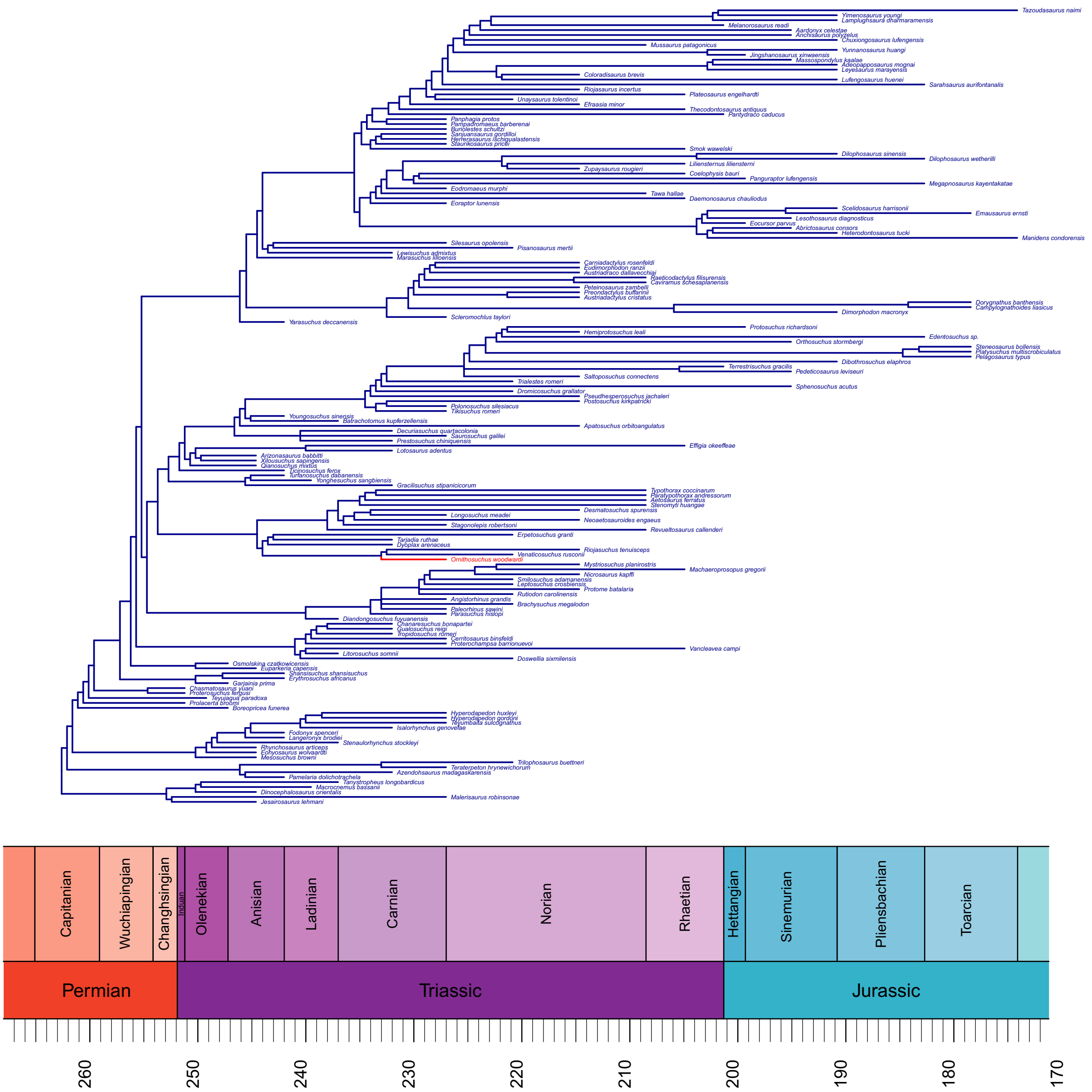

FIGURE 3.7. Positive phenotypic selection of mandibular function in early archosauromorphs based on the extended definition presented herein. Only branches coloured in red were subjected to positive phenotypic selection. For visualization purposes a MBL timescaled consensus tree is used. The supertree is based on the Ornithoscelida topology.


Tree #1
Tree #2
Tree #3
Tree #4
Tree #5
Tree #6
Tree #7
Tree #8
Tree #9
Tree #10
Tree #11
Tree #12
Tree #13
Tree #14
Tree #15
Tree #16
Tree #17
Tree #18
Tree #19
Tree #20
Tree #21
Tree #22
Tree #23
Tree #24
Tree #25
Tree #26
Tree #27
Tree #28
Tree #29
Tree #30
Tree #31
Tree #32
Tree #33
Tree #34
Tree #35
Tree #36
Tree #37
Tree #38
Tree #39
Tree #40
Tree #41
Tree #42
Tree #43
Tree #44
Tree #45
Tree #46
Tree #47
Tree #48
Tree #49
Tree #50

FIGURE 3.8. Positive phenotypic selection of mandibular function in early archosauromorphs in individual trees based on the definition of Baker et al. (2016). Only branches coloured in red were subjected to positive phenotypic selection. The supertrees are based on the Ornithoscelida topology.

CHAPTER 4

COMPLEX SPECIATION DYNAMICS PRIOR TO THE PTME IN EARLY TETRAPODS

This chapter is the result of a collaboration with Dr. Manabu Sakamoto and Dr. Chris Venditti from the University of Reading. Manabu Sakamoto provided some of the R scripts used for the analyses of Sakamoto et al. (2016) and both Manabu Sakamoto and Chris Venditti provided useful comments in regard to the methods. The candidate modified and expanded the scripts according to the needs of the project. Data collection, analyses, and writing of the chapter were all carried out by the candidate. Estimate of total work carried out by the candidate: 90%.

4.1 Abstract

The Permo-Triassic mass extinction (PTME) event was a crucial turning point in the evolution of tetrapods. 89% of all tetrapod genera went extinct. So far, there has been no test whether tetrapods had been 'weakened' prior to the PTME, making them more susceptible to the mass extinction event. Here I show that early tetrapods as a whole were in decline prior to the PTME. The recovered speciation dynamics for early tetrapods are complex. Anamniote 'amphibian' species experienced an increase in net speciation up to the early Carboniferous. Net speciation of 'Amphibia' declined subsequently and about 25 Myr prior to the PTME extinction rates started to exceed speciation rates. Amniota, on the other hand, never experienced such a slowdown in speciation dynamics. Net speciation of amniotes was either rising or remaining relatively stable prior to the PTME. The diversification capacity of amniotes had already overtaken that of 'amphibians' by the end of the Carboniferous. Since potential sampling biases cannot explain the recovered pattern it is interpreted as genuinely biological. The results confirm the importance of the PTME in shaping Mesozoic terrestrial ecosystems. Without the mass extinction event at the

end of the Permian, typical Palaeozoic associations of amniotes would have continued to thrive and archosauromorphs (and ultimately dinosaurs) might never have obtained their Mesozoic dominance.

4.2 Introduction

The Permo-Triassic mass extinction event (PTME), often termed 'the mother of mass extinctions' (Erwin, 1993, 1996; Modesto et al., 2003; Ruta and Benton, 2008), was the most severe biotic crisis of all time leading to the extinction of ~81% of all marine animal species (Benton and Twitchett, 2003; Stanley, 2016). Up to the 1990's it had often not been recognized (e.g., Carroll, 1988, p. 589) that terrestrial vertebrates were also part of this massive extinction event (Benton and Newell, 2014). The importance of the PTME for tetrapod evolution is now general consensus (Benton et al., 2004; Sidor et al., 2013; Roopnarine and Angielczyk, 2015b; Bernardi et al., 2018b). More than 70% of terrestrial tetrapod families (Benton et al., 2004) and 89% of all tetrapod genera went extinct (Benton et al., 2013c). It took up to 9 Myr for the re-emergence of stable, complex ecosystems (Chen and Benton, 2012) and terrestrial faunas had been fundamentally changed. While late Palaeozoic terrestrial ecosystems were dominated by parareptiles and therapsids the aftermath of the PTME saw the rise of archosauromorphs (and ultimately dinosaurs) to dominance (Benton et al., 2004; Roopnarine and Angielczyk, 2015b; Sookias et al., 2012b; Ezcurra and Butler, 2018).

The large igneous province (LIP) volcanism of the Siberian Traps in Russia was the most likely trigger for the PTME (Wignall, 2001; Benton and Twitchett, 2003; Payne and Clapham, 2012; Burgess and Bowring, 2015; Bond and Grasby, 2017; Broadley et al., 2018). A combination of environmental effects such as acid rain, global warming, and massive soil erosion, all resulting from the Siberian Traps LIP volcanism, were the probable main causes for the extinction on land (Benton and Newell, 2014). Other factors such as increased aridity, wildfires, hypoxia, and a destroyed ozone layer might have contributed to the terrestrial extinction to a lesser degree (Benton, 2018). Browsers and predators were heavily hit during the PTME in the terrestrial setting while piscivores flourished in its immediate aftermath (Sahney and Benton, 2008). Acid rain, global warming, and massive soil erosion probably lead to a removal of land plants thereby reducing the available food resource for large browsers (Sahney and Benton, 2008; Benton and Newell, 2014). The Permian members of Archosauromorpha were, indeed, no large herbivores (e.g., Sennikov, 1988; Ezcurra et al., 2014; but see Munk and Sues, 1993) and might therefore have been less affected by the PTME. It has been suggested that an earlier onset of reproductive maturity allowed therapsids to persist through the mass extinction event (Botha-Brink et al., 2016). Studies focused on extinction selectivity and linking it to physiology, however, are still missing for terrestrial tetrapods during the PTME (Benton and Newell, 2014).

The PTME was the largest of the 'big five' (Raup and Sepkoski, 1982) mass extinction events

(Benton and Twitchett, 2003; Stanley, 2016). It is clear, however, that other, smaller events such as the ‘Carboniferous rainforest collapse’ (CRC) during the late Carboniferous (Sahney et al., 2010; Dunne et al., 2018), Olson’s extinction between the early and middle Permian (Sahney and Benton, 2008; Brocklehurst et al., 2017; Brocklehurst, 2018), and the Capitanian (‘end-Guadalupian’) mass extinction event (Day et al., 2015a, 2018b) substantially shaped the diversity of tetrapods prior to the Permo-Triassic (PT) boundary. Indeed, it has even been suggested that the PTME on land was not a single event for Tetrapoda but rather part of a protracted phase of taxonomic turnover and replacement (Padian, 2018).

Recently it has been shown that speciation rates in dinosaurs were in decline tens of millions of years before their final extinction at the Cretaceous-Paleogene (K-Pg) boundary (Sakamoto et al., 2016). Using a database of all valid early tetrapod species sensu Benton et al. (2013c) I test whether such a pattern is also recovered for Tetrapoda prior to the PTME. Previous studies of speciation and extinction patterns in the fossil record of early tetrapods often focused on standing diversity or did not account for phylogenetic non-independence (Ward et al., 2005; Fröbisch, 2008a; Sahney et al., 2010; Benton et al., 2013c; Day et al., 2015a; Brocklehurst et al., 2017; Day et al., 2018b). Here I use an explicit model of speciation dynamics that accounts for the phylogenetic non-independence of data points within a Bayesian framework (Hadfield, 2010; Sakamoto et al., 2016).

The model expects a linear increase of the logarithm of the number of speciation events with time if speciation rate and extinction rate were constant and speciation rate was higher than extinction rate (Figure 4.1). If speciation rate decreased through time the model expects a curvilinear relationship between the logarithm of the number of speciation events and time, resulting in either a constant asymptotic behaviour (speciation rate = extinction rate) or the curve turning down (extinction rate > speciation rate; Sakamoto et al., 2016). This modelling approach allows me to test whether the diversification capacity of early tetrapods had weakened before the PTME.

4.3 Methods

4.3.1 Data collection

I used the six comprehensive early tetrapod supertree topologies (2142 species) presented in chapter 2 (for details see Appendix A). To test for the effect of sampling bias (Smith and McGowan, 2007; Alroy, 2010b) on the results I used three proxies from the updated early tetrapod database (chapter 2): (1) ‘phylogenetic placement’, (2) fossil preservation status, and (3) body size. The ‘phylogenetic placement’ metric indicates whether a taxon has been added to the supertree topologies based on a quantitative phylogenetic analyses or based on taxonomic information only. Modern descriptions of early tetrapod species nowadays generally tend to include a quantitative phylogenetic analysis of the relationships if the specimens are well enough preserved (e.g., Clack

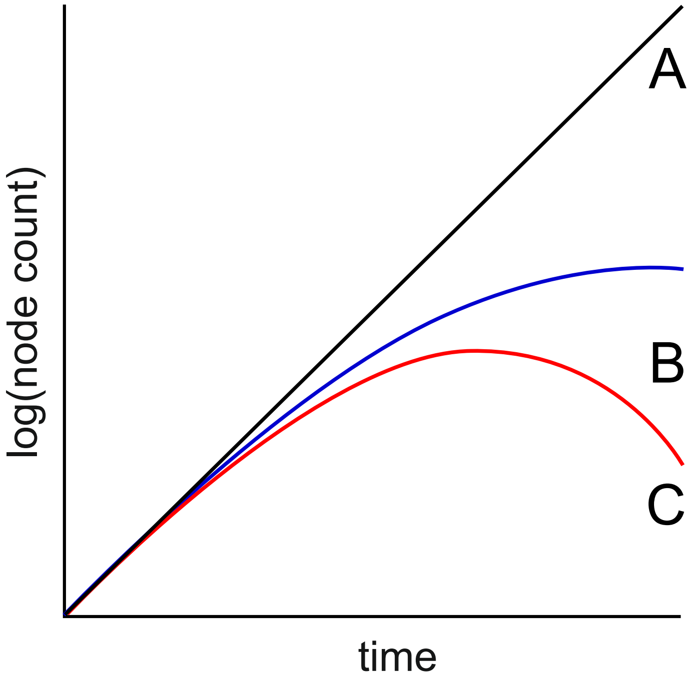

FIGURE 4.1. Schematic models of speciation through time (modified from Sakamoto et al., 2016). Provided that speciation rate exceeded extinction rate and assuming that both speciation and extinction rates were constant, the model predicts a linear increase of the logarithm of the number of speciation events (= logarithm of node counts) with time (**A**). If speciation rate exceeded extinction rate initially but decreased through time, the model predicts a curvilinear relationship between the logarithm of the number of speciation events and time. If speciation rate decreased until being equal to extinction rate this curve turns into an asymptote (**B**), which can be modelled using a square root transformation of the time variable. If speciation rate decreased even further, thereby allowing extinction rate to exceed speciation rate, the curve turns down, which can be modelled using an additional quadratic time term (**C**).

et al., 2016; Nesbitt et al., 2017; Sulej and Niedźwiedzki, 2019; no quantitative analysis in, e.g., Debuysschere et al., 2015). Since the supertree topologies of chapter 2 have been optimized to contain taxa which were part of a quantitative phylogenetic analysis where possible, the 'phylogenetic placement' sampling proxy should reflect the status of knowledge for a particular early tetrapod species. Better known species are expected to have been part of a quantitative phylogenetic analysis (note that this concept could be further extended to take into account the year of publication and the dimensions of the source matrix). The fossil preservation status assigns a quality score to individual tetrapod species, based on whether they are represented by one or multiple fragments (1), at least one complete skull (2), at least one complete skeleton (3), and multiple complete skeletons (Benton et al., 2013c). Body size is another sampling bias proxy since smaller tetrapod fossils might be less likely to be preserved or found (Brown et al., 2013;

Cleary et al., 2015b; Beardmore et al., 2017; but see also Verrière et al., 2016). I used three body size categories, 'small' (snout-vent length <150 mm), 'medium' (snout-vent length between 150 and 1500 mm), and 'large' (snout-vent length >1500 mm), since exact body size measurements are not available for all early tetrapod species.

4.3.2 Time-scaling

I used the probabilistic cal3 method implemented in the `paleotree` R (R Core Team, 2018) package (Bapst, 2012, 2013) to time-scale 100 randomly resolved replicates of all six early tetrapod supertree topologies. Due to the uncertain phylogenetic (Nesbitt et al., 2013d; Baron et al., 2017a; Langer et al., 2017b; Puttick et al., 2017b; Baron and Williams, 2018) and stratigraphic (Nesbitt et al., 2017; Butler et al., 2018) position of *Nyasasaurus parringtoni* and its unusual late diverging position within the Ornithoscelida topology (Baron et al., 2017a), it was dropped from the supertree topologies based on the Ornithoscelida hypothesis prior to time-scaling. Minimum (0.042 lmy^{-1}) and maximum sampling rates (0.18 lmy^{-1}) reported for early tetrapods (Bapst and Hopkins, 2017; Friedman and Brazeau, 2011) were used to create a uniform distribution from which I obtained the required sampling rates for the birth-death sampling model of cal3. Following the approach of Lloyd et al. (2016a) I then used these sampling rates to calculate the necessary extinction and origination rates. I set the step size of increments in the node age function to 0.001 (step.size = 0.001), and excluded the possibility of inferring ancestor-descendant relationships (anc.wt = 0). For each of the supertree topologies I chose three different approaches to the time of observation. For the first approach I restricted the time of observation of the tips to the substage interval of the first appearance date (FAD; dateTreatment: firstLast; FAD.only = TRUE). For the second approach I restricted the time of observation of the tips to the substage interval of the last appearance date (LAD; dateTreatment: firstLast; FAD.only = FALSE). For the last approach the time of observation was randomly sampled between the FAD and LAD (dateTreatment: randObs). Zero-length branches were assigned a minimum length of 0.0001 Myr (= 100 yr) (see also Bapst, 2014; Bapst and Hopkins, 2017).

Prior to the speciation dynamics analyses I pruned all time-scaled trees to include only branches that were present before the PTME, i. e. all branches extending beyond 251.902 Ma (Ogg et al., 2016; International Commission on Stratigraphy (ICS), 2017) were removed using the timeSliceTree function of the `paleotree` package (Bapst, 2012). Branches that passed through the PTME were cut at 251.902 Ma and the label of the earliest appearing tip descendant was applied to the cut branch. Thus I also accounted for range extensions and ghost lineages (Smith, 1994; Ruta and Benton, 2008). Such an approach is more conservative in regard to the null model (which assumes no slowdown in speciation rates prior to the PTME) compared to a literal reading of the fossil record, which only includes taxa that are known from pre-Triassic deposits. Depending on the position of the time-scaled branches relative to the PT boundary, between 1020 to 1079 species were part of the pruned trees.

4.3.3 Speciation dynamics

I used phylogenetic generalised linear mixed models (GLMMs) to analyse speciation dynamics in early tetrapods prior to the PTME. I used the R package `MCMCglmm` (Hadfield, 2010, 2018b) to fit GLMMs in a Bayesian framework using Markov-chain Monte Carlo (MCMC) algorithms. I modelled the total number of speciation events (= total number of nodes) along the phylogenetic path of an early tetrapod species as the response variable. For the most simple linear null model I treated the corresponding phylogenetic path length which corresponds to the time elapsed from the root to the tip (= total of branch lengths from root to tip) as the main effects predictor variable. To test whether early tetrapods were characterised by a speciation slowdown prior to the PTME I created an alternative model which added the quadratic term $time^2$ to the predictor variables. Finally I modelled the slowdown towards an asymptote, representing an equilibrium between speciation and extinction rates, by square root-transforming $\sqrt{time}$, the main effects predictor variable.

Since evolutionary rates have often been shown to be heterogeneous (Venditti et al., 2011; Jetz et al., 2012; Sakamoto et al., 2016; chapter 2; chapter 3), I generated a second set of models in which I estimated separate intercepts, slopes, and quadratic terms for early anamniotes (= 'Amphibia' sensu Benton et al., 2013c) and early amniotes. Following the usage of Benton et al. (2013c) I use the term 'amphibians' herein to designate all early tetrapods that are not part of Amniota. I generated a third set of models which again estimated separate model parameters for 'amphibians' and amniotes but assumed major differences in the speciation dynamics of the two groups. For 'amphibians' I fitted a quadratic (slowdown) model while for amniotes a linear and a square root (equilibrium) model was fitted. Finally, based on the third set of models, I generated a fourth one incorporating the proxies for sampling bias in the fossil record as covariates. Models incorporated all and subsets of the sampling bias proxies. In total 22 models were fitted to each of the 18 combinations of tree topologies and time-scaling approaches.

To account for shared ancestry phylogeny was added as a random effect in the form of an inverse phylogenetic variance-covariance matrix. MCMC chains were run for 1,000,000 iterations, sampling every 1000th iteration and excluding the first 100,000 iterations as burnin. Since the total number of speciation events represents count data I fitted a Poisson GLMM without log-transforming node counts prior to model fitting (O'Hara and Kotze, 2010). When using a Poisson distribution `MCMCglmm` automatically accounts for overdispersion in count data (Hadfield, 2018a). I used default priors for the fixed effects ($\mu = 0$ and $V = I \times 10^{10}$ with the identity matrix I), priors as in Sakamoto et al. (2016) for the R-structure (R: prior for the (co)variances of the residuals; $\nu = 0.002$ and $V = 1$; see also Hadfield, 2018a), and parameter expanded priors for the G-structure (G: prior for the (co)variances of the random effects; $\nu = 1$, $V = 1$, $\alpha\mu = 0$, and $\alpha\mu = 35^2$) to allow for convergence (Hadfield, 2010, 2018a). I assessed model fit using the deviance information criterion (DIC) (Spiegelhalter et al., 2002; Hadfield, 2010). The best fit model was identified by having the lowest DIC score and a DIC difference (Δ DIC) of greater than four compared to the next best model (Sakamoto et al., 2016). If Δ DIC was smaller than four and if there was no difference in the model parameter significance pMCMC (= two times the proportion of the MCMC parameter estimate crossing zero) between two models, they were not deemed significantly different (Sakamoto et al., 2016).

I calculated the net speciation per 1 Myr by calculating model predictions in intervals of 1 million years and then calculating the difference between successive intervals. Net speciation was calculated for the models with the best fit.

Analyses were run for all tree topologies and all time-scaling approaches. The current implementation of `MCMCglmm` (Hadfield, 2010, 2018b,a) can only be applied to single trees. Therefore results reported herein only refer to one of the 100 time-scaled trees for each topology and time-scaling combination. The results obtained for different time-scaled trees, however, do not differ in their qualitative interpretation.

4.4 Results

Early tetrapods experienced a speciation slowdown prior to the PTME. A non-linear model is always favoured over a linear model for all of early Tetrapoda (Table 4.1; Figure 4.2). The square root and quadratic models for Tetrapoda as a whole were not always significantly different (Δ DIC <4; Table 4.1; section 4.6), depending on chosen topology and time-scaling approach. When estimating separate model parameters for 'Amphibia' and Amniota non-linear models always provided a significantly better fit (Δ DIC >4) to the data than the best single-clade model, except for the FAD time-scaled Lissamphibia 'lepospondyl' hypothesis (LH) + Ornithoscelida topology (Table 4.6) where the Δ DIC was just 3.2. Among the two-groups ('Amphibia' and Amniota) models the quadratic model is always significantly better than the linear (Δ DIC >17.9) and the square root model (Δ DIC >5.9; Table 4.1; section 4.6). The model with the lowest (and therefore best) DIC scores is always found among the two-groups models which assume major differences in speciation dynamics between 'Amphibia' and Amniota, the former being represented by a quadratic model and the latter by either a linear or a square root one. These models always had lower DIC scores than two-group models with quadratic terms for both 'Amphibia' and Amniota, albeit the difference was not always significant (Table 4.1; section 4.6). Generally, models with a separate linear term for Amniota and a separate quadratic term for Amphibia had the best fit to the data (Figure 4.3). Models with a square root term for Amniota instead had generally higher DIC scores, but the difference between the linear amniote and the square root amniote model was never significant. Incorporation of sampling bias proxies never led to a significant improvement in model fit, irrespective of the chosen combination, and was often associated with a significantly (Δ DIC >4) worse model fit (Table 4.1; section 4.6). Similarly, model parameters related to the sampling bias proxies were never significant unlike the other model parameters which were always highly significant (pMCMC <0.001; see Supplementary Files).

TABLE 4.1. DIC model comparison of all models for 'traditional' Amphibia & Archosauromorpha topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations: lin., linear; quad., quadratic; sqrt, square root; Full, all sampling bias proxies (S, P, M); S, size; P, 'phylogenetic placement', M, material/fossil preservation status.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5425.7	0.0	5422.0	0.0	5443.7	0.0
Tetrapoda quadratic	5416.6	-9.1	5408.6	-13.4	5430.8	-12.9
Tetrapoda square root	5417.2	-8.5	5403.1	-19.0	5428.7	-15.0
2-Group linear	5429.1	0.0	5425.8	0.0	5445.4	0.0
2-Group quadratic	5411.2	-17.9	5395.5	-30.2	5420.9	-24.5
2-Group square root	5418.1	-10.9	5406.3	-19.4	5433.2	-12.2
2-Group lin.+quad.	5406.0	0.0	5392.3	0.0	5418.6	0.0
2-Group sqrt+quad.	5407.7	1.7	5393.3	1.0	5418.0	-0.5
2-Group lin.+quad. + Full	5412.8	6.8	5396.8	4.5	5422.0	3.5
2-Group sqrt+quad. + Full	5412.7	6.7	5398.2	5.9	5423.1	4.5
2-Group lin.+quad. + S	5409.4	3.4	5392.8	0.5	5421.1	2.5
2-Group lin.+quad. + P	5410.9	4.9	5391.9	-0.4	5418.1	-0.4
2-Group lin.+quad. + M	5409.4	3.4	5393.3	1.0	5419.4	0.8
2-Group sqrt+quad. + S	5409.6	3.6	5393.8	1.5	5419.8	1.3
2-Group sqrt+quad. + P	5408.5	2.5	5392.5	0.2	5419.1	0.6
2-Group sqrt+quad. + M	5408.2	2.2	5394.2	1.9	5419.2	0.6
2-Group lin.+quad. + S + P	5411.0	4.9	5394.1	1.8	5421.6	3.1
2-Group lin.+quad. + S + M	5411.6	5.5	5395.4	3.1	5420.1	1.6
2-Group lin.+quad. + P + M	5411.4	5.4	5396.0	3.7	5422.0	3.4
2-Group sqrt+quad. + S + P	5410.3	4.3	5395.1	2.8	5421.5	3.0
2-Group sqrt+quad. + S + M	5409.5	3.5	5395.3	3.0	5423.0	4.5
2-Group sqrt+quad. + P + M	5410.5	4.5	5396.1	3.8	5421.8	3.2

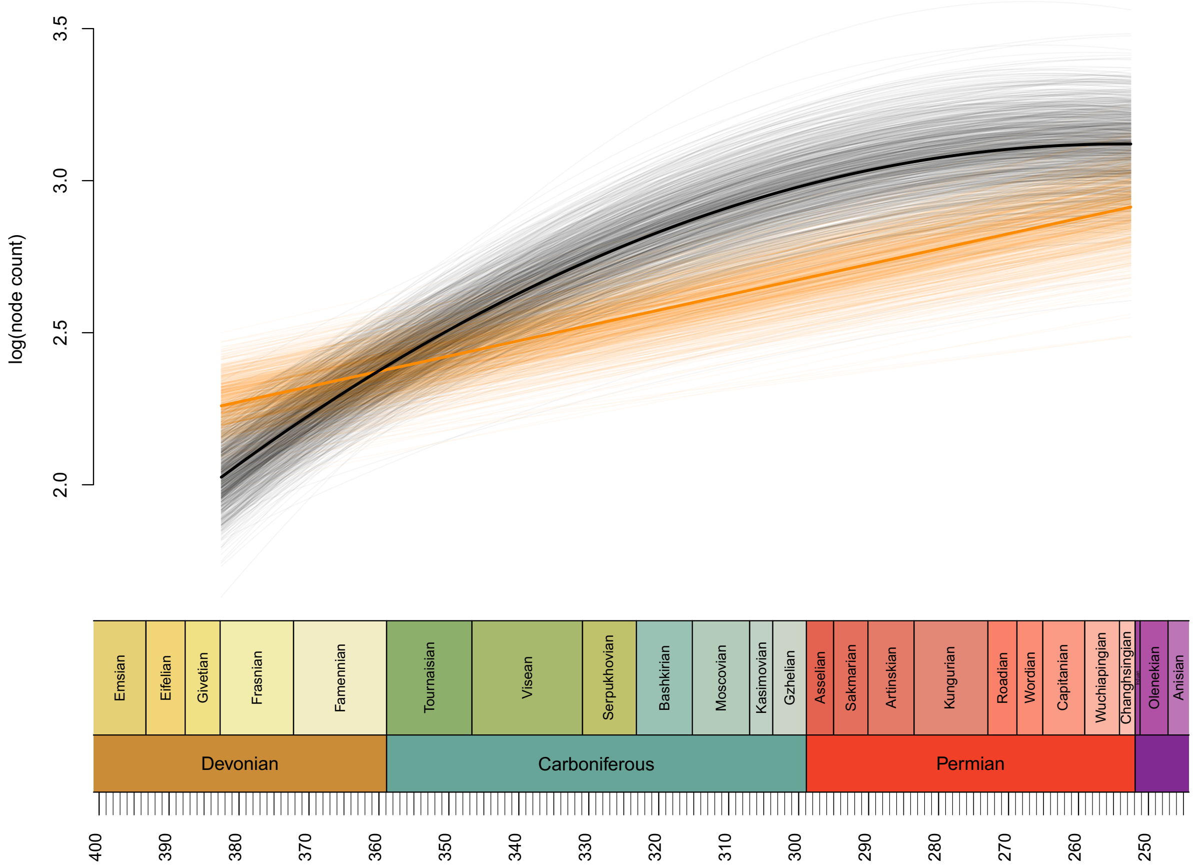

FIGURE 4.2. Model predictions of speciation through time in Palaeozoic tetrapods prior to the PTME based on a LAD time-scaled topology ('traditional' Amphibia & Archosauromorpha). For Tetrapoda as a whole a quadratic speciation slowdown model (black) is always favoured over a linear model (orange), but not always significantly different from a square root model (asymptotic slowdown; not shown). When using a two-groups model ('Amphibia' and Amniota) the pure quadratic model always significantly improves model fit compared to the pure linear one (Δ DIC >17.9) and the pure square root model (Δ DIC >5.9). Posterior predictions showing model uncertainties are represented by transparent lines. Bold lines indicate the mean of the posterior predictions.

'Amphibia' had about 0.16 speciation events per 1 Myr at the origin of the group (Figure 4.4). The net speciation for 'Amphibia' rose throughout the Devonian and into the Carboniferous up to the early to middle Visean, reaching a peak of ~0.22 speciation events per 1 Myr at about 342 Ma. Net speciation started to decline afterwards in 'Amphibia'. The decline in net speciation in 'Amphibia' happened therefore about 90 million years prior to the PTME and speciation rate equaled extinction rate (= net speciation of 0) at about 277 Ma in the middle Kungurian, more than 25 million years before the PTME. The speciation rate continued to the decline reaching a

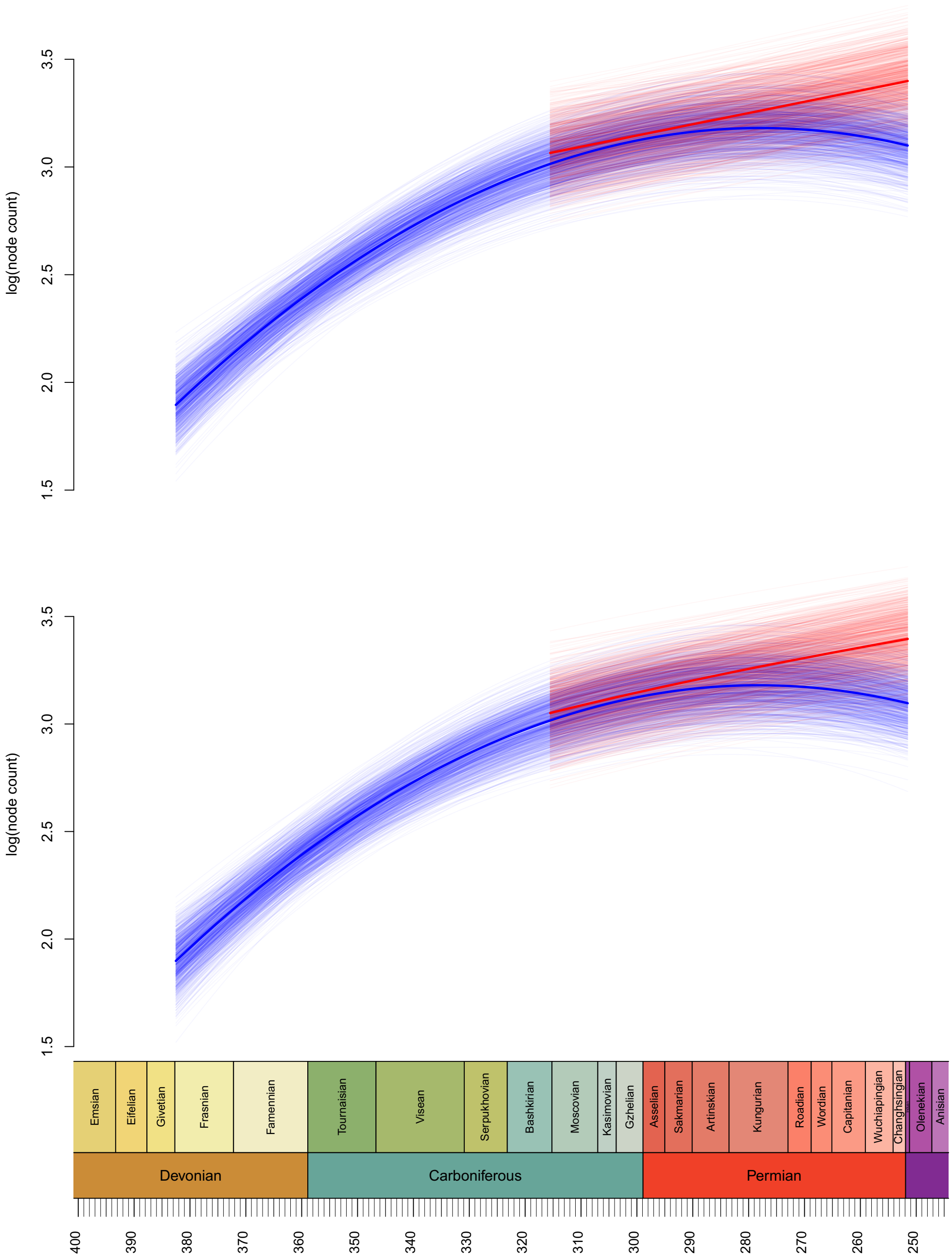

FIGURE 4.3. Model predictions of speciation through time in Palaeozoic tetrapods (complex two-groups model) prior to the PTME based on a LAD time-scaled topology ('traditional' Amphibia & Archosauromorpha). Separate model parameters have been estimated for 'amphibians' (blue; quadratic slowdown) and amniotes (red; top: linear model; bottom: square root model) which substantially improves model fit. Here, the best two models are shown, which cannot be distinguished based on DIC difference and model parameter significance. Note the similarity of the linear and square root model for Amniota. Transparent and bold lines as in Figure 4.2.

minimum of -0.13 net speciation events per 1 Myr right before the PTME.

Assuming a linear model, Amniota had about 0.11 speciation events per 1 Myr at the origin of the clade during the earliest Moscovian (Figure 4.4). Net speciation continued to increase up to the PTME where it reached ~0.16 speciation events per 1 Myr. The net speciation of amniotes surpassed that of 'amphibians' during the latest Givetian, close to the transition from the Carboniferous to the Permian. Assuming a square root model, Amniota had about ~0.13 to ~0.14 speciation events per 1 Myr throughout the evolutionary history of the clade up to the PTME. Similar to the linear model, the net speciation of amniotes surpassed that of 'amphibians' during the (early) Givetian. No major changes in net speciation were observed for Amniota in the square root model. Due to the asymptotic behaviour of square root functions and the late appearance of Amniota in the fossil record relative to the origin of Tetrapoda, the square root model for amniotes appears very similar to the linear model (Figure 4.3; Figure 4.4).

4.5 Discussion

I find clear support (Δ DIC >4) for a speciation slowdown in early tetrapods prior to the PTME, especially when speciation was analysed separately for different tetrapod groups, similar to the decline in speciation rates recovered for dinosaurs prior to the K-Pg mass extinction event (Sakamoto et al., 2016). Speciation dynamics in early tetrapods, however, was complex. While 'Amphibia' experienced a pronounced slowdown in speciation rates reaching a negative net speciation more than 25 Myr before the PTME, Amniota behaved quite differently. Amniota either had a constant speciation and extinction rate with speciation rate surpassing extinction rate (linear model) or experienced a slowdown in speciation rate which, however, would never fall below extinction rate (square root model). Based on my results it is not possible to determine whether the linear or the square root model for Amniota provides the best fit, since their difference in DIC scores is not significant (and since model parameters are significant in both cases). Due to the mathematical properties of square root functions the biological interpretation of these results, however, is similar. Square root functions behave similarly to linear functions at larger domain values, and, indeed, the difference between the net speciation in the linear model (~0.11 to ~0.16 speciation events per 1 Myr) and the square root model (~0.13 to ~0.14 speciation events per 1 Myr) appears small for amniotes and allows similar biological interpretations. Unlike 'Amphibia', Amniota continued to thrive up to the PTME, potentially facing only a minor decrease in speciation rates (square root model). Irrespective of the model, early amniotes always had a higher speciation rate than extinction rate prior to the PTME and net speciation was also always significantly above zero, i. e. speciation and extinction rates were never close to each other prior to the PTME in Amniota (Figure 4.4).

The fossil record is known to be incomplete (Smith and McGowan, 2007; Alroy, 2010b; Smith and McGowan, 2011; Cleary et al., 2015b; Dean et al., 2016; Cleary et al., 2018; Maxwell et al.,

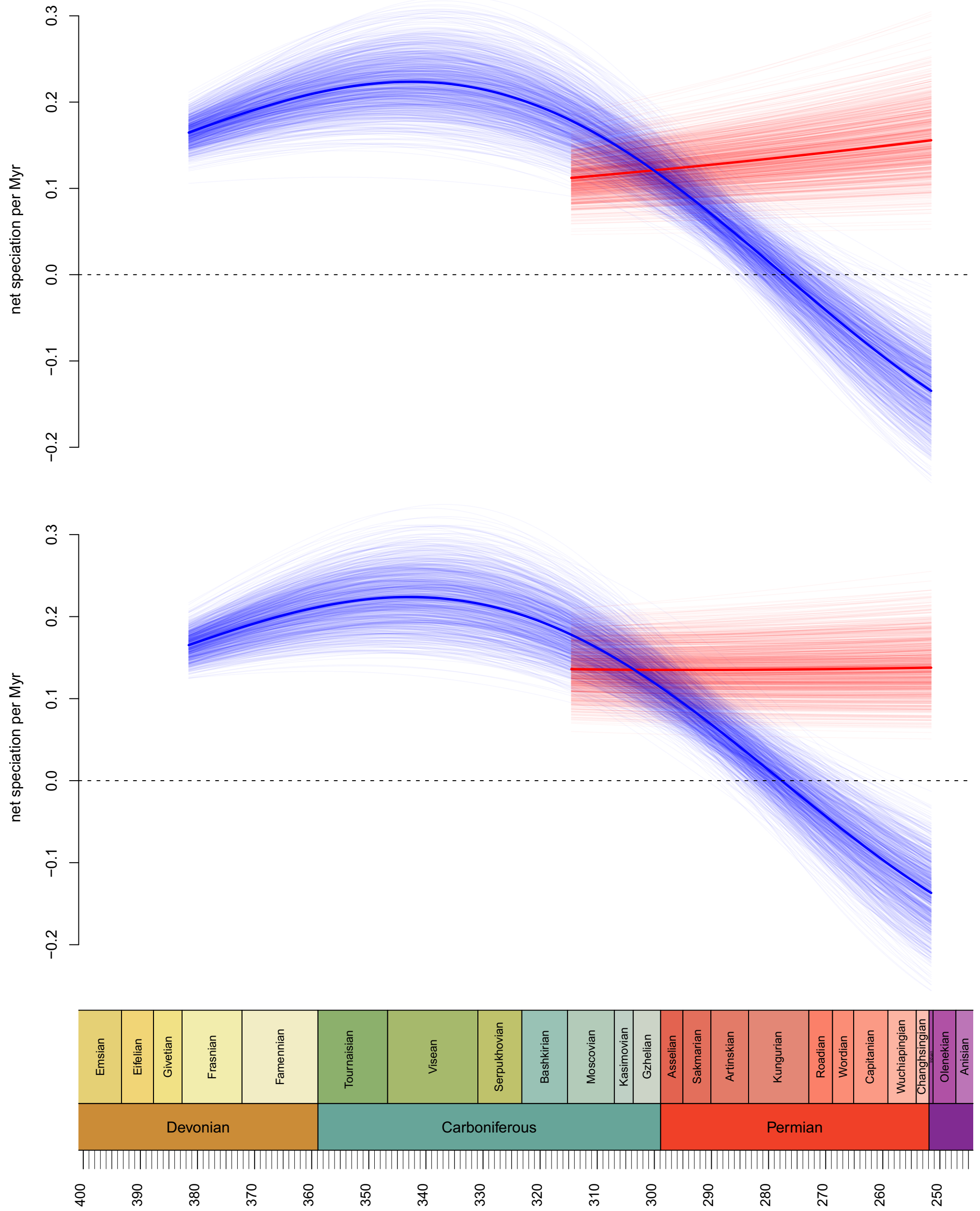

FIGURE 4.4. Net speciation per 1 Myr in Palaeozoic tetrapods (complex two-groups model) prior to the PTME based on a LAD time-scaled topology (‘traditional’ Amphibia & Archosauromorpha). Net speciation of ‘amphibians’ (blue; quadratic slowdown) and amniotes (red; top: linear model; bottom: square root model) is reported for the two best fit models. When net speciation falls below zero (dashed horizontal line), extinction rate exceeds speciation rate. Species counts increase for values above zero and decrease for values below zero. Note again the similarity of the linear and square root model for Amniota. Transparent and bold lines as in Figure 4.2.

2018) and methods that account for the resulting potential bias in the fossil record are heavily debated (Alroy, 2010a,c; Lloyd, 2012; Starrfelt and Liow, 2016; Sakamoto et al., 2017; Dunhill et al., 2018; Close et al., 2018). Generally, it is assumed that the increase in biodiversity towards present times is linked to an increase in preservation potential ("Pull of the Recent"; Raup, 1972; Raup, 1979). Nevertheless, here I have explicitly tested whether the speciation decline in 'amphibians' was a result of undersampling due to a decrease in preservation through time towards the PTME. None of the considered sampling bias proxies leads to a significant increase in model DIC scores. I therefore regard the recovered speciation dynamics as a genuine biological signal.

A significant decrease in rates of morphological character change in early tetrapods has been reported for the 'amphibian'-dominated Devonian-Carboniferous time interval (Ruta et al., 2006). A similar pattern was found in early tetrapods known from the end of the Carboniferous through the Permian but it is not completely clear whether this decrease was significant or not (Ruta et al., 2006). Net speciation increased in 'Amphibia' from the origin of tetrapods to the middle Visean and so appears to have been initially decoupled from the pattern recovered for morphological character change. The subsequent slowdown in speciation rates in 'amphibians', however, fits well with the decrease in rates of morphological character change. The uncertainty in regard to the end-Carboniferous-Permian pattern of morphological character change in Tetrapoda (Ruta et al., 2006) could potentially be connected to the complex speciation dynamics recovered herein. While net speciation was clearly declining at the end of the Carboniferous and throughout the Permian in 'Amphibia', it was increasing (linear model) or remained nearly unchanged in Amniota (square root model).

The recovered slowdown in speciation rates in 'amphibians' prior to the PTME provides further evidence for a long-term decline of 'Amphibia' prior to the mass extinction event, which had already been recognized in previous studies focused on simple standing diversity (Carroll, 2009; Sahney et al., 2010; Benton et al., 2013c). As a result of the 'Carboniferous rainforest collapse' (CRC) during the late Moscovian-Kasimovian several 'amphibian'-grade clades went extinct, amongst which the early diverging baphetids and colosteids, three 'lepospondyl' families, dendrerpetids (Temnospondyli), and the potential stem amniote families Gephyrostegidae, Anthracosauria, and Solenodonsauridae (Sahney et al., 2010). Temnospondyls did not experience a decrease in mean diversity during the late Carboniferous and early Permian (Ruta and Benton, 2008) despite the recovered slowdown in speciation rates for all 'amphibians'. Irrespective of whether the CRC was an actual sudden 'collapse' (Sahney et al., 2010) or rather a gradual transition from wetlands to drylands (Cleal et al., 2009; Dunne et al., 2018), the reign of 'amphibians' was over and amniotes took over as the dominant tetrapods during the Permian (Carroll, 1977, 2009; Sahney et al., 2010; Benton et al., 2013c; Dunne et al., 2018). Latest Carboniferous and early Permian terrestrial ecosystems were characterised by 'pelycosaurian'-grade synapsids (Benson, 2012; Brocklehurst et al., 2013b). There is a nearly perfect temporal fit for the replacement pattern of ‘amphibians’ by amniotes in my recovered speciation dynamics. At the end of the Carboniferous the net speciation of amniotes started to exceed that of ‘amphibians’. This difference grew even larger during the Permian showing that amniotes were not only starting to overtake anamniotes in diversity and ecological niche occupation (Sahney et al., 2010; Benton et al., 2013c) but also in their capacity to replace extinct species with new ones. Most interestingly, smaller extinction events prior to the PTME such as Olson’s extinction, with its transition from early Permian ‘pelycosaur’-dominated faunas to middle Permian faunas dominated by therapsids and parareptiles (Sahney and Benton, 2008; Brocklehurst et al., 2017; Brocklehurst, 2018), and the Capitanian (‘end-Guadalupian’) mass extinction event, which removed nearly all of Dinocephalia, (Day et al., 2015a, 2018b) were too small to have a major effect on the diversification capacity of amniotes as a whole. Note, however, that Olson’s extinction, which also saw a marked decrease in amphibian richness (Brocklehurst et al., 2017), probably contributed to the negative net speciation of ‘Amphibia’ observed in the middle and late Permian. Indeed, this time period had previously been recognized to exhibit a significant lower (phylogenetic) diversity of temnospondyls than the Carboniferous and the early Permian (Ruta and Benton, 2008). Furthermore, while not affecting net speciation, Olson’s extinction has been linked to a diversification shift (expressed as change in tree balance) on the earliest therapsid node (Brocklehurst et al., 2015) indicating its importance on a smaller scale of amniote evolution. Although the rise of amniotes temporally matches the decline of ‘amphibians’, the recovered speciation dynamics do not necessarily imply a competitive replacement scenario. Previous studies (Benton, 1996a,b) have indicated that the occupied niches of early amniotes and early ‘amphibians’ were generally quite different, making competition as an explanation for the observed pattern unlikely.

My results emphasize again the exceptional nature of the PTME (Benton et al., 2004) for amniote evolution. Speciation dynamics indicate that the late Palaeozoic terrestrial fauna dominated by therapsids and parareptiles (Benton et al., 2004; Roopnarine and Angielczyk, 2015b; Sookias et al., 2012b) would have persisted and continued to diversify into the Mesozoic if there had been no PTME. Unlike ‘Amphibia’, amniotes had not yet reached their prime in net speciation prior to the PTME. It was Earth’s most severe mass extinction event (Benton and Twitchett, 2003; Benton et al., 2004), during which 89% of all tetrapod genera were lost (Benton et al., 2013c), that allowed a complete restructuring of ecosystems and the rise of archosaurs as the dominant members of Mesozoic ecosystems (Sahney and Benton, 2008; Sookias et al., 2012b; Ezcurra and Butler, 2018). Unlike dinosaurs (Sakamoto et al., 2016), amniotes were not weakened in their diversification capacity prior to the PTME.

Geographic barriers are known to shape speciation dynamics (Moen and Morlon, 2014; Sakamoto et al., 2016). Recently, increases in vicariance and decreases in dispersal rates of early tetrapods after the CRC and at the end of the Guadalupian have been reported (Brocklehurst et al., 2018). Sahney et al. (2010) argued that increased endemism shaped tetrapod evolution in the aftermath of the CRC, while Dunne et al. (2018) argued for the opposite, i. e. increased cosmopolitanism. Future studies should attempt to test the influence of biogeography on speciation dynamics in Palaeozoic tetrapods.

4.6 Supplementary Information

TABLE 4.2. DIC model comparison of all models for 'traditional' Amphibia & Ornithoscelida topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations as in Table 4.1.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5442.2	0.0	5475.1	0.0	5465.8	0.0
Tetrapoda quadratic	5432.8	-9.4	5459.5	-15.6	5452.8	-13.0
Tetrapoda square root	5438.0	-4.2	5460.8	-14.2	5453.9	-11.8
2-Group linear	5446.5	0.0	5477.7	0.0	5471.0	0.0
2-Group quadratic	5426.1	-20.5	5446.5	-31.2	5443.1	-27.9
2-Group square root	5438.8	-7.8	5461.5	-16.2	5454.9	-16.0
2-Group lin.+quad.	5417.4	0.0	5444.3	0.0	5440.0	0.0
2-Group sqrt+quad.	5417.8	0.4	5443.7	-0.6	5441.6	1.6
2-Group lin.+quad. + Full	5422.1	4.7	5449.3	5.0	5447.4	7.5
2-Group sqrt+quad. + Full	5422.6	5.1	5448.9	4.5	5445.9	5.9
2-Group lin.+quad. + S	5418.2	0.8	5445.0	0.7	5441.9	2.0
2-Group lin.+quad. + P	5419.0	1.6	5446.1	1.8	5441.4	1.4
2-Group lin.+quad. + M	5418.5	1.1	5445.0	0.7	5441.2	1.3
2-Group sqrt+quad. + S	5418.8	1.4	5446.6	2.3	5442.1	2.2
2-Group sqrt+quad. + P	5418.7	1.2	5447.8	3.4	5442.4	2.5
2-Group sqrt+quad. + M	5419.7	2.2	5446.7	2.4	5442.6	2.7
2-Group lin.+quad. + S + P	5421.0	3.6	5446.8	2.4	5444.6	4.6
2-Group lin.+quad. + S + M	5420.0	2.6	5446.1	1.8	5443.7	3.7
2-Group lin.+quad. + P + M	5421.4	3.9	5448.1	3.7	5444.0	4.1
2-Group sqrt+quad. + S + P	5420.4	3.0	5448.2	3.9	5444.9	4.9
2-Group sqrt+quad. + S + M	5421.1	3.7	5446.7	2.4	5444.5	4.6
2-Group sqrt+quad. + P + M	5420.4	3.0	5449.6	5.3	5444.1	4.2

TABLE 4.3. DIC model comparison of all models for polyphyletic 'Lepospondyli' and 'traditional' Archosauromorpha topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations as in Table 4.1.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5457.8	0.0	5425.5	0.0	5438.6	0.0
Tetrapoda quadratic	5446.3	-11.4	5413.6	-11.9	5428.7	-9.9
Tetrapoda square root	5444.5	-13.3	5415.9	-9.5	5425.1	-13.5
2-Group linear	5457.1	0.0	5424.6	0.0	5438.6	0.0
2-Group quadratic	5432.7	-24.5	5398.8	-25.8	5410.4	-28.2
2-Group square root	5442.5	-14.6	5412.7	-11.9	5425.4	-13.2
2-Group lin.+quad.	5430.3	0.0	5395.7	0.0	5407.8	0.0
2-Group sqrt+quad.	5431.2	0.8	5397.8	2.1	5408.8	1.0
2-Group lin.+quad. + Full	5436.3	6.0	5400.8	5.1	5415.2	7.4
2-Group sqrt+quad. + Full	5437.4	7.1	5403.4	7.7	5413.7	5.9
2-Group lin.+quad. + S	5433.1	2.7	5398.9	3.2	5410.8	3.0
2-Group lin.+quad. + P	5433.4	3.0	5397.6	1.9	5411.7	3.9
2-Group lin.+quad. + M	5433.6	3.2	5397.3	1.5	5408.7	0.9
2-Group sqrt+quad. + S	5432.9	2.6	5398.1	2.4	5411.8	4.0
2-Group sqrt+quad. + P	5433.7	3.4	5398.6	2.9	5411.2	3.4
2-Group sqrt+quad. + M	5433.2	2.9	5399.1	3.3	5411.9	4.1
2-Group lin.+quad. + S + P	5434.2	3.9	5400.0	4.3	5411.8	4.0
2-Group lin.+quad. + S + M	5434.2	3.9	5400.8	5.1	5411.0	3.2
2-Group lin.+quad. + P + M	5433.2	2.8	5399.9	4.2	5412.8	4.9
2-Group sqrt+quad. + S + P	5435.2	4.9	5401.2	5.5	5412.3	4.5
2-Group sqrt+quad. + S + M	5434.6	4.3	5401.3	5.6	5414.6	6.8
2-Group sqrt+quad. + P + M	5435.1	4.8	5402.2	6.5	5412.7	4.9

Table 4.4. DIC model comparison of all models for polyphyletic 'Lepospondyli' and Ornithoscelida topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations as in Table 4.1.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5381.8	0.0	5438.0	0.0	5414.5	0.0
Tetrapoda quadratic	5369.1	-12.6	5424.2	-13.8	5400.1	-14.4
Tetrapoda square root	5368.7	-13.1	5421.9	-16.1	5400.2	-14.3
2-Group linear	5381.0	0.0	5434.9	0.0	5410.2	0.0
2-Group quadratic	5359.1	-21.9	5408.2	-26.7	5384.8	-25.4
2-Group square root	5370.3	-10.7	5419.3	-15.6	5397.5	-12.7
2-Group lin.+quad.	5357.6	0.0	5405.6	0.0	5383.5	0.0
2-Group sqrt+quad.	5359.6	2.0	5406.6	1.0	5385.4	1.8
2-Group lin.+quad. + Full	5365.1	7.5	5412.5	6.9	5388.4	4.8
2-Group sqrt+quad. + Full	5364.3	6.7	5412.7	7.1	5389.1	5.5
2-Group lin.+quad. + S	5360.5	2.8	5407.4	1.8	5384.2	0.7
2-Group lin.+quad. + P	5361.6	4.0	5407.0	1.5	5385.5	2.0
2-Group lin.+quad. + M	5361.1	3.5	5408.8	3.3	5386.2	2.7
2-Group sqrt+quad. + S	5362.5	4.9	5409.0	3.4	5386.5	3.0
2-Group sqrt+quad. + P	5361.3	3.7	5408.1	2.5	5386.6	3.0
2-Group sqrt+quad. + M	5360.7	3.1	5408.4	2.8	5385.6	2.1
2-Group lin.+quad. + S + P	5361.3	3.7	5409.2	3.7	5387.0	3.4
2-Group lin.+quad. + S + M	5361.6	4.0	5410.4	4.9	5388.6	5.0
2-Group lin.+quad. + P + M	5362.8	5.1	5410.4	4.9	5386.9	3.4
2-Group sqrt+quad. + S + P	5361.8	4.2	5411.3	5.7	5390.3	6.7
2-Group sqrt+quad. + S + M	5361.4	3.7	5410.5	5.0	5386.6	3.1
2-Group sqrt+quad. + P + M	5362.8	5.1	5411.1	5.5	5388.8	5.3

TABLE 4.5. DIC model comparison of all models for Lissamphibia LH and 'traditional' Archosauromorpha topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations as in Table 4.1.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5413.0	0.0	5417.5	0.0	5409.1	0.0
Tetrapoda quadratic	5401.5	-11.6	5406.5	-11.1	5398.4	-10.7
Tetrapoda square root	5400.0	-13.0	5406.0	-11.5	5396.6	-12.6
2-Group linear	5414.0	0.0	5418.8	0.0	5411.6	0.0
2-Group quadratic	5395.8	-18.2	5394.9	-24.0	5390.0	-21.5
2-Group square root	5401.7	-12.3	5406.7	-12.1	5398.2	-13.3
2-Group lin.+quad.	5391.9	0.0	5392.1	0.0	5388.0	0.0
2-Group sqrt+quad.	5392.1	0.2	5392.1	0.0	5388.4	0.4
2-Group lin.+quad. + Full	5395.3	3.5	5397.9	5.8	5392.0	4.0
2-Group sqrt+quad. + Full	5396.9	5.0	5396.4	4.3	5393.2	5.2
2-Group lin.+quad. + S	5391.9	0.0	5393.4	1.3	5387.9	-0.1
2-Group lin.+quad. + P	5392.5	0.6	5393.5	1.3	5388.8	0.8
2-Group lin.+quad. + M	5392.8	0.9	5393.8	1.6	5388.7	0.7
2-Group sqrt+quad. + S	5393.9	2.1	5393.6	1.5	5389.4	1.4
2-Group sqrt+quad. + P	5394.4	2.5	5392.5	0.4	5390.4	2.4
2-Group sqrt+quad. + M	5394.8	3.0	5394.0	1.9	5390.4	2.5
2-Group lin.+quad. + S + P	5393.4	1.6	5395.7	3.6	5389.9	1.9
2-Group lin.+quad. + S + M	5393.6	1.7	5395.0	2.9	5390.1	2.1
2-Group lin.+quad. + P + M	5395.0	3.2	5395.7	3.6	5389.4	1.4
2-Group sqrt+quad. + S + P	5395.4	3.5	5395.5	3.4	5391.2	3.2
2-Group sqrt+quad. + S + M	5394.4	2.5	5395.4	3.2	5391.2	3.2
2-Group sqrt+quad. + P + M	5395.4	3.5	5396.9	4.8	5390.7	2.7

TABLE 4.6. DIC model comparison of all models for Lissamphibia LH and Ornithoscelida topology (see Appendix A for details). Results are reported for the three different time-scaling approaches, i. e. LAD, FAD, and RAND (= time of observation sampled randomly between FAD and LAD). Three sets of models are compared. The Tetrapoda models estimate model parameters only for Tetrapoda as a whole. The two-group models estimate separate model parameters for 'amphibians' and amniotes. The two-group models are further divided into 'pure' (linear-only, quadratic-only, square root-only) and 'mixed' models (linear or square root model for Amniota + quadratic model for 'Amphibia'). The 'mixed' two-group models also contain models accounting for sampling bias. Δ DIC scores are reported relative to the null models reported in bold. Red DIC values indicate best (local) fit within one of the three sets of models, green DIC values indicate the absolute best model. Note that including sampling bias parameters does not significantly improve model fit. Abbreviations as in Table 4.1.

	FAD		LAD		RAND	
Model	DIC	Δ DIC	DIC	Δ DIC	DIC	Δ DIC
Tetrapoda linear	5393.4	0.0	5420.1	0.0	5419.9	0.0
Tetrapoda quadratic	5384.6	-8.8	5409.9	-10.2	5412.1	-7.8
Tetrapoda square root	5380.3	-13.1	5410.4	-9.7	5409.6	-10.3
2-Group linear	5397.1	0.0	5422.7	0.0	5422.9	0.0
2-Group quadratic	5377.1	-20.0	5401.1	-21.6	5402.5	-20.4
2-Group square root	5386.2	-10.8	5411.6	-11.1	5410.1	-12.8
2-Group lin.+quad.	5373.2	0.0	5397.6	0.0	5399.8	0.0
2-Group sqrt+quad.	5372.9	-0.3	5398.9	1.3	5399.8	0.0
2-Group lin.+quad. + Full	5379.9	6.7	5401.3	3.7	5404.7	4.9
2-Group sqrt+quad. + Full	5381.1	7.8	5400.2	2.6	5403.3	3.5
2-Group lin.+quad. + S	5375.9	2.7	5397.8	0.2	5401.1	1.2
2-Group lin.+quad. + P	5375.5	2.3	5397.5	-0.1	5401.3	1.5
2-Group lin.+quad. + M	5376.1	2.9	5397.5	-0.1	5402.0	2.2
2-Group sqrt+quad. + S	5374.9	1.7	5398.2	0.5	5402.0	2.2
2-Group sqrt+quad. + P	5376.3	3.1	5397.9	0.3	5400.7	0.9
2-Group sqrt+quad. + M	5377.7	4.4	5398.7	1.1	5401.3	1.5
2-Group lin.+quad. + S + P	5375.7	2.5	5398.9	1.3	5402.3	2.4
2-Group lin.+quad. + S + M	5379.2	6.0	5400.9	3.3	5401.4	1.6
2-Group lin.+quad. + P + M	5376.7	3.4	5399.8	2.2	5402.4	2.6
2-Group sqrt+quad. + S + P	5377.2	4.0	5400.2	2.6	5401.5	1.7
2-Group sqrt+quad. + S + M	5378.7	5.5	5399.2	1.6	5402.4	2.6
2-Group sqrt+quad. + P + M	5377.8	4.6	5401.9	4.3	5402.8	2.9

CHAPTER 5

CONCLUSIONS

The eventful evolutionary history of early tetrapods provides us with an exceptional opportunity to test macroevolutionary hypotheses. This has been realised in the past but previous studies often suffered from poor stratigraphic resolution, inappropriate methods, or the unavailability of data and phylogenies which often restricted the focus on smaller subclades (Sookias et al., 2012b; Huttenlocker, 2014; Brocklehurst, 2016; Brocklehurst and Brink, 2017). Palaeontologists and evolutionary biologists have only recently (e.g., Sakamoto et al., 2016; Cooney et al., 2017; Rabosky et al., 2018; Sallan et al., 2018) started to study evolution using phylogenetic comparative methods at a scale that truly compares to what Simpson (1944, p. 98) had termed "mega-evolution". Large-scale evolution can only be understood with large-scale data, which, so far, has not been available for early tetrapods. Here I have presented the largest, up-to-date species level database of early tetrapods which provides stratigraphic ranges at substage level for all valid early tetrapod species. This database is coupled with several supertrees (representing different phylogenetic hypotheses) to allow accounting for the effect of shared ancestry in phylogenetic comparative analyses.

In chapter 2 I have shown that rates of body size evolution were heterogeneous in terrestrial early tetrapods and that the rate pattern of several clades (e.g., various clades of Temnospondyli, Anthracosauria, Archosauromorpha, Anomodontia, Pareiasauria) followed the Simpsonian concept of quantum evolution (Simpson, 1953): quick bursts in the rate of evolution followed by a nearly instantaneous return to baseline rates. These lineages had entered a new adaptive zone (Simpson, 1953). Other bursts of evolution were associated with quick diversifications over short time periods such as the DDE in the aftermath of the CPE (Bernardi et al., 2018a) or mass extinction events (end-Guadalupian mass extinction; PTME). Note, that the burst of evolution after the CPE in the middle Carnian could only be detected due to the high stratigraphic resolution of the dataset. Most importantly, high rates of body size evolution were not found to be tied to the most successful clades. More successful clades such as Archosauromorpha or Dinosauria were generally more likely to exhibit lower rates than their less successful counterparts such as Therapsida, Parareptilia, Temnospondyli, or Pseudosuchia, respectively. This results goes against the traditional narrative of high evolutionary rates as an indicator of 'evolvability' and potential driver of success (Rabosky et al., 2013; Benson et al., 2014b; Lee et al., 2014; Wang and Lloyd, 2016; Fischer et al., 2016; Cooney et al., 2017).

For chapter 3 I tested the hypothesis that strong selection for novel feeding adaptations had ultimately contributed to the success of early archosauromorphs and early dinosaurs (Charig, 1980; Zawiskie, 1986). Simple functional measurements of the early archosauromorph lower jaw, known to be related to the biomechanical feeding properties of mandibles, were analysed in a multivariate Bayesian framework. While I recovered again clear support for heterogeneous evolutionary rates of the mandibular functional complex, I found no support for positive phenotypic selection acting on the early archosauromorph mandible (except for one taxon). This result is consistent with a non-competitive replacement scenario in the aftermath of the PTME, where archosauromorphs (and ultimately dinosaurs) had the chance to invade the now vacant ecological niches.

In chapter 4 I analysed the speciation dynamics of early tetrapods prior to the PTME testing whether their capacity of diversification had weakened prior to the mass extinction event. Tetrapoda as a whole was already declining prior to the PTME, but the pattern was complex. Anamniote 'amphibians' experienced a slowdown in speciation rates tens of millions of years prior to the PTME. Amniotes, on the other hand, were thriving up to end of the Changhsingian and never showed negative net speciation (= extinction rate surpasses speciation rate) prior to the PTME. These results cannot be explained with sampling bias and represent a genuine biological signal. Mesozoic terrestrial ecosystems can therefore be seen as a direct result of the PTME. Without the mass extinction event, faunas dominated by Palaeozoic amniotes would have continued to persist.

The results of all chapters emphasize the pervasiveness of heterogeneous evolutionary rates in early tetrapods, be it rates of body size evolution, rates of mandibular functional disparity, or rates of speciation and extinction. Studies ignoring the potential non-homogeneity of rates in early tetrapods should therefore be viewed with caution. Similarly, thanks to the now available comprehensive supertree topologies for early tetrapods it will no longer be necessary to carry out large-scale analyses without phylogenetic input (Benton et al., 2013c; Sallan and Galimberti, 2015). For the first time it is now possible to account for the non-independence of species data due to shared ancestry (Felsenstein, 1985) in all early tetrapods that appeared between ~390 Ma to 174 Ma.

The analyses presented herein should only be seen as the tip of the iceberg of what can be achieved with the new database and the now available supertree topologies. Future studies could apply the dataset to test for the selectivity of mass extinctions within early tetrapods (Payne et al., 2016; Allen et al., 2019), construct food webs and analyse their changes across the first 200 million years of tetrapod evolution (Roopnarine and Angielczyk, 2015b), or apply network methods to analyse the importance of competition in the evolution of early tetrapods. The analysis of the prevalence of positive phenotypic selection should be further expanded to other clades of early tetrapods and other traits of interest (e.g., traits related to locomotion). The informal supertrees could be used as 'taxonomic source trees' for formal metatree approaches as described in Lloyd et al. (2016b), since they contain also taxa that have never been incorporated in a quantitative phylogenetic analysis. The potential influence of changing environmental parameters (e.g., Haq and Schutter, 2008; Veizer and Prokoph, 2015; Schachat et al., 2018; Krause et al., 2018) on evolutionary rates of early tetrapods could be analysed as well.

APPENDIX A

This appendix details the alpha taxonomic changes made to the early tetrapod database (ETD) of Benton et al. (2013c) and the construction of the early tetrapod supertree(s). The explicit documentation of alpha taxonomic changes eases the comparison between the original database (Benton et al., 2013a) and the new expanded one. Explicitly reporting the supertree construction allows to reproducibly generate the informal supertree(s) used in my analyses.

The original ETD (Benton et al., 2013a) was generated by scanning all relevant journals up to first two months of the year 2012 (Benton et al., 2013c). I updated the original database (Benton et al., 2013a) by scanning all relevant journals and using an exhaustive Google Scholar Search to find all appropriate articles published between the year 2012 (end of year 2011) and the 28th September 2018. Older literature was only considered when deemed necessary and when younger references were not available. The goal of these changes was to provide an alpha taxonomic framework of all early tetrapods that reflects the current consensus of the field. Based on the assumption that newly discovered specimens and newly available methods allow a better understanding of the alpha taxonomy, precedence was generally given to younger studies over older ones when dealing with diverging alpha taxonomic opinions. Additional expert opinion was also consulted when deemed necessary and added as 'pers. comm.'. Unless noted otherwise, changes in alpha taxonomy are herein only reported if non-trivial, i. e. synonymies and *nomina dubia* recognised in 2012 or afterwards are explicitly mentioned in the appendix but newly discovered species in the same time frame are not. If not stated otherwise, *nomina dubia* are excluded from the supertree(s) and from further analyses. Similarly, specimens that could not be determined down to species level are excluded from the database, unless noted otherwise. This also includes specimens that might be distinct but which have remained unnamed (e.g., Modesto and Botha-Brink, 2008; Ezcurra and Butler, 2015b). A missing species name is herein considered to reflect uncertainty, which is why respective specimens are not further considered in the ETD (see also Dunhill and Wills, 2015). Furthermore, by recording only specimens with valid species names, it is easier to revise the ETD in the future. Specimen numbers can easily change and often, especially in older publications, no species number is provided. Thus, taxon entries that are based on indeterminate material, are avoided. An exception are specimens that provide an exceptional extension of the stratigraphic and/or palaeobiogegraphic range of a taxon. If such specimens are recorded in the database, they are mentioned herein.

The articles used in updating and expanding the ETD were also used to extract the phylogenies necessary to construct the informal supertree(s). Graeme Lloyd's website `http://www.graemetlloyd.com/matr.html` was used to cross-check the literature references used to build the supertree(s) to avoid missing any relevant phylogenetic analysis. When selecting phylogenies for the supertree construction preference was given to recent analyses featuring taxon- and character-rich data matrices. Taxa, which have never been included in a phylogenetic analysis, were added based on alpha taxonomic opinion. Adding taxa based on taxonomies for subsequent phylogenetic comparative analyses is warranted if care is taken when placing the taxa (Soul and Friedman, 2015). When alpha taxonomy was vague and only allowed the assignment of taxa to a large clade, the taxa were added as the 'basalmost' (= 'earliest diverging') members of the clade in an unresolved polytomy. Such an approach is conservative in regards to divergence times.

Below I describe the supertree construction (**Phylogeny** section) for each early tetrapod clade and grade and explicitly report alpha taxonomic changes made to the original ETD (**Alpha taxonomy** section). I generated three different topologies for anamniote tetrapods ('traditional' Amphibia, 'polyphyletic 'Lepospondyli', and Lissamphibia 'lepospondyl' hypothesis (LH)) and two different topologies for archosauromorphs ('traditional' Archosauromorpha and Ornithoscelida hypothesis). The description of the alternative topologies is found at the end of the Appendix.

A.1 'Basal' Tetrapoda

Phylogeny: The Bayesian analysis tree of Clack et al. (2016, fig. 5c) is used to create the scaffold tree for 'basal' tetrapods.

Elginerpeton pancheni, *Elpistostege watsoni*, and *Densignathus rowei* are added according to the 50% majority rule consensus tree of Sookias et al. (2014a, fig. 5B), which is based on a modified character matrix of Clack et al. (2012).

Livoniana multidentata is added according to the 50% majority-rule consensus tree of Ahlberg et al. (2000, text-fig. 5). The corresponding polytomy is solved using the 50% majority-rule consensus tree of the supertree analysis I of Ruta et al. (2003a, fig. 2).

Obruchevichthys gracilis is added according to the 50% majority-rule consensus tree of Clack and Ahlberg (2004, fig. 3B), which is based on a modified character matrix of Ahlberg and Clack (1998) (see also Ruta and Coates, 2003, fig. 11.11).

Hynerpeton basseti is added according to the strict consensus tree of Ruta (2011, text-fig. 1C).

Tantallognathus woodi is added according to the 50% majority rule consensus tree of Chen et al. (2018, fig. 3B), which is based on a modified character matrix of Clack et al. (2012).

Pholidogaster pisciformis and *Deltaherpeton hiemstrae* are added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14), which is based on an expanded and modified character matrix of Ruta and Coates (2007).

The material assigned to the elginerpetid (= elginerpetontid; Clack and Milner, 2015, p. 13) *Webererpeton sondalensis* had previously been assigned to *Obruchevichthys gracilis* (Clément and Lebedev, 2014). *Webererpeton sondalensis* is therefore added as the sister taxon of *Obruchevichthys gracilis*.

Umzantsia amazana is added to a polytomy consisting of *Elpistostege watsoni* and the clade consisting of later diverging tetrapods taking into account its similarity to *Ventastega curonica* (Gess and Ahlberg, 2018) and its tentative phylogenetic position in the simplified phylogeny of Gess and Ahlberg (2018, fig. 4).

Sinostega pani shares a few characters with *Acanthostega gunnari* (Clack, 2012, p. 182), which it resembles more than *Metaxygnathus denticulus* (Zhu et al., 2002; Clack and Milner, 2015, p. 32). *Jakubsonia livnensis* is similar to *Ventastega curonica* (Lebedev, 2004; McGhee, 2013, p. 164–167). The two are added in a polytomy with *Densignathus rowei* following the proposed relationships in the cladogram of Benton (2015c, p. 89: Box 4.1).

Tutusius umlambo resembles *Jakubsonia* more than *Ichthyostega* and *Ventastega* (Gess and Ahlberg, 2018). It is added to a polytomy including the clade *Jakubsonia livnensis* + *Sinostega pani* + *Densignathus rowei* and the clade consisting of later diverging tetrapods according to the simplified phylogeny of Gess and Ahlberg (2018, fig. 4).

The skull proportions of *Ichthyostega watsoni* resemble those of *Ichthyostega stensioi* while the skull ornament density is low as in *Ichthyostega eigili* (Blom, 2005). *Ichthyostega watsoni* exhibits therefore an intermediate state between the two other species. The three species are also stratigraphically separated with *Ichthyostega stensioi* being the oldest and *Ichthyostega eigili* being the youngest species (Blom, 2005; McGhee, 2013, p. 170). The stratigraphic position of *Ichthyostega watsoni* is also intermediate between the two other species (Blom, 2005; McGhee, 2013, p. 170). *Ichthyostega watsoni* is therefore added as the sister taxon of *Ichthyostega eigili* and *Ichthyostega stensioi* acts as the sister taxon of the resulting clade.

The humerus of *Mesanerpeton woodi* is structurally intermediate between *Acanthostega* and tetrapods diverging in the later parts of the Carboniferous (Smithson and Clack, 2018). The neural arch described for *Mesanerpeton woodi* is most similar to *Crassigyrinus* and the appendicular skeleton of the species also shows affinities to *Doragnathus*, *Eoherpeton*, *Archeria*, and *Proterogyrinus* (Smithson and Clack, 2018). *Mesanerpeton woodi* is therefore added to a polytomy consisting of *Tantallognathus woodi*, the clade including *Crassigyrinus scoticus* and Colosteidae, and the clade consisting of later diverging tetrapods.

Clack and Milner (2015, p. 69, 70) report *Antlerpeton clarkii* among stem-Tetrapoda *incertae* *sedis*. According to McGhee (2013, p. 219, 220: Table 7.4) *Antlerpeton clarkii* belongs to "basal reptiliomorphs ("anthracosaurs")" (McGhee, 2013, p. 220), together with *Silvanerpeton miripedes*, *Eldeceeon rolfei*, *Eoherpeton watsoni*, *Doragnathus woodi*, *Pholidogaster pisciformis*, and *Westlothiana lizziae*. *Pholidogaster pisciformis* is clearly a colosteid (Panchen, 1975; Clack and Milner, 2015, p. 48) and is therefore not further considered in the placement of *Antlerpeton clarkii*. The composite cladogram of Clack and Milner (2015, fig. 1) hypothesizes the position of the taxon in a polytomy with *Kirktonecta milnerae*, *Casineria kiddi*, and *Westlothiana lizziae*. Following Clack and Milner (2015, fig. 1) *Antlerpeton clarkii* is added at the earliest diverging position to a polytomy including the clade *Casineria kiddi* + Seymouriamorpha and the clade consisting of later diverging tetrapods.

Clack and Milner (2015, p. 66) list *Eldeceeon rolfei* among stem-Tetrapoda *incertae sedis*. The species can clearly be distinguished from *Silvanerpeton miripedes* (Clack, 1994; Ruta and Clack, 2006; Clack, 2012, p. 309) but might represent its sister taxon (Clack, 2012, p. 309). *Eldeceeon rolfei* is therefore added as the sister taxon of *Silvanerpeton miripedes*.

Alpha taxonomy: The Russian material previously referred to *Obruchevichthys gracilis* is considered to be sufficiently different from the Latvian holotype to warrant the erection of a new taxon and is now assigned to *Webererpeton sondalensis* (Clément and Lebedev, 2014). *Obruchevichthys gracilis* and *Webererpeton sondalensis* are treated accordingly.

A nearly complete specimen of *Elpistostege watsoni* has been found in the Escuminac Formation (Cloutier and Béchard, 2013). The database entry for the taxon is updated accordingly.

Jakubsonia livnensis is a valid taxon (Clack and Milner, 2015, p. 32, 33) and is therefore added to the database.

Ossinodus pueri is a valid taxon (Clack and Milner, 2015, p. 41, 42) and is therefore added to the database.

The species name of *Ichthyostega stensioei* is corrected to *I. stensioi* following Snitting and Blom (2009).

Doragnathus woodi is a stem-tetrapod *incertae sedis* (Clack and Milner, 2015, p. 62) and is treated accordingly. The stratigraphic range of the taxon is updated according to Clack and Milner (2015, p. 62).

Antlerpeton clarkii is a valid taxon (Clack and Milner, 2015, p. 69, 70) and is therefore added to the database.

A.1.1 Baphetidae & Spathicephalidae

Phylogeny: Baphetidae and *Spathicephalus mirus* are added according to the the preferred topology of the most parsimonious trees recovered by Milner et al. (2009, fig. 6A).

Loxomma rankini belongs to Loxommatinae (Milner et al., 2009; Clack and Milner, 2015, p. 56–58) but its generic attribution is uncertain (Clack and Milner, 2015, p. 57). *Loxomma* *rankini* might occupy "a position at the base of the *Megalocephalus–Kyrinion* clade" (Milner et al., 2009, p. 329). *Loxomma rankini* is therefore added as the sister taxon of this clade (see also Ruta, 2009, text-fig. 1).

Baphetes planiceps might be the same species as *Baphetes kirkbyi* (Milner et al., 2009). It is therefore added as its sister taxon.

The three species of *Spathicephalus* are assumed to be closely related. A corresponding polytomy is created.

Alpha taxonomy: Milner et al. (2009) reassigned *Baphetes lintonensis* to *Loxomma* and this interpretation is also followed by Clack and Milner (2015, p. 56). The taxon is treated accordingly.

Loxomma rankini is treated as a valid taxon by Clack and Milner (2015, p. 56–58), but it is uncertain whether its generic attribution is correct (Clack and Milner, 2015, p. 57). Herein, *Loxomma rankini* is treated as a valid taxon and provisionally retained in the genus *Loxomma*. The taxon is added to the database.

Specimen NHMUK R.8465 from Ireland that previously had been assigned to *Megalocephalus pachycephalus* is now considered as belonging to *Ophiderpeton brownriggi* (Milner, 1994; Clack and Milner, 2015, p. 58). The two taxa are treated accordingly.

Baphetes orientalis is a valid taxon (Clack and Milner, 2015, p. 55, 56) and is therefore added to the database.

A.1.2 Embolomeri

Phylogeny: *Archeria crassidisca*, *Pholiderpeton attheyi*, *Anthracosaurus russelli*, *Palaeoherpeton decorum*, and *Neopteroplax conemaughensis* are added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14). Note, that both Ruta and Coates (2007, fig. 6) and Marjanović and Laurin (2019, fig. 14) do not recover *Pholiderpeton attheyi* as the sister taxon of *Pholiderpeton scutigerum*, which could therefore be referred again to the genus *Eogyrinus*.

Calligenethlon watsoni has been considered an eogyrinid (Panchen, 1970, p. 52, 53), potentially belonging to Eogyrininae (Panchen, 1977, p. 508, 509). Clack (1987a, p. 91) considered the relationships of the embolomere taxon at family level to be uncertain. Holmes and Carroll (2010) described a specimen (NSM 994 GF 1.1) from Joggins, which probably belongs to *Calligenethlon watsoni*. As none of the diagnostic characters of the taxon are preserved in the specimen, Holmes and Carroll (2010) refrained from definitely assigning it to *Calligenethlon watsoni*. Holmes and Carroll (2010, fig. 9) recovered the specimen as the sister taxon of *Anthracosaurus* and Marjanović and Laurin (2019, fig. 14) recovered it as sister taxon of the clade *Palaeoherpeton* + *Neopteroplax*. Stimson et al. (2012, Table 3) implicitly treat the specimen as belonging to *Calligenethlon watsoni*. Because *Calligenethlon watsoni* either includes the specimen described by Holmes and Carroll (2010) or is probably closely related to it, *Calligenethlon watsoni* is added as the sister taxon of the clade *Palaeoherpeton* + *Neopteroplax*, according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14).

The two species of *Proterogyrinus* are assumed to be sister taxa and are treated accordingly.

Pteroplax cornutus is added as the sister taxon of Archeriidae (= *Archeria crassidisca*) according to the cladogram of Clack (1987b, text-fig. 7).

Pholiderpeton bretonense, whose referral to the genus *Pholiderpeton* is uncertain (Panchen, 1970, p. 48–50), is assumed to be the sister taxon of *Pholiderpeton scutigerum* and is treated accordingly.

Eobaphetes kansensis is an eogyrinid (Panchen, 1977; Clack, 1987a) and potentially synonymous with *Leptophractus obsoletus* (Panchen, 1977). *Neopteroplax*, *Eobaphetes*, and *Leptophractus* form the subfamily Leptophractinae of Panchen (1977) (see also Witzmann et al., 2017). *Eobaphetes kansensis* is therefore added as the sister taxon of *Leptophractus obsoletus*, and the resulting clade is added as sister taxon of *Neopteroplax*. Note, however, that Clack (1987a, p. 90) does not consider Eogyrinidae to be separable into (mainly) European and American subfamilies.

The two species of *Neopteroplax* are assumed to be sister taxa and are treated accordingly.

Nummulosaurus kolbii might be a synonym of *Diplovertebron punctatum* (Panchen, 1970, p. 55, 56; Panchen, 1977, p. 508) and is therefore added as the sister taxon of *Diplovertebron punctatum*.

Panchen (1970, p. 53–55) considered *Diplovertebron punctatum* a potential eogyrinid, and according to Panchen (1977, p. 508) it might belong to the subfamily Eogyrininae (see also Witzmann et al., 2017; but see Clack, 1987a, p. 90). An assignment to Archeriidae or Anthracosauridae was considered unlikely (Panchen, 1970, p. 53). Awaiting further studies of the available material (see discussion of Klembara et al., 2014), the clade *Diplovertebron punctatum* + *Nummulosaurus kolbii* is herein treated as a member of Eogyrininae and is added as the sister taxon of *Pholiderpeton attheyi* (= *Eogyrinus attheyi*). Note, however, that unlike Panchen (1977, p. 508) *Palaeoherpeton decorum*, *Pholiderpeton scutigerum*, and *Pholiderpeton bretonense* are here not treated as members of Eogyrininae (see the placement of the taxa in Marjanović and Laurin (2019, fig. 14), Ruta and Coates (2007, fig. 6) and Buchwitz et al. (2012, fig. 5A)).

Panchen (1970, p. 60) assigned *Spondylerpeton spinatum* to Archeriidae, but considered it later on as a potential member of the eogyrinid Leptophractinae (Panchen, 1977, p. 509). In Carroll (1988, Appendix: p. 613) it is still treated as a member of Archeriidae. According to Milner (1982) the holotype is indeterminate at family level and the species can only be assigned to Embolomeri *incertae sedis* and it is treated as such also by Clack (1987a, p. 91). Godfrey (1997) notes a resemblance with *Archeria crassidisca*. Considering the uncertain placement of the taxon, it is herein added to a polytomy including the clade *Archeria crassidisca* + *Pteroplax cornutus* + *Pholiderpeton* and the clade including Eogyrininae and later diverging Embolomeri. This placement tries to account for both possible placements as either an archeriid or an eogyrinid as proposed by Panchen (1970, p. 60) and Panchen (1977, p. 509).

Klembara (1985) assigned *Carbonoherpeton carrolli* to Embolomeri with uncertain affinities at family level. Carroll (1988, Appendix: p. 613) considered *Carbonoherpeton carrolli* (misspelled as *Carbonerpeton*) as a member of Eogyrinidae. The traditional clade Eogyrinidae, which includes all Embolomeri except for *Proterogyrinus*, *Archeria*, and *Anthracosaurus* (Clack, 1987a; Marjanović and Laurin, 2019), is not recovered as monophyletic in Marjanović and Laurin (2019, fig. 14). *Carbonoherpeton carrolli* is herein added to a polytomy including Eogyrininae and the clade consisting of Leptophractinae and other later diverging Embolomeri.

Alpha taxonomy: *Eogyrinus attheyi* has been referred to the genus *Pholiderpeton* by Clack (1987a) and this referral has also been accepted by Ruta and Clack (2006), Ruta and Coates (2007) and Schoch et al. (2010). The taxon is therefore retained in the database as *Pholiderpeton attheyi*. Note, however, that Ruta and Coates (2007, fig. 6) and Marjanović and Laurin (2019, fig. 14) do not recover *Pholiderpeton attheyi* as the sister taxon of *Pholiderpeton scutigerum*.

The stratigraphic range of *Neopteroplax relictus* is updated using the referred specimens reported by Panchen (1970, p. 52).

Carbonoherpeton carrolli is treated as a valid taxon by Werneburg et al. (2007a), Marjanović (2010, p. 204) and Clack (2012, p. 351). It is therefore included in the database.

Ward et al. (2006, Supporting Appendix) mention *Archeria victori* (without citing Holmes, 1989), but it is a junior synonym of *Archeria crassidisca* (Holmes, 1989) and is treated accordingly in the database.

Ward et al. (2006, Supporting Appendix) also mention *Cricotus heteroclitus* and it is also listed by McGhee (2013, Table 7.6), although both do not cite Holmes (1989). *Cricotus heteroclitus* was treated as a valid member of Archeriidae by Panchen (1970, p. 58–60) and as a potential member of of Leptophractinae by Panchen (1977, p. 509), but it was also mentioned that the taxon had no associated diagnostic cranial material (Panchen, 1970, p. 56). Indeed, according to Holmes (1989) *Cricotus heteroclitus* is clearly a *nomen dubium* and '*Cricotus*' *crassidiscus* and *Cricotus hypantricus* are junior synonyms of *Archeria crassidisca*. De Buffrénil et al. (2016, Table 1) explicitly follow Holmes's (1989) suggestions and consider *Cricotus* a junior synonym of *Archeria*. This, however, goes beyond Holmes's (1989) assessment, as only some species, that previously had been assigned to *Cricotus*, were considered synonymous with *Archeria crassidisca* while *Cricotus heteroclitus* was considered a *nomen dubium*. Herein, Holmes (1989) is followed and *Cricotus heteroclitus* is treated as a *nomen dubium*.

Anthracosaurus lancifer (= *Rhizodus lancifer*) is mentioned by Ward et al. (2006, Supporting Appendix), Clack (2011a), McGhee (2013, Table 7.6) and Schoch and Milner (2014, p. 21) and was treated as a valid taxon by Panchen (1970, p. 45). It is, however, based on indeterminate material (Panchen, 1977; Beaumont, 1977; Hook and Baird, 1986). A large skull (AMNH 6830), that previously had been referred to the taxon is now considered to belong to *Leptophractus obsoletus* (Panchen, 1977; Holmes, 1984; Hook and Baird, 1986; Clack, 1987a; Holmes and Baird, 2011). *Anthracosaurus lancifer* is therefore excluded from the database.

A.1.3 Gephyrostegidae & Enosuchidae

Phylogeny: *Bruktererpeton fiebigi* is added according to the single most parsimonious tree of Klembara et al. (2014, fig. 8A), which is also used to add Seymouriamorpha (section A.12).

According to Carroll (1972, p. 13, 14) *Eusauropleura digitata* is a member of Gephyrostegidae but Klembara et al. (2014) questioned this assignment. Klembara et al. (2014) did not, however, provide an alternative assignment of the taxon, relegating further discussion to a separate paper. *Eusauropleura digitata* is therefore added in a polytomy with all other gephyrostegid taxa.

Golubev (1997b, p. 20, 21) assigned *Enosuchus breviceps* and *Nyctiboetus kassini* to the family Enosuchidae within the order Gephirostegida, and this interpretation has been followed by Ivakhnenko (2001, p. 64), Bulanov (2003, p. S3, S4; S91), Lozovsky (2005), and Ivakhnenko (2011, p. 996) (for *Enosuchus breviceps*). The clade consisting of *Enosuchus breviceps* and *Nyctiboetus kassini* is therefore added as the sister taxon of the clade Gephyrostegidae. Note, however, that the systematic position of these taxa is still uncertain (Novikov et al., 2000, p. 64; see also Bulanov, 2003, p. S10; S29).

Alpha taxonomy: Golubev (1997b, p. 21) moved *Nycteroleter kassini* to the genus *Nyctiboetus* (see also Tsuji et al., 2012, Table 1). Golubev (1997b, p. 21) furthermore synonymized *Nyctiboetus liteus* with *Nyctiboetus kassini* and referred the taxon to Anthracosauria (see also Tsuji et al., 2012). The taxa are treated accordingly.

Olroyd and Sidor (2017, Supplementary Information: Table 10) report *Nyctiboetus kassini* for the Golyusherma Subassemblage. The type specimens of both *Nyctiboetus kassini* and *Nyctiboetus liteus* are known from the Shikhovo-Chirki locality of the Kirov region (Chudinov, 1955; von Huene, 1956, p. 176; Olson, 1962, p. 21; Tatarinov, 1972, p. 73; Tverdokhlebova and Ivakhnenko, 1984, p. 96; Ivakhnenko, 1997b; Ivakhnenko et al., 1997, p. 79; Modesto and Rybczynski, 2000, p. 22; Novikov et al., 2000, p. 64; Ivakhnenko, 2001, p. 64; Bulanov, 2003, p. S91; Lozovsky, 2005) and do indeed belong to the Golyusherma Subassemblage (Ivakhnenko, 1995; Golubev, 1997a, p. 48, 49; Golubev, 2000, p. S217; Ivakhnenko, 2003, p. S433). Brocklehurst et al. (2017, Supplementary Data) report *Nyctiboetus* only for the Inta Assemblage, but not for the Golyusherma Subassemblage. Golubev (2000, p. S214), Golubev (2005), and Lucas (2017, p. 46) also report the taxon for the Inta Assemblage. This occurrence is probably based on the specimen PIN 1582/2 reported as *Nyctiboetus cf. kassini* from Pechora (Golubev, 1997a, p. 48; Ivakhnenko et al., 1997, p. 79; Lozovsky, 2005), which belongs to the Inta Assemblage (Golubev, 2000, p. S214). The database entry of *Nyctiboetus kassini* is modified accordingly. The occurrence from the Inta Assemblage is retained in the database within *Nyctiboetus kassini* due to its stratigraphic importance.

A.2 'Basal' Temnospondyli

Phylogeny: The scaffold tree for Temnospondyli is added according to the strict consensus tree of Strapasson et al. (2015, fig. 7), which is based on an expanded character matrix of the reduced analysis of Schoch (2013). The polytomy including Edopoidea, 'Dendrerpetidae' (= Dendrerpetontidae; Schoch and Milner, 2014, p. 24), and the clade Dvinosauria + Rhachitomi, and the polytomy including *Chenoprosopus milleri*, *Nigerpeton ricqlesi*, and *Cochleosaurus bohemicus* are resolved according to the preferred phylogeny of Schoch (2013, fig. 4, 5), which is based on the strict consensus tree recovered by Schoch (2013).

Eoscopus lockardi, *Chomatobatrachus halei*, and *Capetus palustris* are added according to the strict consensus tree of Dilkes (2015a, fig. 10), which is based on a modified and expanded character matrix of Schoch's (2013) full analysis.

Dendrerpeton confusum is added according to the strict consensus tree of Ruta (2009, text-fig. 1) (see also Ruta and Bolt, 2006, fig. 27). Note, however, that Schoch and Milner (2014, p. 25) considered it a species of *Dendrerpeton* and a potential synonym of *Dendrerpeton acadianum*.

Iberospondylus schultzei is added according to the consensus Bayesian tree of Pardo et al. (2017b, fig. 2C), which is also used to add Batrachia and a few stem-caecilians (section A.10).

Alpha taxonomy: *Dendrerpeton confusum* is a valid taxon (Schoch and Milner, 2014, p. 25) and is therefore added to the database.

Nannospondylus stewarti is listed in Olroyd and Sidor (2017, Supplementary Information: Table 16) and is mentioned in Lucas (2018), but it is a *nomen dubium* (Schoch and Milner, 2014, p. 112) and is treated accordingly in the database.

A.2.1 Edopoidea

Phylogeny: *Saharastega moradiensis* is added as the sister taxon of *Nigerpeton ricqlesi* according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14). Note, however, that the phylogenetic position of the taxon is uncertain (Ruta, 2009; Angielczyk and Ruta, 2012; Schoch and Milner, 2014, p. 111).

Procochleosaurus jarrowensis and *Cochleosaurus florensis* are added according to the strict consensus tree of Ruta (2009, text-fig. 1).

Alpha taxonomy: The stratigraphic range of *Edops craigi* is updated according to Schoch and Milner (2014, p. 18).

Chenoprosopus lewisi is a junior synonym of *Chenoprosopus milleri* (Schoch and Milner, 2014, p. 21) and is treated accordingly. The stratigraphic range of *Chenoprosopus milleri* is updated according to Schoch and Milner (2014, p. 21).

Saharastega moradiensis is a valid taxon (Schoch and Milner, 2014, p. 111; Marjanović and Laurin, 2019) and is therefore added to the database.

A.2.2 Dendrerpetidae

Phylogeny: *Dendrerpeton rugosum* is very similar to *Dendrerpeton acadianum* (Godfrey et al., 1987) and has been treated as the sister taxon *Dendrerpeton acadianum* in Laurin (2004, fig. 1). *Dendrerpeton rugosum* is therefore added as the sister taxon of the type species *Dendrerpeton acadianum*.

Dendrysekos helogenes is a dendrerpetid and includes material, that previously had been assigned to *Dendrerpeton acadianum* (Schoch and Milner, 2014, p. 25, 26). *Dendrysekos helogenes* is therefore added as the sister taxon of the clade *Dendrerpeton acadianum* + *Dendrerpeton rugosum*.

Alpha taxonomy: *Dendrysekos helogenes* is a valid taxon (Schoch and Milner, 2014, p. 26) and is therefore added to the database.

A.3 Dvinosauria

Phylogeny: Dvinosauria are added according to the strict consensus tree of Schoch (2018a, fig. 6), which is based on an expanded character matrix of Englehorn et al. (2008).

Procuhy nazariensis and *Timonya anneae* are added according to the single most parsimonious tree of Cisneros et al. (2015a, fig. 3b).

The relationships of *Dawsonerpeton polydens* within Dvinosauria are unclear (Schoch and Milner, 2014, p. 40). It might represent a trimerorhachid (Milner and Schoch, 2013), but similarities with Dvinosauridae have also been noted (Maňourová, 1992). *Dawsonerpeton polydens* is therefore added to a polytomy consisting of Trimerorhachidae and the clade which includes Dvinosauridae.

The different species of *Dvinosaurus* are herein assumed to be closely related. *Dvinosaurus campbelli* is most similar to *Dvinosaurus* and is substantially different from both *Dvinosaurus purlensis* and *Dvinosaurus egregius* (Gubin, 2004). *Dvinosaurus campbelli* is therefore added as the sister taxon of *Dvinosaurus primus*. *Dvinosaurus purlensis* and *Dvinosaurus egregius* are added to a polytomy including the clade *Dvinosaurus primus* + *Dvinosaurus campbelli*.

Alpha taxonomy: *Dawsonerpeton polydens* is a valid taxon (Schoch and Milner, 2014, p. 40) and is therefore added to the database.

Saurerpeton obtusum is a junior synonym of *Isodectes obtusus* (Schoch and Milner, 2014, p. 34, 35). The taxon is treated accordingly. The stratigraphic range of *Isodectes obtusus* is updated according to Schoch and Milner (2014, p. 35).

Dvinosaurus campbelli is a a valid taxon (Schoch and Milner, 2014, p. 36) and is therefore added to the database.

A.3.1 Trimerorhachidae

Phylogeny: *Trimerorhachis mesops* is added according to the strict consensus tree of McHugh (2012, fig. 4: left).

Trimerorhachis rogersi and *Lafonius lehmani* are added according to the proposed relationships of Trimerorhachidae in Milner and Schoch (2013, fig. 13B). This tree is also used better resolve the position of the taxon *Trimerorhachis mesops*.

Alpha taxonomy: *Lafonius lehmani* is a valid taxon (Schoch and Milner, 2014, p. 33) and is therefore added to the database.

Trimerorhachis medius and *Trimerorhachis alleni* are junior synonyms of *Trimerorhachis insignis* (Schoch and Milner, 2014, p. 30) and are treated accordingly. *Trimerorhachis insignis* is restricted to the Nocona and the Petrolia Formation (Schoch and Milner, 2014, p. 30, 31) and is treated accordingly.

Trimerorhachis mesops and *Trimerorhachis rogersi* are valid taxa (Schoch and Milner, 2014, p. 32) and are therefore added to the database.

A.3.2 Tupilakosauridae

Phylogeny: The strict consensus tree of Dias-da-Silva et al. (2012, fig. 6), according to which various chigutisaurid and brachyopid taxa have been placed (subsection A.9.1; subsection A.9.2), is also used to add *Batrachosuchoides lacer*, taking into account its assignment to Tupilakosauridae (Schoch and Milner, 2014, p. 39).

The specimen described as *Batrachosuchoides* sp. (Shishkin and Sulej, 2009) is assumed to be closely related to *Batrachosuchoides lacer* and is added as its sister taxon.

Kourerpeton bradyi is an early tupilakosaurid (Schoch and Milner, 2014, p. 39, 40), the most plesiomorphic member of the clade (Warren, 1999; Milner and Sequeira, 2004). It is therefore added as an early diverging member of Tupilakosauridae.

The tupilakosaurid reported from the La Lieude Formation of France is similar to *Tupilakosaurus* (Werneburg et al., 2007a). It is added to a polytomy including *Slaugenhopia texensis*, *Thabanchuia oomie*, and *Tupilakosaurus*.

Tupilakosaurus heilmani is assumed to be closely related to *Tupilakosaurus wetlugensis* and is added as its sister taxon.

Alpha taxonomy: *Batrachosuchoides* sp., described by Shishkin and Sulej (2009), is retained in the database due to its palaeobiogeographic importance.

The tupilakosaurid reported from the La Lieude Formation of France (Werneburg et al., 2007a) is retained in the database as “Tupilakosauridae_indet.” due to its palaeobiogeographic and stratigraphic importance.

Tupilakosaurus heilmani is a valid taxon (Schoch and Milner, 2014, p. 37) and is therefore retained in the database.

A.4 'Basal' Rhachitomi

Phylogeny: *Palatinerpeton kraetschmeri*, *Actinodon frossardi*, *Sclerocephalus bavaricus*, *Sclerocephalus jogischneideri*, *Sclerocephalus nobilis*, and *Sclerocephalus stambergi* are added according to the strict consensus tree of Klembara and Steyer (2012, fig. 5), which is based on an expanded character matrix of Schoch and Witzmann (2009a).

A.4.1 Zatracheidae

Phylogeny: *Dasyceps microphthalmus* is added according to the strict consensus tree of McHugh (2012, fig. 3: left). *Dasyceps bucklandi* is assumed to be the sister taxon of *Dasyceps microphthalmus* and is added accordingly (see also the cladogram of Boy (1989, fig. 6) and the informal supertree of Angielczyk and Ruta (2012, fig. 1)).

Alpha taxonomy: *Dasyceps microphthalmus* is a valid taxon (Schoch and Milner, 2014, p. 84) and is therefore added to the database. It is known from the Arroyo Formation (see Romer, 1928, p. 85; Kissel, 2010, p. 136).

The stratigraphic range of *Zatrachys serratus* is updated according to Schoch and Milner (2014, p. 85, 86).

A.4.2 Eryopidae

Phylogeny: *Glaukerpeton avinoffi*, which might be the most plesiomorphic member of Eryopinae (Schoch and Milner, 2014, p. 89), is added according to the single most parsimonious tree of Werneburg and Berman (2012, fig. 19).

Eryops grandis is added according to the strict consensus tree of McHugh (2012, fig. 3: left).

The specimen described as *Eryops* sp. nov. from the Moran Formation (Schoch and Milner, 2014, p. 90) is herein assumed to be closely related to the other species of *Eryops*. It is added to a corresponding polytomy.

Clamorosaurus is a member of Eryopinae (Schoch and Milner, 2014, p. 94) and has been recovered as the sister taxon of *Eryops* (Rasmussen et al., 2016). It is added accordingly. The two species of *Clamorosaurus* are assumed to be sister taxa and are treated accordingly.

Osteophorus roemeri is a member of Eryopinae (Schoch and Milner, 2014, p. 93, 94) which is similar to *Onchiodon* (Werneburg, 1989; Werneburg and Steyer, 1999; Schoch, 2013). *Osteophorus roemeri* is therefore added as the sister taxon of *Onchiodon*.

All species of *Onchiodon* are herein assumed to be closely related. Werneburg (2007) restricted the species of *Onchiodon* to *O. labyrinthicus* and *O. thuringiensis*. *Onchiodon thuringiensis* is therefore added as the sister taxon of *Onchiodon labyrinthicus* (see also Angielczyk and Ruta (2012, fig. 1)). *Onchiodon langenhani* is similar to *Onchiodon manebachensis* (Werneburg, 1996). *Onchiodon langenhani* is therefore added as the sister taxon of *Onchiodon manebachensis*. *Onchiodon credneri* is added to a polytomy including the clade *Onchiodon langenhani* + *Onchiodon manebachensis* and the clade *Onchiodon thuringiensis* + *Onchiodon labyrinthicus*.

Alpha taxonomy: *Eryops grandis* is a valid taxon (Schoch and Milner, 2014, p. 90) and is treated accordingly. The stratigraphic range of *Eryops megacephalus* is updated according to Schoch and Milner (2014, p. 89). The specimen described as *Eryops* sp. nov. from the Moran Formation (Schoch and Milner, 2014, p. 90) is added to the database and treated as a separate species of the genus.

Onchiodon frossardi (= *Sclerocephalus frossardi*) has been reassigned to the genus *Actinodon* (Schoch and Milner, 2014, p. 88) and is treated accordingly.

The stratigraphic range of *Onchiodon labyrinthicus* is updated according to Schoch and Milner (2014, p. 91–93).

Onchiodon langenhani, *Onchiodon manebachensis*, and *Onchiodon thuringiensis* are valid species (Schoch and Milner, 2014, p. 93) and are therefore added to the database.

Sclerocephalus credneri has been reassigned to the genus *Onchiodon* (Schoch and Milner, 2014, p. 93) and is treated accordingly.

Glaukerpeton avinoffi is a valid taxon (Werneburg and Berman, 2012; Schoch and Milner, 2014, p. 91) and is therefore added to the database.

Osteophorus roemeri is a valid taxon (Schoch and Milner, 2014, p. 93, 94) and is therefore added to the database.

A.5 Dissorophoidea

Phylogeny: *Macrerpeton huxleyi* is an indeterminate dissorophoid, not an indeterminate dissorophid (Schoch and Milner, 2014, p. 81, 82; Clack and Milner, 2015, p. 93) and is therefore added as an early diverging member of Dissorophoidea.

Stegops newberryi is a dissorophoid, not an indeterminate dissorophid (Schoch and Milner, 2014, p. 82; Clack and Milner, 2015, p. 93). The informal supertree of Angielczyk and Ruta (2012, fig. 1) recovers *Stegops divaricata* (a junior synonym of *Stegops newberryi*; Schoch and Milner, 2014, p. 82) in a polytomy as an early diverging member of Dissorophoidea (but see the formal supertree of Ruta et al., 2007, fig. 1) which agrees with the analyses of Milner and Schoch (2006). The taxon is added accordingly.

Alpha taxonomy: *Macrerpeton huxleyi* is mentioned among Dissorophoidea *incertae sedis* (not Dissorophidae *incertae sedis*; see Clack and Milner, 2015, p. 93) and is treated as a valid taxon (Schoch and Milner, 2014, p. 81, 82). It is therefore added to the database.

Arkanserpeton arcuatum is a *nomen dubium* according to Schoch and Milner (2014, p. 111) and is treated accordingly.

A.5.1 Olsoniformes

Phylogeny: Olsoniformes is added according to the 50% majority rule consensus tree of Maddin et al. (2013, fig. 6D), which is based on an expanded character matrix of Schoch (2012).

Mordex laticeps is an early diverging trematopid (Milner, 2007; Schoch and Milner, 2014, p. 64, 65) and is added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14).

Actiobates peabodyi and *Acheloma dunni* are added according to the strict consensus tree of Fröbisch and Reisz (2012), which is based on an expanded and modified character matrix of Polley and Reisz (2011).

Rotaryus gothae is added according to the strict consensus tree of Berman et al. (2011, fig. 6), which is based on an expanded character matrix of Berman et al. (2010).

Cacops woehri and the species of *Broiliellus* are added according to the 50% majority rule consensus tree of Holmes et al. (2013, fig. 12: left), which is based on an expanded and modified character matrix of Schoch (2012) (see also Schoch and Sues, 2013, fig. 4).

Phonerpeton whitei is assumed to be closely related to *Phonerpeton pricei* and is therefore added as its sister taxon.

Astreptorhachis ohioensis is very similar to *Platyhystrix rugosus* (Vaughn, 1971; Berman et al., 1981, 2010) and both belong to the clade Platyhistricinae (Schoch and Milner, 2014, p. 79, 80). *Astreptorhachis ohioensis* is therefore added as the sister taxon of *Platyhystrix rugosus*.

Aspidosaurus chiton is very similar to *Aspidosaurus binasser* (Berman and Lucas, 2003). *Aspidosaurus chiton* is therefore added as the sister taxon of *Aspidosaurus binasser*.

Dilkes (2015b) recovered *Dissorophus angustus* in a polytomy with *Dissorophus multicinctus* and four species of *Broiliellus*. The taxon is added accordingly.

Broiliellus arroyoensis is very similar to *Broiliellus texensis* (DeMar, 1967). *Broiliellus arroyoensis* is added as the sister taxon of *Broiliellus texensis* in accordance with the phylogenetic hypothesis of DeMar (1968, text-fig. 18).

Fayella chickashaensis is a dissorophid (Schoch and Milner, 2014, p. 80) whose armor is similar to that of *Cacops* (Olson, 1972b). It is therefore added to a polytomy including the other species of *Cacops* and the clade *Kamacops acervalis* + *Zygosaurus lucius*.

Previous phylogenetic analyses recovered *Parioxys ferricolus* as a member of Eryopoidea (e.g., Holmes et al., 1998, fig. 11; Laurin and Soler-Gijón, 2006, fig. 12; Damiani et al., 2006, fig. 5; McHugh, 2012, fig. 3), but this is probably due to artificial modifications to the respective specimens and the material actually belongs to Eucacopinae and shows several similarities to *Cacops* (Schoch and Milner, 2014, p. 77). *Parioxys ferricolus* is therefore added in a polytomy with the species of *Cacops* and other cacopine species.

Parioxys bolli is assumed to be sister taxon of *Parioxys ferricolus* and is added accordingly.

Anakamacops petrolicus is an eucacopine that is similar to *Kamacops acervalis* (Schoch and Milner, 2014, p. 76). It is therefore added to a polytomy including *Kamacops acervalis* and *Zygosaurus lucius*.

Iratusaurus vorax is a dissorophid (Schoch and Milner, 2014, p. 80) that is more similar to *Kamacops acervalis* than to *Zygosaurus lucius* (Gubin, 1980). The relationships with *Anakamacops petrolicus* are unclear (Li and Cheng, 1999). *Iratusaurus vorax* is therefore added to a polytomy including *Kamacops acervalis*, *Zygosaurus lucius*, and *Anakamacops petrolicus*.

Alpha taxonomy: *Rotaryus gothae* is a valid taxon (Schoch and Milner, 2014, p. 68) and it is therefore added to the database.

Trematops willistoni and *Trematops stonei* are junior synonyms of *Acheloma cumminsi* (Schoch and Milner, 2014, p. 66) and are treated accordingly.

Phonerpeton whitei is a valid taxon (Schoch and Milner, 2014, p. 68) and is therefore added to the database. Dilkes (1990) reports *Phonerpeton pricei* for the Archer City Formation, the Nocona and the Petrolia Formation. According to Schoch and Milner (2014, p. 67), the species is restricted to the Archer City Formation. The specimens from the Petrolia Formation have been assigned to *Phonerpeton whitei* (Schoch and Milner, 2014, p. 68) and the specimen from the Nocona Formation has been assigned to *Anconastes* sp. (Schoch and Milner, 2014, p. 67). The stratigraphic range of *Phonerpeton pricei* is updated accordingly.

Cacops morrisi is a valid species (Schoch and Milner, 2014, p. 74) and is therefore added to the database.

Conjunctio multidens is only known from the Abo Formation (Schoch and Milner, 2014, p. 76) and the stratigraphic range of the taxon is updated accordingly. A specimen initially assigned to *Conjunctio* sp. (Carroll, 1964a, p. 220–223) is now regarded the holotype of *Scapanops neglectus* (Schoch and Sues, 2013; Schoch and Milner, 2014, p. 77, 78). It is treated accordingly.

Schoch and Milner (2014, p. 70) assigned *Dissorophus angustus* to *Broiliellus brevis*, but it appears to be a distinct taxon that does not belong to either of the genera *Dissorophus* and *Broiliellus* (Dilkes, 2015b). Herein, the species is retained as ‘*Dissorophus*’ *angustus*.

Broiliellus olsoni is a valid taxon (Schoch and Milner, 2014, p. 72) and is therefore added to the database.

Parioxys bolli (Schoch and Milner, 2014, p. 77) is a valid species and is therefore added to the database.

The stratigraphic range of *Parioxys ferricolus* is updated according to Schoch and Milner (2014, p. 77).

Alegeinosaurus is a junior synonym of *Aspidosaurus* and Gee (2018) treats *Alegeinosaurus aphthitos* as *Aspidosaurus* sp. The taxon is treated accordingly in the database.

Schoch and Milner (2014, p. 78) treat *Aspidosaurus glascocki* as a valid taxon. According to Berman and Lucas (2003), however, it is a *nomen dubium*, and this interpretation is also followed by Gee (2018). The taxon is therefore not included in further analyses.

Schoch and Milner (2014, p. 80) mention "*Aspidosaurus*" *peltatus* among Dissorophidae *incertae sedis*. The species is based on very fragmentary material and is therefore not included in further analyses.

A.5.2 Micromelerpetidae

Phylogeny: *Branchierpeton saalense*, *Branchierpeton reinholdi*, *Limnogyrinus edani*, *Micromelerpeton boyi*, and *Micromelerpeton ulmetense* are added according to the single most parsimonious tree of Boy (2002, fig. 7A).

Eimerisaurus guembeli (see also Boy, 2002, fig. 7B) and *Nyranerpeton amilneri* are added according to the strict consensus tree of Schoch and Witzmann (2018, fig. 6).

Eimerisaurus graumanni is assumed to be closely related to *Eimerisaurus guembeli* and is added as its sister taxon, in accordance with the informal supertree of Angielczyk and Ruta (2012, fig. 1).

Alpha taxonomy: *Eimerisaurus graumanni* and *Eimerisaurus guembeli* are valid species according to Schoch and Milner (2014, p. 43) and are therefore added to the database.

Micromelerpeton boyi and *Micromelerpeton ulmetense* are both valid taxa (Schoch and Milner, 2014, p. 44, 45) and are therefore added to the database.

The palaeobiogeographic and stratigraphic range of *Branchierpeton saalense* is updated according to Schoch and Milner (2014, p. 43).

Branchiosaurus amblystomus is a junior synonym of *Branchierpeton amblystomum* (Schoch and Milner, 2014, p. 42) and is treated accordingly.

Branchierpeton reinholdi is a valid species and is added to the database (Schoch and Milner, 2014, p. 42).

The stratigraphic and palaeobiogeographic range of *Branchiosaurus salamandroides* is updated according to Schoch and Milner (2014, p. 50).

A.5.3 Branchiosauridae

Phylogeny: The *Melanerpeton*-clade and most species of *Apateon* are added according to the strict consensus tree of Schoch (2014b, fig. 5), which is based on the modified character matrix of Schoch and Milner (2008).

Tungussogyrinus bergi is added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14).

Eumicrerpeton parvum belongs to Branchiosauridae *incertae sedis* (Schoch and Milner, 2014, p. 52) and is therefore added as an early diverging member of Branchiosauridae.

Milnererpeton huberi is very similar to *Branchiosaurus salamandroides* (Werneburg et al., 2013) and is therefore added as its sister taxon.

M. pusillum is still considered a member of *Melanerpeton* (Schoch and Milner, 2008; Schoch and Milner, 2014, p. 51) and is added in a polytomy with *Melanerpeton sembachense* and *Schoenfelderpeton* + *Leptorophus* according to the phylogenetic hypotheses of Boy (1978, fig. 28) and Werneburg (1989, fig. 18).

Melanerpeton arnhardti is added as the sister taxon of *Melanerpeton pusillum*, following the phylogenetic hypotheses of Boy (1978, fig. 28), Werneburg (1989, fig. 18), Werneburg et al. (2007b, fig. 10), and Schneider and Werneburg (2012, fig. 6).

According to Werneburg and Schneider (1996) and Werneburg (2001) the morphology of *Apateon intermedius* is somewhat 'intermediate' between *Branchiosaurus*, *Apateon*, and *Melanerpeton*, but is most similar to *Apateon dracyi*. Indeed, in Werneburg et al. (2007b, fig. 10) and Schneider and Werneburg (2012, fig. 6) a close relationships between the two species is proposed. According to Schoch and Milner (2008), however, *Apateon intermedius* is more similar to *Melanerpeton* than to *Branchiosaurus* or *Apateon* and Schoch and Milner (2014, p. 54) consider it Branchiosauridae *incertae sedis*. Phylogenetic analysis recovers *Apateon intermedius* in a polytomy with the *Apateon*-clade and the *Melanerpeton*-clade (Schoch and Milner, 2008). The taxon is therefore added in a polytomy with the *Apateon*-clade and the *Melanerpeton*-clade.

Apateon umbrosus is similar to *Apateon pedestris*, *Apateon kontheri*, and *Apateon dracyi* (Werneburg, 1986; Boy, 1987; Werneburg, 1988). *Apateon umbrosus* is therefore added in a polytomy with *Apateon kontheri* and the clade consisting of *Apateon pedestris* and later diverging species of the genus *Apateon*.

Alpha taxonomy: *Eumicrerpeton parvum* is a valid species (Schoch and Milner, 2014, p. 52) and is therefore included in the database.

Apateon f. flagrifer and *Apateon f. oberhofensis* are subspecies of *Apateon flagrifer* (Schoch and Milner, 2014, p. 48). They are both retained within *Apateon flagrifer*. *Branchiosaurus brachyrhynchus* is a junior synonym of *Apateon flagrifer* (Schoch and Milner, 2014, p. 48) and is treated accordingly.

Apateon gracilis and *Apateon umbrosus* are valid taxa (Schoch and Milner, 2014, p. 48) and are therefore added to the database.

Apateon dracyiformis is a junior synonym of *Apateon dracyi* (Schoch and Milner, 2014, p. 47) and is treated accordingly. The stratigraphic range of *Apateon dracyi* is updated according to Schoch and Milner (2014, p. 47).

Melanerpeton arnhardti is a valid taxon (Schoch and Milner, 2014, p. 51) and is therefore added to the database.

Werneburg et al. (2007b) described *Melanerpeton eisfeldi* from the Rio su Luda Formation of Sardinia (Italy), but Schoch and Milner (2014, p. 54) treat the specimens as indeterminate branchiosaurid material. The Sardinian material is therefore excluded from the *Melanerpeton eisfeldi* entry in the database. "*Branchiosaurus*" *darrahi* is also treated as indeterminate branchiosaurid material (Schoch and Milner, 2014, p. 54). It is therefore not included in the database.

A.5.4 Amphibamidae

Phylogeny: *Tersomius texensis*, *Tersomius dolesensis*, *Pasawioops mayi*, and *Rubeostratilia texensis* are added according to the 50% majority rule consensus tree of Maddin et al. (2013, fig. 6B), which is based on an expanded and modified character matrix of Fröbisch and Schoch (2009). This tree is also used to increase the resolution within Branchiosauridae.

Georgenthalia clavinasica and *Plemmyradytes shintoni* are added according to the majority rule consensus tree of Anderson and Bolt (2013, fig. 10: left), which is based on an expanded character matrix of Bourget and Anderson (2011).

Broiliellus hektotopos is an amphibamid (May et al., 2011) that is similar to *Pasawioops mayi* (Schoch and Milner, 2014, p. 63). *Broiliellus hektotopos* is therefore added as the sister taxon of *Pasawioops mayi*.

Tersomius mosesi is very similar to *Tersomius texensis* (Bolt, 1977; Maddin et al., 2013) and is therefore added as its sister taxon (see also Huttenlocker et al., 2007, fig. 8).

Ruta and Bolt (2006) and Ruta (2009) recovered *Perryella olsoni* as a dvinosaur, but it is probably an amphibamid (Schoch and Milner, 2014, p. 82; Clack and Milner, 2015, p. 93). This interpretation has also been followed by Angielczyk and Ruta (2012). *Perryella olsoni* is added according to the relationships proposed in the informal supertree of Angielczyk and Ruta (2012, fig. 1).

The two species of *Platyrhinops* are assumed to be closely related and *Platyrhinops fritschi* is added as the sister taxon of *Platyrhinops lyelli*.

Nanobamus macrorhinus is an amphibamid that shares several apomorphies with *Amphibamus grandiceps* (Schoch and Milner, 2014, p. 60, 61). It is therefore added as the sister taxon of *Amphibamus grandiceps*.

Alpha taxonomy: Maddin et al. (2013) described *Pasawioops cf. mayi* from the Archer City Formation of Texas. Due to its stratigraphic importance, the occurrence is added to the database. The specimen appears to be "morphologically indistinguishable" from the holotype of *Pasawioops mayi* (Maddin et al., 2013, p. 458) and is therefore herein treated as another occurrence of the species *P. mayi*. Note, that Schoch and Milner (2014, p. 61) also mention this material among the referred material of *Pasawioops mayi*.

The specimens reported as *Platyrhinops cf. lyelli* by Clack and Milner (1993) and Milner and Sequeira (2003) were deemed a distinct species by Clack and Milner (2010). The material was then described by Werneburg (2012) as *Platyrhinops fritschi* and is treated as such herein.

The specimen MCZ 1911 previously assigned to *Tersomius texensis* from the Markley-Archer City Formation boundary (formerly Pueblo-Moran Formation boundary; Carroll, 1964a; Bolt, 1977; Lucas, 2018, fig. 4) has been reassigned as the holotype of the new taxon *Reiszerpeton renascentis* (Maddin et al., 2013). The stratigraphic range of the taxon *Tersomius texensis*, which is also known from Archer City Bone bed (Schoch and Milner, 2014, p. 62), is updated accordingly. Note, that Schoch and Milner (2014, p. 77) consider *Reiszerpeton renascentis* valid, but still report referred material of *Tersomius texensis* from the Markley-Archer City Formation boundary (Schoch and Milner, 2014, p. 62). This is probably just a lapsus calami as no material of *Tersomius texensis* from strata older than the Archer City Bone bed is known and the respective section in Schoch and Milner (2014) was written before the publication of Maddin et al. (2013) (A. R. Milner, pers. comm., 2017).

Schoch and Milner (2014, p. 63) consider *Tersomius mosesi* to be a valid species. It is added to the database.

'*Broiliellus*' *hektotopos* does not belong to the genus *Broiliellus*, but it is probably a valid amphibamid species (May et al., 2011; Schoch and Milner, 2014, p. 63) and is therefore retained in the database.

According to Schoch and Rubidge (2005) *Micropholis stowi* is definitely found in the lower *Lystrosaurus* AZ but the upper limit of its stratigraphic range is uncertain. Damiani (2004), however, does report the species also for the upper *Lystrosaurus* AZ. The stratigraphic range of the species is updated accordingly.

Gerobatrachus hottoni is known from the 'Cedar Top sandstone' of the Clear Fork Formation (D. Chaney, pers. comm., 2016; Nelson et al., 2013). The stratigraphic range of the taxon is treated accordingly.

A.6 'Basal' Stereospondylomorpha

Phylogeny: *Memonomenos dyscriton*, *Glanochthon latirostris*, *Glanochthon angusta*, *Chelidérpeton vranyi* (see also McHugh, 2012, fig. 3), *Intasuchus silvicola*, and *Archegosaurus decheni* are added using the consensus tree of Schoch and Witzmann (2009b, text-fig. 6), which is mainly based on a modified and expanded character matrix of Schoch and Witzmann (2009a). The clade *Archegosaurus decheni* + *Glanochthon latirostris*, recovered by Strapasson et al. (2015, fig. 7) and Schoch (2013, fig. 5) (but see Schoch, 2013, fig. 3), is therefore herein modified to represent a grade. This modification agrees with the results of Dilkes (2015a, fig. 10) and Schoch (2013, fig. 3). According to Schoch (2013) the clade is only poorly supported and the alternative as a grade "is similarly weak" Schoch (2013, p. 687). This placement also does not contradict the topology recovered by Pacheco et al. (2017, fig. 5), who found *Archegosaurus decheni* as the sister taxon to all other Stereospondylomorpha except for *Sclerocephalus*, while Strapasson et al. (2015) recovered a separate clade consisting of *Sclerocephalus haeuseri* and *Archegosaurus decheni* + *Glanochthon latirostris*.

Platyoposaurus stuckenbergi, *Platyoposaurus watsoni*, *Melosaurus kamaensis*, *Melosaurus* *uralensis*, *Prionosuchus plummeri*, *Melosaurus platyrhinus*, Konzhukoviidae, *Peltobatrachus pustulatus*, and *Arachana nigra* are added according to the strict consensus tree of Pacheco et al. (2017, fig. 5), which is based on an expanded data matrix of Eltink and Langer (2014).

Tryphosuchus kinelensis is added according to the strict consensus tree of Eltink and Langer (2014, p. 9). The OTU *Tryphosuchus* was based on character scores derived from both *Tryphosuchus kinelensis* and *Tryphosuchus paucidens* (Eltink and Langer, 2014, Appendix 1), the latter taxon now being considered a *nomen dubium* (Pacheco et al., 2017).

The formal supertree of Ruta et al. (2007, fig. 1) recovers *Lysipterygium risinense* as an early diverging stereospondylomorph. The source tree for the placement of *Lysipterygium risinense* is Schoch and Milner (2000, fig. 51, 52), which is not based on a formal quantitative phylogenetic analysis. *Lysipterygium risinense* is added according to the phylogenetic hypothesis of Schoch and Milner (2000, fig. 52) (see also Boy, 1996, fig. 7).

The informal supertree of Angielczyk and Ruta (2012) recovers *Syndyodosuchus tetricus* as the sister taxon of the clade *Sclerocephalus haeuseri* + *Sclerocephalus bavaricus* + *Sclerocephalus jogischneideri*. This placement seems to be based on the formal supertree of Ruta et al. (2007, fig. 1), which recovers the species again as the sister taxon of *Sclerocephalus haeuseri* (the other species of *Sclerocephalus* were not included in the analysis). It should be noted, however, that the source tree for the placement of *Syndyodosuchus tetricus* in Ruta et al. (2007, fig. 1) is Schoch and Milner (2000, fig. 51, 52), which is not based on a formal quantitative phylogenetic analysis. The placement of *Syndyodosuchus tetricus* therein is based on the cladogram of Boy (1993, fig. 7), which recovers it as the sister taxon of the clade *Clamorosaurus* + *Eryops*. Schoch and Milner (2000, p. 52, 53) considered *Syndyodosuchus tetricus* a member of (potentially paraphyletic) Actinodontidae, but recognised that it was also very similar to *Intasuchus silvicola* (Schoch and Milner, 2000, p. 49). Indeed, Gubin (1997b, p. 7), Shishkin et al. (2000, p. 41), and Ivakhnenko (2001, p. 33) considered *Syndyodosuchus tetricus* a member of Intasuchidae and it was treated as such by Lozovsky (2005). Similar to Schoch and Milner (2000, p. 52, 53), Milner (1989) also argued for placing *Syndyodosuchus tetricus* within Actinodontidae. Both Schoch and Milner (2000, p. 52, 53) and Milner (1989), however, assumed *A. frossardi* to belong to the genus *Sclerocephalus*, while now it is recognised as a member of the eryopid genus *Actinodon* (Schoch and Milner, 2014, p. 88). Schoch and Milner (2014, p. 88–94) do not include *Syndyodosuchus tetricus* in Eryopidae. As the relationships between *Syndyodosuchus tetricus* and *Sclerocephalus stambergi* (which Klembara and Steyer (2012, fig. 5) did not recover within the *Sclerocephalus* clade) are unclear, *Syndyodosuchus tetricus* is added in a polytomy with the *Sclerocephalus* clade (without *Sclerocephalus stambergi*) and the clade consisting of *Sclerocephalus stambergi* and later diverging stereospondylomorphs.

The three species of *Platyoposaurus* are assumed to be sister taxa and *Platyoposaurus rickardi* is therefore added in a polytomy with the two other species.

Bashkirosaurus cherdyncevi is added as the sister taxon of *Platyoposaurus* according to the phylogenetic hypothesis of Gubin (1997a, fig. 10) (see also Schoch and Milner, 2000, fig. 52; Ruta et al., 2007, fig. 1).

Dias and Barberena (2001) assigned *Bageherpeton longignathus* to Platyoposaurinae *sensu* Gubin (1991). Gubin (1991, p. 13, 14) included *Platyoposaurus*, *Prionosuchus*, and *Bashkirosaurus* in Platyoposaurinae. Pacheco et al. (2017, fig. 5) does not recover *Prionosuchus* within a monophyletic Platyoposaurinae *sensu* Gubin (1991), but this might be due to the fragmentary status of the holotype (Pacheco et al., 2017). *Bageherpeton longignathus* is therefore added in a polytomy with the 'platyoposaurines' *Bashkirosaurus cherdyncevi* and *Platyoposaurus*.

Kashmirosaurus ornatus is added as the sister taxon of the clade consisting of *Bashkirosaurus cherdyncevi*, *Bageherpeton longignathus*, and *Platyoposaurus* following the hypothesized phylogeny of Schoch and Milner (2000, fig. 52) (see also Ruta et al., 2007, fig. 1).

Collidosuchus tchudinovi is added as the sister taxon of *Kashmirosaurus ornatus* according to the hypothesized phylogeny of Schoch and Milner (2000, fig. 52) (see also Ruta et al., 2007, fig. 1).

Melosaurus compilatus resembles *Melosaurus uralensis* to a certain degree (Golubev, 1995) and is therefore added to the polytomy consisting of *Melosaurus uralensis*, *Melosaurus kamaensis*, *Prionosuchus plummeri*, and the clade consisting of later diverging members of Stereospondylomorpha.

Following the hypothesis of Schoch and Milner (2000, fig. 52) *Uralosuchus tverdochlebovae* is added as the sister taxon of *Melosaurus platyrhinus* (see also Ruta et al., 2007, fig. 1), which is recovered as the latest diverging member of the genus in Pacheco et al. (2017, fig. 5).

Following the hypothesis of Schoch and Milner (2000, fig. 52), *Koinia silantjevi* is added as the sister taxon of the clade consisting of *Melosaurus compilatus*, *Melosaurus kamaensis*, *Melosaurus uralensis*, *Prionosuchus plummeri*, and the clade including later diverging members of Stereospondylomorpha (see also Ruta et al., 2007, fig. 1). Note, that the addition *Koinia silantjevi* and similar 'melosaurines' can only be considered tentative, as 'Melosaurinae' *sensu* Schoch and Milner (2000, p. 60) is not recovered as monophyletic in Pacheco et al. (2017, fig. 5).

Alpha taxonomy: Klembara and Steyer (2012, fig. 5) included *Sclerocephalus jogischneideri* in their phylogenetic analysis, but questioned its validity. They did not, however, explicitly consider it a *nomen dubium*. The taxon is therefore retained in the database.

Schoch and Witzmann (2009b) created the new generic name *Glanochthon* for the taxon *Cheliderpeton latirostre*. This interpretation is followed by Fortuny et al. (2011b), Angielczyk and Ruta (2012, Appendix), Witzmann (2013b), Witzmann (2013a), Eltink and Langer (2014), Schoch (2013, Table 1), and Schoch (2014a, p. 110). *Cheliderpeton latirostre* is therefore retained in the database as *Glanochthon latirostris*. Note, that the species name is often misspelled as *G. latirostre* (e.g., Fortuny et al., 2011b; Angielczyk and Ruta, 2012, Appendix; Eltink and Langer, 2014; Schoch, 2014a, p. 110).

Milner (1978) reassigned *Memonomenos dyscriton* to the genus *Archegosaurus*. This interpretation is also followed by Schoch and Milner (2000, p. 56, 57), Stayton and Ruta (2006), Witzmann and Scholz (2007), Štamberg and Zajíc (2008), and Angielczyk and Ruta (2012). Note, however, that Schoch and Witzmann (2009b) appear to favour retaining the old genus name. Indeed, both Schoch and Witzmann (2009b, text-fig. 6) and the supertree of Ruta et al. (2007, fig. 1) do not recover *Archegosaurus dyscriton* as the sister taxon of *Archegosaurus decheni*. Herein, *M. dyscriton* is therefore retained within the genus *Memonomenos*.

Shishkin et al. (2000, p. 44) argued that the fragmentary taxon *Tryphosuchus kinelensis* needed re-evaluation, but Eltink and Langer (2014) and Pacheco et al. (2017) treat it as a valid taxon and it is therefore included in the database. Note, however, that Pacheco et al. (2017) exclude *Tryphosuchus kinelensis* and *Uralosuchus tverdochlebovae* from their character data matrix, as they are represented by very incomplete material which results in a "dubious" (Pacheco et al., 2017, p. 251) position of the taxa in their phylogenetic analyses.

Platyoposaurus vjuschkovi is mentioned by Eltink and Langer (2014), but it is based on fragmentary material and needs to be re-assessed (Shishkin et al., 2000, p. 44). It is therefore not included in the database.

Tryphosuchus paucidens is a *nomen dubium* (Pacheco et al., 2017) and is treated accordingly.

A.7 'Basal' Stereospondyli

Phylogeny: Rhinesuchidae, *Uruyiella liminea*, and *Eolydekkerina magna* are added according to the single most parsimonious tree of Marsicano et al. (2017, fig. 14).

The consensus Bayesian tree of Pardo et al. (2017b, fig. 2C) recovers *Lapillopsis nana* as the sister taxon of Dissorophoidea. The single most parsimonious tree of Marsicano et al. (2017, fig. 14) recovers it as sister taxon of Trematosauria. Both results do not conform to the interpretations of Schoch (2013), who interpreted the taxon as an early diverging stereospondyl or late diverging stereospondylomorph. *Lapillopsis nana* is therefore added according to the single most parsimonious tree of Eltink et al. (2016, fig. 10), whose results are not in contradiction with the interpretation of Schoch (2013).

Rotaurisaurus contundo is added according to the strict consensus tree of McHugh (2012, fig. 4: left).

The 50% majority rule consensus tree of Dias-da-Silva and Marsicano (2011, fig. 5B), which is used to add 'Rhytidosteidae' (subsection A.9.4), is also used to add *Luzocephalus blomi* (see also Maganuco et al. (2014, fig. 25) and Dias-da-Silva and Hewison (2013)).

The 50% majority-rule consensus tree of Maganuco et al. (2014, fig. 25) is used to add *Deltacephalus whitei*, *Acerastea wadeae*, *Sclerothorax hypselonotus*, and *Rhytidosteus capensis*.

Syrtosuchus samarensis is added to a polytomy including Capitosauria and Trematosauria according to the strict consensus tree of Fernández-Coll et al. (2019, fig. 4a), which also provides the scaffold for Trematosauridae (subsection A.9.5). Note, that Novikov (2016, p. 308) considered it the "most archaic" representative of the family Benthosuchidae but also stressed similarities between *Syrtosuchus* and Selenocarinae, especially *Selenocara*. *Syrtosuchus morkovini* is assumed to be closely related to *Syrtosuchus samarensis* and is added accordingly.

Manubrantlia khaki is a lapillopsid (Warren et al., 2009) and has been suggested as the sister taxon of the clade *Lapillopsis nana* + *Rotaurisaurus contundo* (Yates and Sengupta, 2002). *Manubrantlia khaki* is added accordingly.

The formal supertree of Ruta et al. (2007, fig. 1) recovers *Broomulus dutoiti* as the sister taxon of the clade *Limnoiketes paludinatans* + *Lydekkerina huxleyi*. The source tree for the placement of *Broomulus dutoiti* and *Limnoiketes paludinatans* in Ruta et al. (2007, fig. 1) is Schoch and Milner (2000, fig. 68, 69), which is not based on a formal quantitative phylogenetic analysis (see also Milner, 1991, fig. 1). The phylogenetic analysis of Dias-da-Silva and Hewison (2013) recovered both *Broomulus dutoiti* and *Limnoiketes paludinatans* as part of the same subfamily within Lydekkerinidae. *Broomulus dutoiti* and *Limnoiketes paludinatans* are herein added according to the phylogenetic hypothesis of Schoch and Milner (2000, fig. 69).

Luzocephalus kochi and *Luzocephalus johanssoni* have been suggested to be conspecific (Warren, 1998; Shishkin et al., 1996; Jeannot et al., 2006). *Luzocephalus johanssoni* is therefore added as the sister taxon of *Luzocephalus kochi*. The species of *Luzocephalus* are assumed to be closely related (but see Bjerring, 1999 and Hewison, 2007) and the clade *Luzocephalus kochi* + *Luzocephalus johanssoni* is added as sister taxon to *Luzocephalus blomi*.

Phylogenetic analyses recovered *Lydekkerina panchetensis* in a lydekkerinid subfamily including *Chomatobatrachus halei*, *Luzocephalus blomi*, and *Luzocephalus kochi* (Dias-da-Silva and Hewison, 2013). *Lydekkerina panchetensis* is therefore added to the polytomy including Lydekkerinidae (consisting mainly of members of the other subfamily mentioned by Dias-da-Silva and Hewison, 2013), *Chomatobatrachus halei*, *Luzocephalus*, *Arachana nigra*, and the clade *Eolydekkerina magna* + later diverging stereospondyls.

Alpha taxonomy: Jeannot et al. (2006) considered *Broomulus dutoiti* a junior synonym of *Lydekkerina huxleyi*. This interpretation was (implicitly) followed by Dias-da-Silva and Marsicano (2011) and Maganuco et al. (2014). Hewison (2007, p. 42–44), however, argued against such an interpretation and considered the taxa to be distict from each other. A similar interpretation had been given earlier by Shishkin et al. (1996) and this was followed by Schoch and Milner (2000, p. 77). Indeed, Sidor et al. (2008, Table) and Piñeiro et al. (2012) did treat *Broomulus dutoiti* as a valid taxon and it was used in the phylogenetic analyses reported by Dias-da-Silva and Hewison (2013) as a separate OTU. *Broomulus dutoiti* is therefore kept in the database as a separate taxon. Similarly *Limnoiketes paludinatans* was also considered a junior synonym of (Shishkin et al., 1996; Jeannot et al., 2006). This interpretation was (implicitly) followed by Dias-da-Silva and Marsicano (2011). Hewison (2007, p. 44–46) argued against such an interpretation and kept the taxa separate. Dias-da-Silva and Hewison (2013) kept the taxa again as separate OTUs in their phylogenetic analysis. *Limnoiketes paludinatans* is therefore retained in the database as a separate taxon.

Dias-da-Silva and Hewison (2013) treat *Lydekkerina panchetensis* as a valid taxon but do not recover it as the sister taxon of *Lydekkerina huxleyi* in their phylogenetic analysis. It is therefore retained in the database as '*Lydekkerina*' *panchetensis*. Note, however, that Hewison (2007) considered *Lydekkerina huxleyi* a *nomen vanum* in his self-published 'Journal of Temnospondyl Palaeontology'.

Bjerring (1999) assigned *Luzocephalus kochi* to the new genus *Aquiloniferus* (see also Marzola et al., 2018), but the assignment is contentious (Kear et al., 2016). *Luzocephalus* is therefore kept as a member of the genus *Luzocephalus* following Schoch and Milner (2000, p. 79).

The correct spelling *Luzocephalus johanssoni* (see Säve-Söderbergh, 1935, p. 164) is often mistakenly reported as *Luzocephalus johannsoni* (e.g., Warren and Black, 1985, p. 309; Schoch and Milner, 2000, p. 79; Jeannot et al., 2006, p. 822). The correct spelling is applied to the database.

The type specimen of *Wetlugasaurus samarensis* is now referred to *Syrtosuchus* (Novikov, 2016). The taxon is treated accordingly.

A.7.1 Rhinesuchidae

Phylogeny: The strict consensus tree of Strapasson et al. (2015, fig. 7), which also provides the scaffold tree for Temnospondyli (section A.2), is used to add *Parapytanga catarinensis* as the sister taxon of the rhinesuchid *Australerpeton cosgriffi*.

Alpha taxonomy: *Rhinesuchus capensis* is reassigned to the genus *Rhinesuchoides* (Marsicano et al., 2017) and is herein treated accordingly.

Rhinesuchus avenanti and *Rhinesuchus rubidgei* are junior synonyms of *Rhinesuchoides tenuiceps* (Marsicano et al., 2017) and are treated accordingly.

Rhinesuchus broomianus, *Rhinesuchus beaufortensis*, and *Muchocephalus muchos* are junior synonyms of *Rhinesuchus whaitsi* (Marsicano et al., 2017) and are treated accordingly.

Schoch and Milner (2000, p. 74) mentioned *Laccosaurus watsoni* among Rhinesuchidae *incertae sedis*. Damiani and Rubidge (2003) treat it as a valid taxon among Rhinesuchidae. It is also treated as a valid taxon by Damiani (2004), Jeannot et al. (2006), McHugh (2012, p. 19), Eltink et al. (2016), Eltink et al. (2017, Table 1), and Marsicano et al. (2017). The taxon is treated accordingly in the database.

Lydekkerina kitchingi (= *Muchocephalus kitchingi*) is a *nomen dubium* (Marsicano et al., 2017) and is herein treated accordingly.

A.8 Capitosauria

Phylogeny: Capitosauria are added according to the strict consensus tree of Liu (2016, fig. 7), which is based on a modified character matrix of Sidor et al. (2014a), which is itself based on

Fortuny et al. (2011a).

Tomeia witecki is added according to the strict consensus tree of Eltink et al. (2017, fig. 7), which is based on an expanded character matrix of Fortuny et al. (2011a).

Warrenisuchus aliciae, *Watsonisuchus magnus*, *Watsonisuchus rewanensis* are added according to the 50% majority-rule consensus tree of Maganuco et al. (2014, fig. 25), which is mainly based on an expanded character matrix of Maganuco et al. (2009).

Jammerbergia formops is added according to the strict consensus tree of McHugh (2012, fig. 4), thereby considering also its position in the strict consensus tree of McHugh (2012, fig. 5) and the description given by Damiani and Hancox (2003), who reported the species as an early diverging member of "the 'advanced' mastodonsaurid clade" (Damiani and Hancox, 2003, p. 64) similar to *Paracyclotosaurus*.

Damiani (2001, p. 434) considered *Wetlugasaurus vjatkensis* a junior synonym of *Wetlugasaurus angustifrons*. It is therefore added as the sister taxon of *Wetlugasaurus angustifrons*.

Wetlugasaurus malachovi is assumed to be closely related to the other (Russian) species of *Wetlugasaurus* and is therefore added as the sister taxon of the clade *Wetlugasaurus vjatkensis* + *Wetlugasaurus angustifrons*.

According to Bjerring (1997) there are enough differences between *Wetlugasaurus groenlandicus* and the other species of *Wetlugasaurus* to warrant a generic separation. This interpretation is followed by Novikov (2016). Both Schoch and Milner (2000, p. 102) and Damiani (2001, p. 435) argue against this interpretation, but a few minor differences are noted. Furthermore, *W. groenlandicus* is the oldest *Wetlugasaurus* species and the only one, which is known from Greenland (all other species are known from Russia). *Wetlugasaurus groenlandicus* is therefore added as the sister taxon of all other species of *Wetlugasaurus*.

The supertree of Ruta et al. (2007, fig. 1) recovers *Sassenisaurus spitzbergensis* as an early diverging member of Capitosauroidea. The source tree for the supertree analysis is Schoch and Milner (2000, fig. 89), which was not obtained using a quantitative analysis of a character matrix. Schoch and Milner (2000, fig. 89) hypothesize *Sassenisaurus spitzbergensis* as the sister taxon of the genus *Wetlugasaurus*. Indeed, Novikov (2016) reports *Sassenisaurus spitzbergensis* as a potential member of Wetlugasaurinae. *Sassenisaurus spitzbergensis* is therefore added as the sister taxon of *Wetlugasaurus*.

The family Capitosauridae *sensu* Novikov (2016) consists of the subfamilies Selenocarinae (*Samarabatrachus* and *Selenocara*), Wetlugasaurinae (*Wetlugasaurus*, *Vladlenosaurus*, and potentially *Sassenisaurus*), and Parotosuchinae (*Parotosuchus* and *Eryosuchus*). Current phylogenetic analyses (Sidor et al., 2014a, fig. 7; Liu, 2016, fig. 7) recover such a grouping as paraphyletic.

Novikov (2016) considered *Selenocara rossica* as the second species of *Selenocara*,the first one being *S. groenlandica*, which is herein retained as *Wetlugasaurus groenlandicus* (see Schoch and Milner, 2000, p. 102; Damiani, 2001, p. 435; Kear et al., 2016; but see Marzola et al., 2018). *Selenocara rossica* is therefore added as the sister taxon of the clade *Sassenisaurus* +

Wetlugasaurus, reflecting the similarity and previous assignment of the taxon.

Samarabatrachus and *Selenocara* form the subfamily Selenocarinae (Novikov, 2016). *Samarabatrachus bjerringi* is therefore added as the sister taxon of *Selenocara rossica*. The resulting clade represents the sister taxon of *Wetlugasaurus* + *Sassenisaurus*. Indeed, specimens of both taxa previously had been assigned to *Wetlugasaurus samarensis*.

The species of *Cherninia* are assumed to be closely related (see also Schoch, 2008b) and *Cherninia megarhina* is added as the sister taxon of *Cherninia denwai*.

Stanocephalosaurus pronus has previously been considered as not belonging to the genus *Stanocephalosaurus* (Dahoumane et al., 2016; Schoch, 2008b). *Stanocephalosaurus rajareddyi* and *Stanocephalosaurus amenasensis* are therefore assumed to be more closely related to the type species *Stanocephalosaurus birdi* and are placed in a corresponding polytomy.

According to Schoch (2008b) the three species of *Paracyclotosaurus* are very similar to each other. *Paracyclotosaurus davidi* is therefore added as the sister taxon of *Paracyclotosaurus crookshanki* (see also Maganuco et al., 2014, fig. 25). The strict consensus tree in the PhD thesis of McHugh (2012, fig. 4: left) recovered no sister taxon relationship between *Paracyclotosaurus davidi* and *Paracyclotosaurus morganorum*. So far, the species assignment of *Paracyclotosaurus* has not been questioned in the peer-reviewed literature (but see the discussions in Sidor et al., 2014a). *P. morganorum* is therefore retained as a species *Paracyclotosaurus*. The result of McHugh (2012, fig. 4: left) is interpreted as indicating a less close relationship of *Paracyclotosaurus morganorum* with the other species of *Paracyclotosaurus*. *Paracyclotosaurus morganorum* is therefore added as the sister taxon of the clade *Paracyclotosaurus davidi* + *Paracyclotosaurus crookshanki*.

Eocyclotosaurus appetolatus is considered to be more closely related to *Eocyclotosaurus wellesi* than to other species of the same genus (Rinehart et al., 2015) and is therefore added as the sister taxon of *Eocyclotosaurus wellesi*.

Eocyclotosaurus woschmidti has been considered to be synonymous with *Eocyclotosaurus lehmani* (Schoch and Milner, 2000, p. 150). It is therefore added as its sister taxon, which agrees also with the phylogenetic hypotheses of Ingavat and Janvier (1981, fig. 6) (who, however, treated both species as members of the genus *Stenotosaurus*) and Kamphausen (1989, fig. 10).

Milner et al. (1990) did not attempt to assign the material of *Eocyclotosaurus* sp. from the Otter Sandstone Formation to a species, as it was unclear at that time, whether *Eocyclotosaurus woschmidti* and *Eocyclotosaurus lehmani* were synonymous or not. This implicitly indicates a close relationship between the Otter Sandstone material and the two other species. While *Eocyclotosaurus wellesi* and *Eocyclotosaurus appetolatus* are only known from North America, *Eocyclotosaurus lehmani*, *Eocyclotosaurus woschmidti* and the Otter Sandstone material are restricted to Europe. Considering the palaeobiogeographic proximity and following the assessment of Milner et al. (1990), *Eocyclotosaurus* sp. from the Otter Sandstone Formation is added as the sister taxon of the clade *Eocyclotosaurus lehmani* + *Eocyclotosaurus woschmidti*. All species of

Eocyclotosaurus are assumed to be closely related and therefore the resulting clade is added as the sister taxon to the clade *Eocyclotosaurus wellesi* + *Eocyclotosaurus appetolatus*.

According to Sidor et al. (2008) the systematic position of *Kryostega collinsoni* is uncertain, but it probably belongs to either the Heylerosauridae or the basal Mastodonsauridae *sensu* Damiani (2001). Damiani (2001, p. 392) defined Heylerosauridae as “all mastodonsauroids sharing a more recent common ancestor with *Eocyclotosaurus* than with *Mastodonsaurus*”. Mastodonsauridae were defined as “all mastodonsauroids sharing a more recent common ancestor with *Mastodonsaurus* than with *Eocyclotosaurus*” (Damiani, 2001). *Kryostega collinsoni* is therefore added in a polytomy with the two clades. Note, however, that the content of the two clades differs from the original analyses of Damiani (2001, fig. 34, 35).

Alpha taxonomy: Specimens that previously had been referred to *Wetlugasaurus samarensis* are now considered to belong to *Selenocara rossica* and *Samarabatrachus bjerringi* (Novikov, 2016). The specimens are treated accordingly. Novikov (2016) considers *Wetlugasaurus groenlandicus* to be another species of the genus *Selenocara*, following Bjerring (1997). Damiani (2001) argued against this interpretation and Kear et al. (2016) also treat *Wetlugasaurus groenlandicus* as a valid taxon (but see Marzola et al., 2018). Herein *W. groenlandicus* is treated as a valid taxon of the genus *Wetlugasaurus*.

Ruta et al. (2007), Warren (2012), Scheyer et al. (2014b) and Kear et al. (2016) treat *Sassenisaurus spitzbergensis* as a valid taxon and it is therefore retained in the database. Note, however, that Damiani (2001) considered the taxon to be based on indeterminate material.

Watsonisuchus aliciae has been reassigned to the new genus *Warrenisuchus* by Maganuco et al. (2009). Fortuny et al. (2011a) retained the species tentatively in the genus *Watsonisuchus*, but Kear et al. (2016) treat the genus *Warrenisuchus* as valid. The taxon is retained in the database as *Warrenisuchus aliciae*.

McHugh (2015) mentions *Watsonisuchus magnus* for the Induan Katberg Formation, citing hereby Damiani (2001). Damiani (2001), however, does not report this species for the Katberg Formation. According to Shishkin (2005) specimens of *Watsonisuchus* that previously have been reported from the *Lystrosaurus* AZ (Damiani et al., 2001) actually do not belong to this taxon and the taxon is restricted to the lower part of the *Cistecephalus* AZ. Indeed, also Sidor et al. (2008, Table) only reports the taxon for the *Cistecephalus* AZ. Similarly, the holotype of *Kestrosaurus dreyeri* comes from the *Cistecephalus* AZ, not from the *Lystrosaurus* AZ (Shishkin et al., 2004). *Parotosuchus haughtoni* is also restricted to the lower part of the *Cistecephalus* AZ (Damiani, 2002, 2004; Sidor et al., 2014a). The stratigraphic range of these taxa is treated accordingly.

Morales and Shishkin (2002) erect the new genus *Xenotosuchus* for *Wellesaurus africanus*. The validity of *Xenotosuchus africanus* has also been accepted by Damiani and Rubidge (2003), Damiani (2008), Schoch (2008b), McHugh (2012, Appendix B: Table B1) and it is also treated as valid by Sidor et al. (2014a) and Liu (2016). Therefore, *Wellesaurus africanus* is herein included within *Xenotosuchus africanus*.

Wellesaurus peabodyi is a junior synonym of *Stanocephalosaurus birdi* according to Schoch and Milner (2000, p. 146), Schoch (2008b), and Fortuny et al. (2011a). It is also treated as such by McHugh (2012, Appendix B: Table B1) and Witzmann (2013a). The taxon is treated accordingly in the database. Note, however, that Marsicano et al. (2014) treat the taxon *Wellesaurus peabodyi* as being valid.

Dahoumane et al. (2016) consider *P. crookshanki* a valid species of *Stanocephalosaurus*, following Schoch and Milner (2000, p. 146), but Damiani (2001) assigned it to *Paracyclotosaurus* and this view is also followed by Schoch (2008b), Sengupta et al. (2016), and Liu (2016). The taxon is therefore retained in the database as *Paracyclotosaurus crookshanki*.

S. pronus might not belong to the genus *Stanocephalosaurus* (Dahoumane et al., 2016; Schoch, 2008b), although some phylogenetic analyses do recover it as the sister taxon of *S. birdi* (Liu, 2016). Indeed, Damiani (2001) created the new combination *Eryosuchus pronus* for the taxon, but Schoch (2008b) does not follow this suggestion. Herein, the genus name *Stanocephalosaurus* is retained for the species, awaiting further investigations of the relationships of the taxon.

Schoch and Milner (2000, p. 147) reassigned *Parotosaurus rajareddyi* to the genus *Stanocephalosaurus*. Damiani (2001), on the other hand, considered it to be a species of *Eryosuchus*. Sengupta (2003) argued against the referral to the genus *Eryosuchus* and, following Schoch and Milner (2000, p. 147), proposed to use *Stanocephalosaurus rajareddyi* until better material was available. Dahoumane et al. (2016) also consider *S. rajareddyi* to be a valid species of the genus *Stanocephalosaurus*. The taxon is therefore retained in the database as *Stanocephalosaurus rajareddyi*.

The taxon mentioned in Schoch and Milner (2000, p. 150, 151) as *Eocyclotosaurus* nov. spec. represents *Eocyclotosaurus wellesi*. The database is updated accordingly.

Eocyclotosaurus sp. from the Otter Sandstone Formation, described by Milner et al. (1990) and mentioned by Schoch and Milner (2000, p. 150), is retained in the database due to its palaeobiogeographic and stratigraphic importance.

Dahoumane et al. (2016) consider *Stanocephalosaurus* “nov. spec.”, mentioned by Schoch and Milner (2000, p. 146), as being invalid. The taxon is therefore excluded from further analyses.

Quasicyclotosaurus randalli is mentioned briefly in Rinehart et al. (2015) with the specimen number UCMP 37754. Welles (1947) erected the new species *Cyclotosaurus randalli*. Shishkin (1960) made one of the referred specimens of *Cyclotosaurus randalli* the type specimen of *Moenkopisaurus randalli*. Both *Cyclotosaurus randalli* and *Moenkopisaurus randalli* are now considered *nomina dubia* (Schoch and Milner, 2000, p. 165–167). The new combination *Quasicyclotosaurus randalli* is not mentioned elsewhere and specimen UCMP 37754 actually represents the type specimen of *Quasicyclotosaurus campi* (Schoch, 2000b; Schoch, 2000a; Schoch, 2008b; Marzola et al., 2017). *Quasicyclotosaurus randalli* is therefore not further considered herein.

A.8.1 Capitosauroidea

Phylogeny: *Kestrosaurus dreyeri* is added as the sister taxon of *Parotosuchus* according to the strict consensus tree of McHugh (2012, fig. 5) (see also McHugh, 2012, fig. 4).

Parotosuchus haughtoni, *Parotosuchus nasutus*, and *Parotosuchus helgolandicus* are added according to the consensus tree of Schoch (2018b), which is based on an expanded character matrix of Schoch (2008b).

Stenotosaurus semiclausus is added according to the consensus tree of Schoch (2008b, fig. 11), aided by the strict consensus tree of Damiani (2001, fig. 34) (see also Ruta et al., 2007, fig. 1; Schoch, 2008b, fig. 13). Note, however, that Damiani (2001) considered *Procyclotosaurus stantonensis* to be a species of the genus *Stenotosaurus*. The OTU *Stenotosaurus* in Damiani's (2001) analyses is therefore based on a mix of characters of *Stenotosaurus semiclausus*, *Stenotosaurus gracilis*, and *Procyclotosaurus stantonensis*.

Mastodonsaurus cappelensis and several species of *Cyclotosaurus* (*C. buechneri*, *C. mordax*, *C. naraserluki*, *C. ebrachensis*, *C. intermedius*, *C. posthumus*, and *C. hemprichi*) are added according to the single most parsimonious tree of Marzola et al. (2017, fig. 7), which is based on an expanded character matrix of Witzmann et al. (2016).

The supertree of Ruta et al. (2007, fig. 1) recovers *Meyerosuchus fuerstenbergianus* as the sister taxon of *Stenotosaurus semiclausus*. The respective source tree, Schoch and Milner (2000, fig. 106), however, is not based on a formal quantitative phylogenetic analysis. *Meyerosuchus fuerstenbergianus* is therefore added at the base of the Capitosauroidea in a polytomy with *Parotosuchus* and the rest of Capitosauroidea, according to the new interpretation given by Schoch (2011c). Note, however, that the content of Capitosauroidea *sensu* Schoch (2008b), as used in Schoch (2011c), differs from the one recovered in recent analyses (Sidor et al., 2014a; Liu, 2016).

Parotosuchus ptaszynskii is morphologically "intermediate" (Sulej and Niedźwiedzki, 2013, p. 65) between the (stratigraphically) older *Parotosuchus helgolandicus* and the younger *Parotosuchus orenburgensis*. The three taxa have been interpreted as potentially forming an evolutionary lineage (Sulej and Niedźwiedzki, 2013). *Parotosuchus ptaszynskii* is therefore added as the sister taxon of *Parotosuchus orenburgensis*, with *Parotosuchus helgolandicus* acting as sister to the resulting clade.

The Russian taxa *Parotosuchus orientalis* and *Parotosuchus orenburgensis* are known from the same formation and the proportions of the subtemporal fossa of *Parotosuchus ptaszynskii* appear to be nearly identical to that of *Parotosuchus orientalis* (Sulej and Niedźwiedzki, 2013). The material assigned to *Parotosuchus orientalis* is consistent with that of *Parotosuchus orenburgensis* (Schoch, 2018b). *Parotosuchus orientalis* is therefore added in a polytomy with *Parotosuchus ptaszynskii* and *Parotosuchus orenburgensis*.

Parotosuchus speleus potentially belongs to the "*P. helgolandicus*" group and might be close to *Parotosuchus orientalis* (Shishkin and Sulej, 2009). It is therefore added as the sister taxon of *Parotosuchus orientalis*. Note, however, that Schoch (2018b) considers the assignment of *Parotosuchus speleus* to Parotosuchidae as currently impossible, as the available fragmentary material bears no clear apomorphies of *Parotosuchus*.

Distinguishing *Parotosuchus sequester* from *Parotosuchus nasutus* appears difficult (Damiani, 2001, p. 421). *Parotosuchus komiensis* is similar to *Parotosuchus sequester* and *Parotosuchus nasutus* (Novikov, 1986). *Parotosuchus panteleevi* belongs to the "*P. nasutus*" group (Shishkin et al., 2006). *P. sequester*, *P. komiensis*, and *P. panteleevi* all stem from the former territory of the USSR and are herein assumed to be closely related. A corresponding polytomy is created and the resulting clade is added as the sister taxon to *Parotosuchus nasutus*, following the interpretations given by Damiani (2001, p. 421), Novikov (1986), and Shishkin et al. (2006).

Stenotosaurus gracilis is assumed to be a sister taxon of *Stenotosaurus semiclausus* and is placed accordingly.

Tatrasuchus kulczyckii is added according to the phylogenetic hypothesis of Schoch (2008b, fig. 12) as the sister taxon of the clade *Kupferzellia* + *Cyclotosaurus* (see also Sulej, 2009; Schoch and Milner, 2000, fig. 106; Ruta et al., 2007, fig. 1).

If the taxonomic assignment is correct, *Cyclotosaurus papilio* is by far the earliest representative of the genus *Cyclotosaurus* (Damiani, 2001; Schoch, 2008b; Witzmann et al., 2016) and is therefore added as the sister taxon to the clade consisting of all other *Cyclotosaurus* species. Note, however, that the assignment of the taxon to the genus is unclear (Schoch, 2008b).

The Japanese capitosauroid is added according to the preferred phylogenetic position of the taxon in Nakajima and Schoch (2011, fig. 3).

The species of *Eryosuchus* are assumed to be closely related and *Eryosuchus tverdochlebovi* is added as the sister taxon of *Eryosuchus garjainovi*.

Eryosuchus nov. spec. from Kazahkstan might belong to a different genus (Schoch and Milner, 2000, p. 145) and is therefore added as the sister taxon to the clade consisting of the other two species of *Eryosuchus*.

Specimens assigned to *Mastodonsaurus* sp. from the Upper Bromsgrove Sandstone Formation of England (Schoch and Milner, 2000, p. 142) might belong to a different genus (Damiani, 2001, p. 438). Milner et al. (1990) mention a resemblance with *Mastodonsaurus cappelensis*. *Mastodonsaurus* sp. from the Upper Bromsgrove Sandstone Formation is the only material of the genus, that is known from Europe, but not from Germany. The English *Mastodonsaurus* sp. is therefore added as the sister taxon of the clade *Mastodonsaurus giganteus* + *Mastodonsaurus cappelensis*.

Mastodonsaurus torvus is the only Russian species of *Mastodonsaurus* and might belong to a different genus (Shishkin et al., 2000, p. 48; Damiani, 2001, p. 412; Niedźwiedzki et al., 2016). It is therefore added as the sister taxon to all other species of *Mastodonsaurus*.

Alpha taxonomy: *Meyerosuchus fuerstenbergianus* is a valid taxon according to Schoch (2011c) and is therefore retained in the database.

According to Damiani (2001) and Damiani and Rubidge (2003) *Kestrosaurus dreyeri* is based on indeterminate material, but Shishkin et al. (2004) argued against such an interpretation and considered the taxon to be valid. Shishkin et al. (2004) considered *Parotosuchus haughtoni* and potentially also *Watsonisuchus magnus* junior synonyms of *Kestrosaurus dreyeri*. They also erected the new species *Kestrosaurus kitchingi*. Gaetano et al. (2012) treat *Kestrosaurus kitchingi* as a valid taxon. Sidor et al. (2008) and McHugh (2012, Appendix B: Table B1) treat the type specimen and most of the referred specimens of *Kestrosaurus kitchingi* as specimens of *Kestrosaurus dreyeri*. *Kestrosaurus kitchingi* is therefore herein assumed to be a junior synonym of *Kestrosaurus dreyeri*. Sidor et al. (2013, Supporting Information: Table S2) report *Watsonisuchus magnus* and *Parotosuchus haughtoni* as separate taxa for the Karoo Basin, but do not mention any of the *Kestrosaurus* species. *Parotosuchus haughtoni* is also mentioned by Sulej and Niedźwiedzki (2013) (but not among the referred species of *Parotosuchus*; Sulej and Niedźwiedzki, 2013, p. 67, 68) and Sidor et al. (2014a). Shishkin (2005) and Shishkin (2010) continues to advocate that both *Watsonisuchus magnus* and *Parotosuchus haughtoni* are synonyms of *Kestrosaurus dreyeri*. As there appears to be no consensus, *Watsonisuchus magnus*, *Parotosuchus haughtoni*, and *Kestrosaurus dreyeri* are retained as separate taxa in the database. Indeed, Eltink et al. (2017, Table 1) treats the three taxa as separate valid species.

Parotosuchus ptaszynskii is a valid species (Sulej and Niedźwiedzki, 2013) and is therefore added to the database. *Parotosuchus panteleevi* is treated as a valid species by Shishkin et al. (2000, p. 47), Shishkin and Sulej (2009), Fortuny et al. (2011a), and Sulej and Niedźwiedzki (2013). *Parotosuchus sequester* is treated as a valid species by Shishkin et al. (2000, p. 47), Sidor et al. (2007), Shishkin and Sulej (2009), and Sulej and Niedźwiedzki (2013). The two species are included in the database.

Damiani (2001) assigns *Kupferzellia wildi* to the genus *Tatrasuchus* and it is treated as such by Liu (2016). According to Schoch (2008b), however, it is different enough to warrant generic separation and it is treated as such also by Sulej (2009), Sues and Schoch (2013b), Schoch and Milner (2014, p. 109), Schoch (2015a, p. 203, 208, 209, 214), and Witzmann et al. (2016). *K. wildi* is therefore retained in the database within the genus *Kupferzellia*.

Jenkins et al. (1994) reported *Cyclotosaurus cf. posthumus* for the Fleming Fjord Formation of Greenland. Schoch and Milner (2000, p. 156) considered it to be a new species (see also Schoch, 2008b). Indeed, Marzola et al. (2017) assign it to the new species *Cyclotosaurus*. The taxon is treated accordingly.

Similarly, *Cyclotosaurus cf. posthumus* has also been reported for the Huai Hin Lat Formation of Thailand (Ingavat and Janvier, 1981). According to Schoch (2008b, p. 215) the specimen is "almost identical to *Cyclotosaurus posthumus*". Herein, it is treated as another occurrence of *Cyclotosaurus posthumus*.

Due to its palaeobiogeographical importance, the capitosauroid "Japanese taxon" reported by Nakajima and Schoch (2011) is added to the database.

The large specimen reported as *Eryosuchus* nov. spec. by Schoch and Milner (2000, p. 145) is retained in the database as a separate species.

Mastodonsaurus jaegeri is a subjective junior synonym of *Mastodonsaurus giganteus* (Moser and Schoch, 2007). It is treated accordingly.

Due to its palaeobiogeographic and stratigraphic relevance, the occurrence of *Mastodonsaurus* sp. from the Upper Bromsgrove Sandstone Formation of England, reported in Schoch and Milner (2000, p. 142), is retained in the database in a separate row. According to Damiani (2001, p. 438) the specimens might even belong to a different genus.

Sulej (2007) and Niedźwiedzki et al. (2016) treat *Bulgosuchus gargantua* as a valid taxon. Damiani (2001) assigned the taxon to Mastodonsauridae *incertae sedis*, while Schoch and Milner (2000, p. 157) assigned it to Capitosauroidea *incertae sedis*. Due to its uncertain status, the taxon is excluded from further analyses.

Eryosuchus antiquus is considered a *nomen dubium* by Schoch and Milner (2000, p. 145) and according to Damiani (2001) a specific separation does not seem warranted for the respective material. The taxon is treated accordingly by Niedźwiedzki et al. (2016), but note, that Ivakhnenko (2011, p. 1004) still treats it as a valid taxon. Herein, the taxon is not included in further analyses, following the interpretations of Schoch and Milner (2000, p. 145) and Damiani (2001).

Schoch and Milner (2000, p. 160) mentioned *Promastodonsaurus bellmanni* among indeterminate capitosauroid material while Damiani (2001) considered it to belong to Mastodonsauridae *incertae sedis*. Martínez et al. (2011, Supporting Online Material), Martínez et al. (2012), and Eltink et al. (2017) treat the taxon as being valid, but Martínez et al. (2012, Appendix 2) mention that the holotype requires further examination. Herein, the species is excluded from further analyses, awaiting additional descriptions of the material.

A.9 Trematosauria

Phylogeny: The strict consensus tree of Fernández-Coll et al. (2019, fig. 4a), which provides the scaffold for Trematosauridae (subsection A.9.5), is also used to add the taxon *Benthosuchus sushkini*. The position of *Benthosuchus sushkini* relative to Trematosauria and Trematosauroidea is determined by comparisons with Damiani and Yates (2003, fig. 3), Ruta et al. (2007, fig. 1), Sues and Schoch (2013a, fig. 5), and the comments in Schoch (2013).

Almasaurus habbazi is added according to the strict consensus tree of Sues and Schoch (2013a, fig. 5), which is based on an expanded character matrix of Schoch (2008a) and Schoch (2011b).

Capulomala is a stereospondyl which shares several features with Plagiosauridae and Rhytidosteidae (Warren et al., 2009). The genus *Capulomala* is therefore added to a polytomy including Rhytidosteidae and Brachyopoidea (which also includes Plagiosauridae herein; Schoch, 2013). *Capulomala panchetensis* and *Capulomala arcadiaensis* are assumed to be closely related and are added as sister taxa.

Based on morphological differences Novikov (2012b) hypothesizes the phylogenetic series *Benthosuchus gusevae–Benthosuchus korobkovi–Benthosuchus sushkini*. *Benthosuchus gusevae* and *Benthosuchus korobkovi* are added accordingly. The referral of *Benthosuchus bashkiricus* to the genus *Benthosuchus* is uncertain (Getmanov, 1989, p. 17; Schoch and Milner, 2000, p. 105). *Benthosuchus bashkiricus* is therefore added as the sister taxon of all other *Benthosuchus* species.

Qantas samarensis is the only member of the benthosuchid subfamily Qantasinae (Novikov, 2012a). *Qantas samarensis* is therefore added as the sister taxon of *Benthosuchus*.

Novikov (2012a) considers *Vyborosaurus mirus* another representative of Benthosuchinae. The formal supertree of Ruta et al. (2007, fig. 1) recovers *Vyborosaurus mirus* as the sister taxon of *Benthosuchus sushkini*. The source tree for the placement of *Vyborosaurus mirus* in Ruta et al. (2007, fig. 1) is Schoch and Milner (2000, fig. 88, 89), which has not been analyzed in a formal quantitative framework. *Vyborosaurus mirus* is added according to the phylogenetic hypothesis of Schoch and Milner (2000, fig. 89).

Yarengia perplexa has been considered a member of Yarengiidae and closely related to Benthosuchidae (Novikov, 1993; Shishkin and Welman, 1994) or alternatively a member of Benthosuchidae (Schoch and Milner, 2000, p. 105). *Vyborosaurus mirus* exhibits an "intermediate" morphology (Novikov, 1990; Novikov, 1993, p. 370) between *Benthosuchus* and *Yarengia* and has been suggested to represent "an ancestral form of *Yarengia*" (Novikov, 1990). The interpretation of yarengiids as descendants of benthosuchids is also mentioned by Shishkin and Welman (1994) and Shishkin et al. (2006). *Yarengia perplexa* is therefore added as the sister taxon of *Vyborosaurus mirus*.

Alpha taxonomy: *Laidleria gracilis* is restricted to either subzone A or B of the *Cynognathus* AZ (Damiani, 2004, fig. 2) and is treated accordingly.

Benthosuchus uralensis and *Benthosuchus bystrowi* are considered junior synonyms of *Benthosuchus sushkini* (Novikov, 2012b) and are treated accordingly. The holotype of *Benthosuchus uralensis* is probably not from the lower Vokhmian Gorizont (Shishkin et al., 2000, p. 49; Schoch and Milner, 2000, p. 104–105), but actually stems from the Rybinskian Gorizont (Novikov, 2012b). Indeed, *Benthosuchus sushkini* is restricted to the Rybinskian Gorizont (Novikov, 2012b). *Benthosuchus sushkini* (and therefore also *Benthosuchus uralensis*) is treated accordingly. *Benthosuchus bashkiricus* is considered a valid species (Novikov, 2012b) and is therefore added to the database.

A.9.1 Chigutisauridae

Phylogeny: Chigutisauridae (including the specimen described as *Compsocerops* sp. (Dias-da-Silva et al., 2012)) are added according to the strict consensus tree of Dias-da-Silva et al. (2012, fig. 6), which is based on an expanded character matrix of Warren and Marsicano (2000) (see Pacheco et al. (2017, fig. 5) for a slightly different placement of *Pelorocephalus tenax*).

The different species of *Pelorocephalus* are assumed to be sister taxa and are placed in a corresponding polytomy (see also McHugh, 2012, fig. 4).

Alpha taxonomy: *Compsocerops* sp., described by Dias-da-Silva et al. (2012), might represent a distinctive species (Dias-da-Silva et al., 2012; Dias-da-Silva and Dias, 2013) and is retained in the database due to its palaeobiogeographic importance.

A.9.2 Brachyopidae

Phylogeny: Brachyopidae are added according to the preferred phylogeny of Damiani and Kitching (2003, fig. 6B), which is based on an updated and expanded character matrix of Warren and Marsicano (2000). Dias-da-Silva et al. (2012) also used the character matrix of Warren and Marsicano (2000) (without the modifications of Damiani and Kitching, 2003) but were only able to recover a large polytomy of brachyopid taxa. The consensus tree of Warren et al. (2011, fig. 9A) is used to add the taxon *Bothriceps australis* and to improve the resolution for *Keratobrachyops australis* and the genus *Pelorocephalus* within Chigutisauridae.

The strict consensus tree of Dias-da-Silva et al. (2012, fig. 6), which provides the scaffold tree for Chigutisauridae (subsection A.9.1), is also used to add the brachyopid species (Schoch and Milner, 2014, p. 101–103; Ruta and Bolt, 2008) *Notobrachyops picketti*, *Batrachosuchus concordi*, *Platycepsion wilkinsoni*, and *Hadrokkosaurus bradyi* (see Maganuco et al. (2014, fig. 25) for a different phylogenetic position of *Hadrokkosaurus bradyi*).

Bathignathus poikilops is assumed to be closely related to *Bathignathus watsoni* and is added according to the strict consensus tree of McHugh (2012, fig. 4: left).

Alpha taxonomy: Schoch and Milner (2014, p. 101) treat *Notobrachyops picketti* as a valid taxon. It is treated accordingly in the database.

Schoch and Milner (2014, p. 102, 103) do not mention *Hadrokkosaurus bradyi* among the valid species of Brachyopidae and assign the referred specimens of the taxon from the Moenkopi Formation to *Vigilius wellesi*. The holotype of *Hadrokkosaurus bradyi*, however, is recognised as being different from the referred specimens. Here, *Hadrokkosaurus bradyi* is retained in the database following the analyses of Ruta and Bolt (2008). The referred specimens of *Hadrokkosaurus bradyi*, which have been reassigned to *Vigilius wellesi* (Warren and Marsicano, 2000; Schoch and Milner, 2014, p. 102, 103), are treated as specimens of *Vigilius wellesi*.

The type of *Batrachosuchus watsoni* has been assigned to the genus *Bathignathus* and specimens previously referred to *Batrachosuchus watsoni* are now considered to belong to *Bathignathus poikilops* (Damiani and Jeannot, 2002; Schoch and Milner, 2014, p. 98). The taxa are treated accordingly.

Gobiops desertus is a valid taxon (Schoch and Milner, 2014, p. 101) but is younger (Upper Jurassic) than the observed time interval and is therefore not added to the database. The same applies to *Sinobrachyops placenticephalus* (Schoch and Milner, 2014, p. 102).

A.9.3 Plagiosauridae

Phylogeny: *Plagiosternum granulosum* and *Megalophthalma ockerti* are added according to the (strict consensus) tree of Schoch et al. (2014, fig. 5), which is based on an expanded character matrix of Schoch (2008a).

Plagioscutum and *Plagiosuchus* are the only members of Plagiosuchinae (Schoch and Milner, 2014, p. 104, 105). *Plagioscutum* is therefore added as the sister taxon of *Plagiosuchus*. The two species of *Plagioscutum* are assumed to be sister taxa and are treated accordingly.

Plagiobatrachus australis is mentioned among Plagiosauridae *incertae sedis* (Schoch and Milner, 2014, p. 110). It is added as an early diverging member of Plagiosauridae in a polytomy with Plagiosuchinae and the clade Plagiosaurinae + Plagiosterninae (see also Warren, 1985, fig. 6).

Gerrothorax pulcherrimus and *Plagiosaurus depressus* are the only members of the subfamily Plagiosaurinae (Schoch and Milner, 2014, p. 106–108). *Plagiosaurus depressus* is therefore added as the sister taxon of *Gerrothorax pulcherrimus*.

Aranetsia improvisa and *Melanopelta antiqua* are members of Plagiosterninae (Schoch and Milner, 2014, p. 108). *Melanopelta antiqua* has been described as similar to *Plagiosternum* (Shishkin, 1967; Hellrung, 2003; Schoch and Milner, 2014, p. 108) Phylogenetic analyses recovered both *Aranetsia improvisa* and *Melanopelta antiqua* as early diverging members of the subfamily Plagiosterninae (Müller, 2005b) and both taxa are herein added accordingly.

Plagiorophus paraboliceps and *Plagiorophus danilovi* are assumed to be closely related and are added as sister taxa. *Plagiorophus* belongs to Plagiosterninae (Schoch and Milner, 2014, p. 109) and both *Plagiorophus paraboliceps* and *Plagiorophus danilovi* have been considered to be very similar to *Plagiosternum* (Shishkin, 1967) or have even been assigned to the genus *Plagiosternum* (Warren, 1995; Shishkin, 1987, p. 13). *Plagiorophus* is therefore added as the sister taxon of *Plagiosternum*.

Alpha taxonomy: *Gerrothorax pustuloglomeratus*, *Gerrothorax franconicus*, and *Gerrothorax rhaeticus* are junior synonyms of *Gerrothorax pulcherrimus* (Schoch and Milner, 2014, p. 106) and are treated accordingly.

Plagiosternum nanum is a junior synonym of *Plagiosternum granulosum* (Schoch and Milner, 2014, p. 109). The taxon is treated accordingly.

Plagiosternum danilovi is referred to the genus *Plagiorophus* (Schoch and Milner, 2014, p. 109) and is treated accordingly in the database.

Plagiorophus paraboliceps is a valid taxon (Schoch and Milner, 2014, p. 109) and is treated accordingly.

A.9.4 Rhytidosteidae

Phylogeny: The inner relationships of 'Rhytidosteidae' (Schoch, 2013) are based on the 50% majority rule consensus tree of Dias-da-Silva and Marsicano (2011, fig. 5B). This analysis has been chosen instead of the more recent one of Maganuco et al. (2014, fig. 25) as the latter has been ignored so far in the stereospondyl literature (except for a short mention in Fortuny et al., 2018) and thus cannot be considered to represent the current consensus on 'rhytidosteid' relationships. Dias-da-Silva and Marsicano (2011), on the other hand, has been cited multiple times in the literature, e.g., in Angielczyk and Ruta (2012), Schoch (2013), Schoch and Milner (2014), Kear et al. (2016), and Pacheco et al. (2017). Furthermore, Maganuco et al. (2014, p. 8) describe their phylogeny as "tentative" and the ratio between the number of characters and the number of taxa appears quite low (108 characters, 77 taxa), especially when compared with the analysis of Dias-da-Silva and Marsicano (2011) (87 characters, 28 taxa). Indeed, Maganuco et al. (2014, fig. 24–26) only report the 50% majority-rule consensus trees, as the strict consensus tree was "poorly resolved and showed many unresolved politomies [*sic*]" (Maganuco et al., 2014, p. 34). Awaiting further studies to confirm the results of Maganuco et al. (2014), Dias-da-Silva and Marsicano (2011, fig. 5B) is used instead and Maganuco et al. (2014, fig. 25) is only used for taxa which were not part of the analysis of Dias-da-Silva and Marsicano (2011), unless noted otherwise. The 'Rhytidosteidae' of Dias-da-Silva and Marsicano (2011, fig. 5B) are added according to the strict consensus tree of Sues and Schoch (2013a, fig. 5) (see also Pardo et al., 2017b, fig. 2C).

Deltasaurus pustulatus is added according to the cladogram of Cosgriff and Zawiskie (1979, fig. 12).

A.9.5 Trematosauridae

Phylogeny: Trematosauridae are added according to the strict consensus tree of Fernández-Coll et al. (2019, fig. 4a), which is based on an expanded character matrix of Fortuny et al. (2018). The character matrix of Fortuny et al. (2018) is based on a modified data matrix of Steyer (2002). The strict consensus tree of Fernández-Coll et al. (2019, fig. 4b), which excludes *Angusaurus succedaneus*, is used to improve the resolution for the taxa *Angusaurus dentatus*, *Angusaurus tsylmensis*, and *Prothoosuchus blomi*.

Tertremoides madagascariensis is added according to the majority-rule consensus tree of Maganuco et al. (2014, fig. 25).

Peltostega erici is added according to the strict consensus tree of Strapasson et al. (2015, fig. 7) (see also Sues and Schoch, 2013a, fig. 5), which also provides the scaffold tree for Temnospondyli (section A.2).

Calamops paludosus and *Hyperokynodon keuperinus* are added according to the strict consensus tree of Sues and Schoch (2013a, fig. 5), which is also used to add *Almasaurus habbazi* (see section A.9).

Erythrobatrachus noonkanbahnensis is added according to the strict consensus tree of Steyer (2002, text-fig. 7) (see Ruta et al. (2007, fig. 1) for a slightly different position of *Erythrobatrachus noonkanbahnensis*).

The formal supertree of Ruta et al. (2007, fig. 1) recovers *Bukobaja enigmatica* as the sister taxon of *Tertremoides madagascariensis*, with *Trematolestes hagdorni* as the sister taxon of the respective clade. The source tree (Schoch and Milner, 2000, fig. 88, 89) for this placement is not based on a formal quantitative phylogenetic analysis. Schoch (2006) mentions similarities between *Bukobaja enigmatica* and *Trematolestes hagdorni* but also considers the taxa as clearly distinct from each other. Following to phylogenetic hypothesis of Schoch and Milner (2000, fig. 89) *Bukobaja enigmatica* is added to a polytomy including *Tertremoides madagascariensis* and *Trematolestes hagdorni*.

The formal supertree of Ruta et al. (2007, fig. 1) recovers *Trematotegmen otschevi* as the sister taxon of *Angusaurus dentatus*. The source tree (Schoch and Milner, 2000, fig. 88, 89) for this placement is not based on a formal quantitative phylogenetic analysis. *Trematotegmen otschevi* is added as the sister taxon of the clade consisting of *Angusaurus* and *Prothoosuchus* according to the phylogenetic hypothesis of Schoch and Milner (2000, fig. 89) and the results of Fernández-Coll et al. (2019, fig. 4b).

Benthosphenus lozovskii has previously been considered a benthosuchid (Shishkin and Lozovsky, 1981; Schoch and Milner, 2000, p. 103). The formal supertree of Ruta et al. (2007, fig. 1) recovered it as the sister taxon of the clade *Benthosuchus sushkini* + *Vyborosaurus mirus*. The source tree (Schoch and Milner, 2000, fig. 88, 89) for this placement is not based on a formal quantitative phylogenetic analysis. Damiani (2001, p. 445) suggested that *Benthosphenus lozovskii* was closer to trematosaurids, especially to *Thoosuchus*. Indeed, Novikov (1994, p. 46) assigned *Benthosphenus lozovskii* to Thoosuchinae (which also include *Thoosuchus*, *Prothoosuchus*, and *Trematotegmen*; Novikov, 2007) and this interpretation was also followed by Novikov (2007). Furthermore, Benthosuchidae *sensu* Shishkin and Lozovsky (1981) did not include just *Benthosuchus* and *Benthosphenus*, but also *Thoosuchus*. *Benthosphenus lozovskii* is therefore added to a polytomy including *Thoosuchus yakovlevi* and the clade consisting of later diverging trematosaurines.

The different species of *Angusaurus* are assumed to be closely related. *Angusaurus weidenbaumi* is therefore added to a polytomy including *Angusaurus dentatus*, *Angusaurus succedaneus*, and the clade *Angusaurus tsylmensis* + *Prothoosuchus blomi*.

The different species of *Trematosaurus* are assumed to be closely related. As it is not completely clear, whether *Trematosaurus thuringiensis* is distinct from *Trematosaurus brauni* (Novikov, 2010), it is added as its sister taxon. Indeed, the holotype of *Trematosaurus thuringiensis* had initially been regarded as another specimen of *Trematosaurus brauni* and was only later on described as distinct (Werneburg, 1993). *Trematosaurus galae* is added as the sister taxon of the resulting clade *Trematosaurus brauni* + *Trematosaurus thuringiensis*.

The holotype of *Trematosuchoides africanus* was initially described as another specimen of *Trematosuchus sobeyi* (Shishkin and Welman, 1994) and is, indeed, considered to be most closely related to *Trematosuchus sobeyi* (Novikov, 2012a). *Trematosuchoides africanus* is therefore added as the sister taxon of *Trematosuchus sobeyi*.

Tirraturhinus smisseni has been described as a member of Trematosaurinae (Nield et al., 2006; Warren, 2012) and appears to be most closely related to *Tertrema acuta* (Nield et al., 2006). *Tirraturhinus smisseni* is therefore added as the sister taxon of *Tertrema*. Note, however, that it could potentially also belong to Qantasinae (Novikov, 2012a).

The specimen described as *Tertrema* sp. mentioned by Schoch and Milner (2000, p. 111) is assumed to be closely related to *Tertrema acuta* and is added as its sister taxon.

Microposaurus averyi is assumed to be closely related to *Microposaurus casei* and is added as its sister taxon.

Gonioglyptus longirostris is a member of Lonchorhynchinae (Welles, 1993; Schoch and Milner, 2000, p. 115), which also includes *Aphaneramma*, *Cosgriffius*, *Erythrobatrachus*, *Stoschiosaurus*, and *Wantzosaurus* (Schoch and Milner, 2000, p. 111–114). *Gonioglyptus* might be closely related to *Aphaneramma* (Tripathi, 1969; Fortuny et al., 2018) and is therefore added to a polytomy consisting of *Aphaneramma*, *Erythrobatrachus noonkanbahnensis*, and *Cosgriffius*. The two species of *Gonioglyptus* are assumed to be closely related and are added as sister taxa.

Alpha taxonomy: *Trematosaurus galae* is treated as a valid species by Novikov (2012a) and Sennikov (2012). It is therefore included in the database.

The specimen described as *Tertrema* sp. by Lehman (1979) and mentioned by Schoch and Milner (2000, p. 111) and Fortuny et al. (2018) is retained in the database due to its palaeobiogeographic importance.

Calamops paludosus is a valid taxon (Sues and Schoch, 2013a) and is treated accordingly in the database.

Schoch and Milner (2000, p. 115, 119, 120) also considered *Gonioglyptus longirostris* and *Indolyrocephalus huxleyi* as *nomina dubia*. Warren et al. (2009, Table 1), however, treat them as valid members of Trematosauridae (*Indolyrocephalus huxleyi* is treated as a member of the genus *Gonioglyptus*) and Das and Gupta (2012) also report them among the (valid) amphibians from the Panchet Formation. Yates and Sengupta (2002) treat *Gonioglyptus longirostris* as a valid species and Shishkin et al. (2006) also treat the genus *Gonioglyptus* as a valid taxon. *Gonioglyptus longirostris* and *Gonioglyptus huxleyi* (= *Indolyrocephalus huxleyi* of Schoch and Milner, 2000, p. 119, 120) are therefore herein treated as valid taxa and are retained in the database.

Aphaneramma kannemeyeri might belong to the genus *Trematosaurus* and is considered a *nomen dubium* (Damiani and Rubidge, 2003; Fortuny et al., 2018). It is therefore excluded from further analyses.

Glyptognathus fragilis, *Indolyrocephalus panchetensis* and *Panchetosaurus panchetensis* are considered *nomina dubia* by Schoch and Milner (2000, p. 115, 119) and Warren et al. (2009, Table 1) mention them among Trematosauridae *incertae sedis*. Das and Gupta (2012) do not mention these taxa among the (valid) amphibians of the Panchet Formation. Due to the taxonomic uncertainty surrounding these fragmentary (Schoch and Milner, 2000, p. 115, 119) taxa, they are excluded from further analyses.

A.9.6 Metoposauridae

Phylogeny: *Apachesaurus gregorii*, *Dutuitosaurus ouazzoui*, and *Arganasaurus lyazidi* are considered metoposaurids (Schoch and Milner, 2000, p. 121–123) and are added according to the strict consensus tree of McHugh (2012, fig. 4:left).

The 50% majority-rule consensus tree of Maganuco et al. (2014, fig. 25) is used to add the taxon *Koskinonodon perfectus* (see Pacheco et al. (2017, fig. 5) for a slightly different placement of the taxon).

Koskinonodon maleriensis is assumed to be closely related to *Koskinonodon perfectus* (but see Chakravorti and Sengupta, 2016) and is added as its sister taxon.

Metoposaurus algarvensis shares several features with *Metoposaurus diagnosticus*, which are not present in *Metoposaurus krasiejowensis* (Brusatte et al., 2015a). *Metoposaurus algarvensis* is therefore added as the sister taxon of *Metoposaurus diagnosticus*. Sulej (2007) considered *Metoposaurus diagnosticus* to be represented by the two subspecies *Metoposaurus diagnosticus diagnosticus* and *Metoposaurus diagnosticus krasiejowensis* indicating the close relationship between the two taxa. *Metoposaurus krasiejowensis* is therefore added as the sister taxon of the clade *Metoposaurus diagnosticus* + *Metoposaurus algarvensis* (see also Maganuco et al., 2014, fig. 25).

As it is currently not completely clear whether *M. bakeri* belongs to the genus *Metoposaurus* or not (Hunt, 1993; Schoch and Milner, 2000, p. 125; Sulej, 2002; Sulej, 2007; Sues and Olsen, 2015; Gee et al., 2017; Gee and Parker, 2017), *Metoposaurus bakeri* is added as the sister taxon of all other *Metoposaurus* species (see also McHugh, 2012, fig. 4).

Alpha taxonomy: Following Mueller (2007), the genus name of *Buettneria perfecta* is replaced by *Koskinonodon*, resulting in the taxon name *Koskinonodon perfectus*.

Brusatte et al. (2015a) explicitly refrain from commenting the systematic position of *Metoposaurus maleriensis*, which has been assigned to the genus *Koskinonodon* (Hunt, 1993; Schoch and Milner, 2000, p. 124; Sengupta, 2002; Mueller, 2007) but note that “the interclavicular sculpture appears to be consistent” (Brusatte et al., 2015a, p. e912988-3) with such a referral. In their conference abstract, Chakravorti and Sengupta (2016) propose a new genus name for the taxon. Awaiting the formal erection of the genus name, *M. maleriensis* is herein retained as ‘*Koskinonodon*’ *maleriensis*.

The stratigraphic range of *Apachesaurus gregorii* is updated using Schoch and Milner (2000, p. 121, 122), Martz (2008, p. 305), Parker and Martz (2011), Spielmann and Lucas (2012, p. 14), and Martz et al. (2012). *Apachesaurus gregorii* might be a growth stage of *Koskinonodon perfectus* but it could also represent a juvenile of another large metoposaurid (Gee et al., 2017; Gee and Parker, 2017). *Apachesaurus gregorii* is therefore retained in the database as a separate species.

Case (1931) described *Koskinonodon bakeri* (the original genus name, *Buettneria*, had to be replaced by *Koskinonodon*; Mueller, 2007). Hunt (1993) and Schoch and Milner (2000, p. 125) referred the taxon to the genus *Metoposaurus*. Sulej (2002) and Sulej (2007) followed Case (1931) in considering it a member of the genus *Koskinonodon*. Brusatte et al. (2015a) do not attempt to solve the alpha taxonomy of the species, but appear to implicitly follow Sulej (2007). On the other hand, McHugh (2012) and Sues and Olsen (2015) treat *Metoposaurus bakeri* as the correct taxon name. Herein, *Metoposaurus bakeri* is used as the valid taxon name, but it is acknowledged that further research is necessary to disentangle the alpha taxonomy of the species (see also Gee et al., 2017).

Metoposaurus krasiejowensis is considered a valid taxon by Brusatte et al. (2015a) and is therefore added to the database. Note that Sulej (2002) and Sulej (2007) considered *Metoposaurus diagnosticus* to be represented by the two subspecies *Metoposaurus diagnosticus diagnosticus* and *Metoposaurus diagnosticus krasiejowensis*. Brusatte et al. (2015a) treat them as different species and this interpretation is also followed by Gruntmejer et al. (2016). The taxa are treated accordingly.

Sulej (2002) and Brusatte et al. (2015a) follow Hunt (1993) in treating *Metoposaurus azerouali* a *nomen dubium*. The taxon is therefore excluded from further analyses. Note, however, that McHugh (2012, p. 27) treats *Metoposaurus azerouali* as a valid species.

Metoposaurus santaecrucis is probably a *nomen dubium* (Sulej, 2002) and Brusatte et al. (2015a) also report its uncertain status. The species is therefore excluded from further analyses.

A.10 Batrachia & Caecilia

Phylogeny: *Chinlestegophis jenkinsi*, *Rileymillerus cosgriffi*, *Eocaecilia micropodia*, and Batrachia (represented by *Triadobatrachus massinoti*) are added according to the consensus Bayesian tree of Pardo et al. (2017b, fig. 2C), which is mainly based on a combination of the character matrices of Schoch (2013) and Maddin et al. (2012). Note, that previous phylogenetic analyses (Maddin et al., 2012, fig. 4) recovered Lissamphibia as the monophyletic clade consisting of *Gerobatrachus* + Batrachia and Gymnophiona.

The alternative placement of *Eocaecilia micropodia* and Batrachia in Olori (2015, Supporting Information: S2) or Huttenlocker et al. (2013) would imply a polyphyletic origin of modern Lissamphibia, as current phylogenetic analyses recover lepospondyls as being closer to amniotes than to temnospondyls (e.g., Vallin and Laurin, 2004; Ruta and Coates, 2007; Marjanović and

Laurin, 2009, Electronic Supplementary Material 2: Supplementary Figure; Klembara et al., 2014; Olori, 2015, Supporting Information: S1; Clack et al., 2016; Marjanović and Laurin, 2019). The “polyphyly hypothesis” predicts Lissamphibia therefore to be paraphyletic with respect to Amniota (Marjanović and Laurin, 2013). This paraphyly is not supported by molecular analyses (Anderson, 2008; San Mauro, 2010; Pyron, 2011; Marjanović and Laurin, 2013; San Mauro et al., 2014; but see Fong et al., 2012). The “polyphyly hypothesis” is therefore not further considered herein.

Czatkobatrachus polonicus, *Notobatrachus reigi*, *Prosalirus bitis*, and *Vieraella herbstii* are added according to the strict consensus tree of Dong et al. (2013, fig. 8), which is based on a modified character matrix of Wang (2006) (see also Chen et al., 2016, fig. 3).

Latiscopus disjunctus has been considered to be similar to *Almasaurus habbazi* (Shishkin, 1980; Cosgriff and Zawiskie, 1979) and to particularly resemble *Rileymillerus cosgriffi* (Bolt and Chatterjee, 2000). *Latiscopus disjunctus* is therefore added as the sister taxon of *Rileymillerus cosgriffi*.

Alpha taxonomy: The strata of the Cañadón Asfalto Formation (Chubut Province, Argentina) in which *Asfaltomylos patagonicus* was found are assigned a middle to late Toarcian age (Cúneo et al., 2013; but see Hauser et al., 2017). Sediments, that are stratigraphically slightly lower within the Cañadón Asfalto Formation, yielded the remains of *Notobatrachus reigi* (Báez and Nicoli, 2008). Thus, this taxon is included in the database.

A.11 Chroniosuchia

Phylogeny: Chroniosucha are added according to the strict consensus tree of Witzmann and Schoch (2018, fig. 16), which is based on an updated character matrix of Clack and Klembara (2009). The ingroup relationships of Chroniosucha follow the strict consensus tree of Buchwitz et al. (2012, fig. 5B), which is based on a modified and expanded character matrix of Schoch et al. (2010).

Laosuchus naga is added according to the strict consensus tree of Arbez et al. (2019, fig. 10) as an early diverging chroniosuchian, taking also into account the strict consensus tree of Arbez et al. (2019, Supplemental material: fig. SI-2). Arbez et al. (2019, fig. 10) is based on an expanded character matrix of Schoch et al. (2010), while Arbez et al. (2019, Supplemental material: fig. SI-2) is based on an expanded character matrix of Buchwitz et al. (2012).

Phratochronis qilianensis is a chroniosuchid (Li and Cheng, 1999; Wang et al., 2008, p. 23, 24; Shishkin et al., 2014). Buchwitz et al. (2012) were not able to recover Chroniosuchidae as monophyletic in their favoured analysis (Buchwitz et al., 2012, fig. 5B), which is used here as the scaffold tree for Chroniosuchia. *Phratochronis qilianensis* is therefore added in a polytomy with *Madygenerpeton pustulatus*, *Laosuchus naga*, and the clade consisting of all other chroniosuchians. Note, however, that Buchwitz et al. (2012, Table 1) consider *Ingentidens corridoricus*, *Phratochronis qilianensis*, and *Bystrowiana sinica nomina dubia*.

The two species of *Chroniosuchus* are assumed to be sister taxa and are treated accordingly.

The bystrowianid *Jiyuanitectum flatum* is reported to be more basal than all other known members of Bystrowianidae (Liu et al., 2014b). It is added as the sister taxon to the clade consisting of all other bystrowianid taxa.

Ingentidens corridoricus is possibly a bystrowianid (Shishkin et al., 2014). It is added accordingly in a polytomy with the clades *Synesuchus* + *Bystrowiella* and *Bystrowiana* + *Axitectum* + *Dromotectum*.

Yumenerpeton yangi is a bystrowianid and member of Bystrowianinae (Jiang et al., 2017). The clade Bystrowianinae as assumed by Jiang et al. (2017) is not recovered by the phylogenetic analysis of Buchwitz et al. (2012, fig. 5). *Yumenerpeton yangi* shares synapomorphies with *Bystrowiella* and *Synesuchus* and most closely resembles *Synesuchus* (Jiang et al., 2017). *Yumenerpeton yangi* is therefore added as the sister taxon of *Synesuchus muravjevi*.

The two species of *Bystrowiana* are assumed to be sister taxa and are treated accordingly.

Vyushkoviana operta is added as the sister taxon of *Bystrowiana* following the hypothesized relationships of Shishkin et al. (2014, fig. 4).

The two species of *Axitectum* are assumed to be sister taxa and are treated accordingly.

Dromotectum spinosum and *Dromotectum abditum* are stratigraphically and palaeobiogeographically closer to each other (Shishkin et al., 2014) than to *Dromotectum largum* (Liu et al., 2014b). Herein they are therefore also assumed to be more closely related. *Dromotectum abditum* is added as the sister taxon of *Dromotectum spinosum* and *Dromotectum largum* is added as the sister taxon of the resulting clade.

Alpha taxonomy: *Bystrowiella schumanni* is treated as a valid taxon by, e.g., Buchwitz et al. (2012), Schoch (2014a, p. 39, 40, 203), Schoch (2015a), Martinelli et al. (2016a) and Danto et al. (2016). It is therefore added to the database.

Bystrowiana sinica is a valid species according to Liu et al. (2014b). It is therefore added to the database.

A.12 Seymouriamorpha

Phylogeny: The clade Seymouriamorpha is added according to the single most parsimonious tree of Klembara et al. (2014, fig. 8A), which is based on an expanded character matrix of Klembara and Ruta (2004b) with modifications introduced by Klembara (2011).

Microphon exiguus and *Leptoropha talonophora* are added according to the strict consensus tree of Ruta and Coates (2007, fig. 6).

The seymouriamorph *Kotlassia prima* (Klembara and Ruta, 2004b; Buchwitz et al., 2012) is added according to to the representation of all MPTs from analysis R4 of Marjanović and

Laurin (2019, fig. 14). Unlike Pawley (2006, fig. 62), Ruta and Coates (2007), and Pardo (2014, fig. 3.17–3.20) this is the only recent phylogenetic analysis that includes both *Kotlassia prima* and *Karpinskiosaurus secundus*.

Urumqia liudaowanensis was initially described as a discosauriscid (Zhang et al., 1984) and it is treated as such by Wang et al. (2008, p. 24), who urge, however, the importance of a re-description of the material. Ivakhnenko (1987, p. 21) synonymized the taxon with *Utegenia shpinari*. The synonymization is also mentioned by Klembara and Ruta (2004a) and Klembara (2005), who also stress the need for revision of the assigned material. Schoch (2014a, p. 38) treats *Urumqia liudaowanensis* as a basal seymouriamorph. Bulanov (2003, p. S10, S11) follows the interpretations of Ivakhnenko (1987), but considers it likely that *U. liudaowanensis* represents a distinct species (of the genus *Utegenia*) that is closely related to *Utegenia shpinari*. Following the interpretations of Ivakhnenko (1987, p. 21) and Bulanov (2003, p. S10, S11) *Urumqia liudaowanensis* is added as the sister as the sister taxon of *Utegenia shpinari*.

The three species of *Microphon* are assumed to be sister taxa and are added in a corresponding polytomy.

Biarmica tchudinovi is either a member of Leptorophidae (Novikov et al., 2000, p. 63; Bulanov, 2002a) or forms Leptorophinae together with *Leptoropha* within Kotlassiidae (Bulanov, 2003, p. S2; S12; Bulanov, 2014). *Biarmica tchudinovi* is therefore added as the sister taxon of *Leptoropha*.

Buzulukia butsuri is a karpinskiosaurid (Ivakhnenko, 1997a, p. 15; Novikov et al., 2000, p. 63; Tverdokhlebov et al., 2005, p. 51). It is very similar to *Kotlassia prima* (Tatarinov, 1972, p. 71–73) and, indeed, Ivakhnenko (2011) treats it as a member of Kotlassiidae. *Buzulukia butsuri* is therefore added as the sister taxon of *Kotlassia prima*.

According to Bulanov (2003, p. S2; S15–S17) *Rhinosauriscus jasykovii* and *Seymouria* form the family Seymouriidae. *Rhinosauriscus jasykovii* is therefore added as the sister taxon of *Seymouria*.

Seymouria baylorensis and *Seymouria sanjuanensis* are more closely related to each other than to *Seymouria grandis* (Berman and Martens, 1993; Berman et al., 1987, 2000). *Seymouria grandis* is therefore added as the sister taxon to the clade *Seymouria baylorensis* + *Seymouria sanjuanensis*.

Alpha taxonomy: Gorsky et al. (2003, Table 2; Table 6) report *Biarmica tchudinovi* only for the Urzhumian, but other publications report the taxon only for the Lower Kazanian of the Golyusherma Subassemblage (Ivakhnenko et al., 1997, p. 58; Golubev, 1997a, p. 49; Golubev, 2000; Bulanov, 2003, p. S6; S12; S25; S90; S95; fig. 52; Brocklehurst and Fröbisch, 2017; Olroyd and Sidor, 2017, Supplementary Information: Table 10). The stratigraphic range of *Biarmica tchudinovi* as reported in Gorsky et al. (2003, Table 2; Table 6) is therefore not further considered herein.

Rhipaeosaurus talonophorus is a seymouriamorph (Ivakhnenko, 1987, p. 39; Lee, 2000, p. 83, 84) and a synonym of *Leptoropha talonophora* (Ivakhnenko, 1987, p. 39; Tsuji et al., 2012). The taxon is treated accordingly.

Leptoropha novojilovi is a junior synonym of *Leptoropha talonophora* (Ivakhnenko, 1987, p. 39; Lee, 2000, p. 84; Bulanov, 2003, p. S12; S29). It is treated accordingly.

Leptoropha talonophora is reported for the Golyusherma Subassemblage (Olroyd and Sidor, 2017, Supplementary Information: Table 10) and is restricted to its type locality Shikhovo-Chirki (Bulanov, 2003, p. S29), from which *Platyoposaurus watsoni*, *Melosaurus platyrhinus*, and *Nyctiboetus kassini* have been described as well (Chudinov, 1955; Schoch and Milner, 2000, p. 61; Shishkin et al., 2000, p. 43; Bulanov, 2003, p. S90, S91). The stratigraphic range of *Leptoropha talonophora* is updated accordingly.

Raphanodon tverdochlebovae is a junior synonym of *Microphon exiguus* (Bulanov, 2014; Säilä, 2009; Bulanov, 2003, 2002b). The taxon is treated accordingly.

Bulanov (2003, p. S13) erected the two taxa *Microphon gracilis* and *Microphon arcanus* and Ivakhnenko (2008a, p. 977) and Bulanov (2014) also treat them as being valid. The two species are added to the database.

Discosauriscus austriacus is also known from France (Steyer et al., 2012) and the stratigraphic range of the taxon is updated accordingly. Štamberg and Zajíc (2008) and Opluštil et al. (2016, fig. 6) report the taxon also for the Ruprechtice horizon of the middle Broumov Formation, but this occurrence is not reported in the thorough description of the species of Klembara (1997) and, indeed, the first occurrence date (FOD) of *Discosauriscus austriacus* defines the *Discosauriscus austriacus* zone of Schneider and Werneburg (2012, p. 131), which spans the middle to upper Letovice Formation, but does not include the Broumov Formation. The occurrence from the Ruprechtice horizon is therefore not included in the database.

Discosauriscus pulcherrimus is also found in the Kochov and Bačov horizon (middle and upper Letovice Formation; Klembara, 1997; Štamberg and Zajíc, 2008, p. 178; Opluštil et al., 2017, fig. 6) and its stratigraphic range is updated accordingly.

Kuhn (1972, p. 35) mentions in error *Discosauriscus egregius* and *Discosauriscus purlensis* and actually meant *Dvinosaurus egregius* and *Dvinosaurus purlensis* (J. Klembara, pers. comm., 2016). The taxa are treated accordingly.

A kotlassid carapace that previously had been referred to *Buzulukia butsuri* was reassigned to *Chroniosuchus paradoxus* by Ivakhnenko (1997a, p. 15) (see also Buchwitz et al., 2012). The holotype of *Buzulukia butsuri*, however, is still treated as valid by Tverdokhlebov et al. (2005) and Ivakhnenko (2011). The taxon is treated accordingly.

Nycteroleter ultimus was moved to the genus *Raphanodon* by Ivakhnenko (1987, p. 41), then to *Karpinskiosaurus* by Bulanov (2002a). Klembara (2011) reassigns most of the specimens of *Karpinskiosaurus ultimus* to *Karpinskiosaurus* (see also Tsuji et al., 2012). Additional revision of the holotype of *Karpinskiosaurus ultimus* appears to be necessary to determine whether it actually represents a different species (Klembara, 2011). Herein the taxon is assumed to represent a junior synonym of *Karpinskiosaurus secundus*.

The occurrence of *Karpinskiosaurus* sp. from the Vozdvizhenka locality (Upper Tatarian Substage) reported in Bulanov (2003, p. S9) is excluded from the database. The occurrence of *Karpinskiosaurus ultimus* from Malokinelskaya Svita (Tverdokhlebov et al., 2005) is retained within *Karpinskiosaurus secundus* (see above).

The exact locality and formation, in which *Rhinosauriscus jasykovii* was found, is unknown (Tatarinov, 1972, p. 73). It might be from the Tatarian of Ul'yanovsk Region (Storrs et al., 2000, Table 11.1), potentially Zone I or II (Romer, 1947). The taxon is treated accordingly.

Following Vaughn (1966) and Olson (1980), Berman et al. (1987) consider specimens of *Seymouria* from the Archer City Formation (former Putnam and Admiral Formation; Lucas, 2018) too incomplete to safely assign to species. Indeed, both Vaughn (1966, p. 609) and Olson (1980, p. 139; 149) refrain from assigning these specimens to a species of *Seymouria baylorensis*, but also note that they resemble *Seymouria baylorensis*. Olson (1980, p. 137) also considers a specimen from the younger portion of the Wichita Group (former Belle Plains Formation; Lucas, 2018) to be safely assignable to *Seymouria baylorensis*. Sander (1989, Table II) does report the species *Seymouria baylorensis* for the Archer City Formation (former Putnam Formation). The specimens known from the former Putnam, Admiral, and Belle Plains formations are therefore retained in the database for *Seymouria baylorensis*, but it is acknowledged, that these assignments can only be tentative.

Kuhn (1972, p. 25) reports *Seymouria baylorensis* from the "Upper Clear Fork Beds", but this is probably a mistake resulting from translating Romer (1947, p. 282). *Seymouria baylorensis* is mainly known from the Arroyo Formation (lower part of the Clear Fork Group; Lucas, 2018) and its youngest occurrence is a questionably assigned specimen from the lower Vale Formation (middle part of the Clear Fork Group; Olson, 1979; Olson, 1980; Olson and Mead, 1982, p. 137–139; Berman et al., 1987, fig. 5). The stratigraphic range of the taxon is updated accordingly.

According to Kuhn (1972, p. 40) *Waggoneria knoxensis* belongs to the family Waggonerida within Seymouriamorpha. On the other hand, Holmes (1984) explicitly excludes the taxon from Seymouriamorpha and recognizes affinities with Captorhinidae. Due to the uncertain status of the taxon, it is excluded from further analyses.

A.13 Lepospondyli

Phylogeny: Lepospondyli (except for *Eocaecilia micropodia*) are added according to the strict consensus tree of Olori (2015, Supporting Information: S2), which is based on a re-analysed character matrix of Huttenlocker et al. (2013). The latter is based on the modified character matrix of Anderson (2001), Anderson (2007), and Anderson et al. (2008).

Solenodonsaurus janenschi, *Acherontiscus caledoniae*, *Dolichopareias disjectus*, and *Ade-*

lospondylus watsoni are added according to the strict consensus tree of Danto et al. (2012, fig. 9), which is based on an expanded character matrix of Ruta et al. (2003b).

Hyloplesion longicostatum is added according to the strict consensus tree of Olori (2015, Supporting Information: S3), which is based on a modified and expanded character matrix of Huttenlocker et al. (2013).

The strict consensus tree of Anderson (2007, fig. 5.5), which also provides the placement of a few urocordylids (subsection A.13.1), is used to add the unnamed 'microsaur' from Mazon Creek (FMNH PR 981) (Carroll and Gaskill, 1978, p. 134–138; Carroll, 1998b, p. 58, 59) and *Odonterpeton triangulare*. For a slightly different placement of *Odonterpeton triangulare* see Ruta and Coates (2007, fig. 7) and Danto et al. (2012, fig. 9). Ruta et al. (2003a, fig. 2) also gives a slightly different arrangement of *Odonterpeton triangulare*, *Hyloplesion longicostatum*, *Microbrachis pelikani*, and the Mazon Creek 'microsaur'.

The diplocaulid *Ductilodon pruitti* (Gubin, 1999) is added according to the strict consensus tree of Pardo (2014, fig. 3.17), which is based on an expanded character matrix of Huttenlocker et al. (2013).

Diplocaulus minimus and *Diplocaulus primus* are added according to the single most parsimonious tree of Germain (2010, fig. 6), who does not follow Milner (1996) and Bossy and Milner (1998, p. 127) in treating *D. primus* another species of *Diplocaulus* but retains it within the genus *Peronedon*.

Crinodon limnophyes is added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14).

Trihecaton howardinus is assigned to the monospecific Trihecatontidae (Carroll, 1998b, p. 51–54), which might be closely related to Ostodolepidae, although differences are noted (Carroll and Gaskill, 1978, p. 102, 103). Ostodolepidae *sensu lato* are currently not recovered as a monophyletic clade (Huttenlocker et al., 2013). *Trihecaton howardinus* is added according to the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14) taking into account its hypothesized closer relationship with Ostodolepidae (see also Marjanović and Laurin, 2019, fig. 19).

The strict consensus tree of Anderson (2007, fig. 5.5) recovers the taxon *Llistrofus pricei* as the sister taxon of *Saxonerpeton geinitzi*. According to Bolt and Rieppel (2009), however, only *Llistrofus pricei* and *Hapsidopareion lepton* can be confidently assigned to Hapsidopareiidae (= Hapsidopareiontidae; see Marjanović and Laurin, 2019). The placement of *Llistrofus pricei* in Anderson (2007, fig. 5.5), which contradicts the assessment of Bolt and Rieppel (2009), is probably caused by several problematic character states (Bolt and Rieppel, 2009). *Llistrofus pricei* is therefore added as the sister taxon of *Hapsidopareion lepton*, following the single most parsimonious tree of Anderson (2001, fig. 6) (see also Ruta et al., 2003a, fig. 2). Such a placement of *Saxonerpeton geinitzi* (and of *Llistrofus pricei*) leaves it open, whether *Saxonerpeton geinitzi* belongs to Hapsidopareiidae or not.

Altenglanerpeton schroederi and *Sparodus validus* are added according to the strict consensus tree of Glienke (2012, fig. 7), which is based on a modified character matrix of Anderson (2007).

Brachystelechidae are added according to the single most parsimonious tree of Glienke (2015, fig. 14).

Aletrimyti gaskillae and *Dvellecanus carrolli* are added according to the majority rule consensus tree of Pardo et al. (2017a, Extended Data fig. 7a). The same tree is also used to improve the resolution of the supertree for *Nannaroter mckinziei*.

The 'microsaur' *Kirktonecta milnerae* most closely resembles *Microbrachis pelikani*, *Asaphestera intermedia*, *Saxonerpeton geinitzi*, *Hyloplesion longicostatum*, and *Llistrofus pricei* (Clack, 2011b). *Kirktonecta milnerae* represents the earliest appearance of 'microsaurs' in the fossil record (Clack, 2011b; Clack and Milner, 2015, p. 70, 71). Considering its resemblance to other 'microsaurs' and its stratigraphic range, *Kirktonecta milnerae* is added as an early diverging lepospondyl, part of a polytomy consisting of *Utaherpeton franklini* and the clade consisting of later diverging lepospondyls.

Palaeomolgophis scoticus is an adelogyrinid/adelospondyl (Andrews and Carroll, 1991; Carroll and Andrews, 1998, p. 160; Ruta et al., 2003b; Laurin, 2004, fig. 6; Carroll, 2012) and is therefore added to a polytomy including *Adelospondylus watsoni* and the clade *Adelogyrinus simorhynchus* + *Dolichopareias disjectus*.

The 50% majority-rule consensus tree of the supertree analysis I of Ruta et al. (2003a, fig. 2) is used to add *Sauravus* (see the hypothesized relationships in Milner (1980, fig. 6) for the source tree; see also Milner, 1993, fig. 3).

The two species of *Sauravus* are assumed to be sister taxa and are treated accordingly. The same applies to the two species of *Scincosaurus*, those of *Brachydectes*, and those of *Keraterpeton*.

Except for *Diplocaulus minimus* and *Diplocaulus primus* which are added according to Germain (2010, fig. 6) (see above), all other species of *Diplocaulus* are assumed to be closely related and are added accordingly. *Diplocaulus parvus* resembles *Diplocaulus recurvatus* in all features except for the adult ratio of skull length to skull width (Olson, 1972a; Bossy and Milner, 1998, p. 127; Germain, 2010) and is therefore added as its sister taxon. *Diplocaulus recurvatus* is quite similar to *Diplocaulus magnicornis* (Olson, 1952; Bossy and Milner, 1998; Germain, 2010). The clade *Diplocaulus recurvatus* + *Diplocaulus parvus* is therefore added as the sister taxon of *Diplocaulus magnicornis*. The resulting clade is added in polytomy with *Diplocaulus salamandroides* and *Diplocaulus brevirostris*.

Boii crassidens is a tuditanid (Carroll, 1998b, p. 37–39; Marjanović and Laurin, 2008, Appendix-Table 1), which is probably more closely related to *Asaphestera intermedia* than to *Tuditanus punctulatus* (Carroll and Gaskill, 1978, p. 26). *Boii crassidens* is therefore added as sister taxon of *Asaphestera intermedia*.

Ricnodon copei has been considered a member of Hapsidopareiidae (Carroll and Gaskill, 1978, p. 39–41; Carroll, 1998b, p. 42), but this assignment is uncertain (Carroll, 1998b, p. 42; Bolt and

Rieppel, 2009). *Ricnodon copei* is here added to a polytomy including *Saxonerpeton geinitzi* and the clade *Llistrofus pricei* + *Hapsidopareion lepton*. *Ricnodon* sp., based on specimens from the Joggins Formation of Canada (Carroll and Gaskill, 1978, p. 40, 41; Carroll, 1998b, p. 42), is herein considered to be sister taxon of *Ricnodon copei* and is treated accordingly.

The family Pantylidae consists of *Trachystegos megalodon* and *Pantylus cordatus* (Carroll and Gaskill, 1978, p. 53, 54; Carroll, 1998b, p. 42). A close relationship of the two taxa is also mentioned by Carroll (2009, p. 165) and Schoch (2014a, p. 43). *Trachystegos megalodon* is therefore added as the sister taxon of *Pantylus cordatus*.

Huttenlocker et al. (2013) recovered a monophyletic Ostodolepidae *sensu stricto*, including only *Pelodosotis elongatum* and *Micraroter erythrogeios*, while other presumed ostodolepids (*Nannaroter mckinziei*, *Tambaroter carrolli*) were found as paraphyletic. Such relationships are also found by Olori (2015, Supporting Information: S2), which is used as the scaffold tree for Lepospondyli. *Ostodolepis brevispinatus* is a member of Ostodolepidae (Carroll and Gaskill, 1978, p. 76, 77; Carroll, 1998b, p. 50, 51; Henrici et al., 2011). A nearly complete skeleton, that previously had been referred to *Ostodolepis brevispinatus* (Case, 1929), represents now the type specimen of *Pelodosotis elongatum* (Carroll and Gaskill, 1978, p. 77), indicating a close relationship. *Ostodolepis brevispinatus* is therefore added as the sister taxon of *Pelodosotis elongatum*.

Alpha taxonomy: The unnamed ‘microsaur’ from Mazon Creek (FMNH PR 981), described by Carroll and Gaskill (1978, p. 134–138) and Carroll (1998b, p. 58, 59) and also mentioned by Anderson (2001, Table 1) and Ruta et al. (2003b) is retained in the database as a separate taxon due to its palaeobiogeographic importance.

Pardo and Anderson (2016) report specimens of *Brachydectes newberryi* from the Speiser Shale and the Eskridge Shale. The stratigraphic range of the taxon is updated accordingly. Pardo and Anderson (2016) also provisionally synonymized all members of Molgophida/Coctynidae with *Brachydectes newberryi*, but also state that the presence of multiple species of molgophids is likely, as specimens with quite different numbers of trunk vertebrae are known. Herein, *Molgophis macrurus* and *Pleuroptyx clavatus* are treated as junior synonyms of *Brachydectes newberryi* as they appear to form an ontogenetic series, with *Pleuroptyx clavatus* representing the adult form (J. D. Pardo, pers. comm., 2016). The specimen referred to *Brachydectes* sp. by Wellstead (1998, p. 144), initially described as *Lysorophus minutus* by Romer (1952), from the Greene Formation of West Virginia probably also represents *Brachydectes newberryi* (J. D. Pardo, pers. comm., 2016) and is treated accordingly. *Brachydectes elongatus* is probably a separate species (J. D. Pardo, pers. comm., 2016) and is treated accordingly.

Batrachiderpeton lineatum is a junior synonym of *Batrachiderpeton reticulatum* according to Bossy and Milner (1998, p. 124). It is treated accordingly.

The specimens described as *Ricnodon* sp. from the Joggins Formation of Canada (Carroll and Gaskill, 1978, p. 40, 41; Carroll, 1998b, p. 42) are retained in the database as a separate taxon due to their stratigraphic and palaeobiogeographic importance.

Diploceraspis conemaughensis is a junior synonym of *Diploceraspis burkei* (Bossy and Milner, 1998, p. 128). The stratigraphic range of the taxon is updated accordingly.

May and Hall (2016) report *Diploceraspis* from the Wellington Formation of Oklahoma. It might represent a new species, but May and Hall (2016) were only able to identify the specimens as *Diploceraspis* sp. The occurrence is therefore not included in the database.

The specimens assigned to *Lysorophus dunkardensis* are not diagnostic (J. D. Pardo, pers. comm., 2016) and the taxon is herein treated as a *nomen dubium*. *Lysorophus tricarinatus* is a *nomen vanum* (J. D. Pardo, pers. comm., 2016) and is treated accordingly.

Carroll (1964b) described *Archerpeton anthracos* as a captorhinomorph, but according to Reisz and Modesto (1996) it does not represent an amniote but is actually a 'microsaur'. This interpretation was followed by, e.g., Falcon-Lang et al. (2006, Table 2), but Ward et al. (2006, Supporting Appendix) still treat the taxon as an amniote. Similarly, Healy et al. (2014) treat *Archerpeton anthracos* as the oldest amniote and use it to calibrate their tree. Neither Ward et al. (2006) nor Healy et al. (2014), however, cite Reisz and Modesto (1996). Recent analyses do not recover Microsauria as monophyletic (Ruta et al., 2003b; Ruta and Coates, 2007; Anderson, 2001, 2007; Huttenlocker et al., 2013) and Reisz and Modesto (1996) did not attempt to assign *Archerpeton anthracos* to one of the 'microsaurian' groups because of the fragmentary nature of the holotype. Due to the uncertain phylogenetic position of *Archerpeton anthracos*, the taxon is not included in further analyses.

Cymatorhiza kittsi is listed in Olroyd and Sidor (2017, Supplementary Information: Table 16) and is mentioned in Lucas (2018) and Brocklehurst et al. (2017), but it is based on fragmentary remains and its assignment to 'microsaurs' is dubious (Carroll, 1998b, p. 67). The taxon is therefore not included in further analyses.

A.13.1 Urocordylidae

Phylogeny: *Lepterpeton dobbsii* is added according to the preferred most parsimonious tree of Anderson (2001). The position of the taxon is not shown in the included figures but the species is reported as being "placed [...] as a basal sauropleurine nectridean" (Anderson, 2001, p. 178).

Crossotelos annulatus and *Ctenerpeton remex* are added according to the strict consensus tree of Milner and Ruta (2009, text-fig. 10).

Sauropleura pectinata and *Sauropleura bairdi* are added according to the strict consensus tree of Anderson (2007, fig. 5.5).

Montcellia, *Lepterpeton*, *Crossotelos*, and *Sauropleura* form the subfamily Sauropleurinae (Bossy and Milner, 1998, p. 109–116). *Montcellia longicaudata* is therefore added to a polytomy including *Lepterpeton*, *Crossotelos* and *Sauropleura*.

A.13.2 Aïstopoda

Phylogeny: Aïstopoda are added according to the strict consensus tree of Germain (2008, fig. 4), which is based on an expanded character matrix of Anderson (2003a).

The two species of *Ophiderpeton* are assumed to be sister taxa and are treated accordingly.

The two species of *Oestocephalus* are assumed to be sister taxa and are treated accordingly.

Sillerpeton permianum might be the sister taxon of the genus *Phlegethontia* (Germain, 2008) and is added according to the proposed relationship in Germain (2008, fig. 4).

Alpha taxonomy: Anderson (2003b) considered *Oestocephalus vicinum* and *Oestocephalus granulosum* to be junior synonyms of *Oestocephalus amphiuminum*. Carroll (1998a, p. 180) kept these taxa separate, but accepted their synonymy in Carroll (2009, p. 133). Herein, the interpretation of Anderson (2003b) is followed and the taxa are treated accordingly. Note, however, that Štamberg and Zajíc (2008, p. 181) do not consider these taxa to be synonymous.

Aornerpeton mazonensis has been considered a junior synonym of *Phlegethontia longissima* (Hook, 2000; Anderson, 2002a) and a referred specimen has been used to erect the taxon *Pseudophlegethontia turnbullorum* (Anderson, 2003a). This interpretation is followed herein and the taxa are treated accordingly. Note, however, that Schultze (2013) and Benton (2015c, p. 102, 103) still treat *Aornerpeton mazonensis* as a valid separate taxon.

The occurrence of *Phlegethontia* sp. described by Germain (2008) from Montceau-les-Mines in France is retained in the database due to its stratigraphic importance. It is herein assumed to represent another occurrence of *Phlegethontia longissima* as this species is already known from Europe.

Carroll (1998a, p. 180) mentions ‘*Ophiderpeton*’ *swisshelmense* among Ophiderpetontidae *incertae sedis*, while Anderson et al. (2003) consider it to belong to Aïstopoda *incertae sedis* (see also Anderson, 2003b). Due to the uncertain assignment of the taxon, it is excluded from further analyses.

A.13.3 Gymnarthridae

Phylogeny: The 50% majority-rule consensus tree of the supertree analysis I of Ruta et al. (2003a, fig. 2) is used to resolve the polytomy consisting of *Pariotichus brachyops*, *Euryodus*, and *Cardiocephalus*. The same tree is also used to add the taxon *Leiocephalikon problematicum* (see again the phylogenetic scheme of Schultze and Foreman, 1981, fig. 6 for the source tree).

Hylerpeton dawsoni is a gymnarthridid (Carroll, 1998b, p. 50; Marjanović and Laurin, 2008, Appendix-Table 1), which is poorly known but resembles *Cardiocephalus* and *Leiocephalikon* in a few characters (Carroll and Gaskill, 1978, p. 73, 74). *Hylerpeton dawsoni* is added to a polytomy including *Leiocephalikon problematicum* and the clade consisting of all the other gymnarthridids.

The gymnarthrid *Elfridia bulbidens* is similar to *Hylerpeton dawsoni* (Carroll, 1998b, p. 50) and appears to be less closely related to *Cardiocephalus* and *Euryodus* (Thayer, 1985). *Elfridia bulbidens* is therefore added as the sister taxon of *Hylerpeton dawsoni*.

Alpha taxonomy: *Euryodus bonneri* has been assigned to the new genus *Proxilodon* (Huttenlocker et al., 2013) and is treated accordingly.

Material that previously had been referred to *Euryodus primus* is now assigned to *Opisthodontosaurus carrolli* (Reisz et al., 2015). The taxa are treated accordingly.

Carroll and Gaskill (1978, p. 57–61) erected the species *Cardiocephalus peabodyi*. Schultze and Foreman (1981) reassigned the species to *Euryodus*. Carroll (1998b, p. 44) did not follow this reassignment and kept the original generic designation. Indeed, in recent phylogenetic analyses *C. peabodyi* is recovered as the sister taxon of *Cardiocephalus sternbergi* (e.g., Anderson et al., 2008, fig. 4; Huttenlocker et al., 2013, fig. 8). The taxon is treated accordingly.

A.14 Diadectomorpha

Phylogeny: Diadectomorpha are added according to the strict consensus tree of Liu and Bever (2015, fig. 2) (see also Liu and Bever, 2015, Supplementary Materials: fig. S1), which is based on an expanded character matrix of Kissel and Reisz (2004).

Diadectes sanmiguelensis, *Diadectes absitus*, *Diadectes tenuitectus* are added according to the most parsimonious tree C of Kissel (2010, fig. 28C). The strict consensus tree of Kissel (2010, fig. 28A) is not used, as Liu and Bever (2015, fig. 2) assume in their analysis that both *Diadectes sideropelicus* and *Diadectes tenuitectus* are part of a monophyletic genus *Diadectes*.

The two species of *Limnoscelis* are assumed to be sister taxa and are treated accordingly.

The two species of *Desmatodon* are assumed to be sister taxa and are treated accordingly.

According to Berman et al. (1998) the vertebrae of the German diadectid *Phanerosaurus naumanni* are very similar to those of *Diadectes*. Kissel (2010, p. 27) notes both similarities and differences between *Phanerosaurus naumanni* and *Diadectes absitus*, which is also known from Germany. *Phanerosaurus naumanni* is therefore added in a polytomy with *Diadectes absitus* and the clade consisting of *Diasparactus zenos* and later diverging diadectids.

According to Kissel (2010, p. 36, 37) *Diadectes lentus* and *Diadectes carinatus* do not differ from *Diadectes sideropelicus* in any of the characters used in the phylogenetic analysis of Kissel (2010, fig. 28). *Diadectes lentus* also does not differ from *Diasparactus zenos* (Kissel, 2010, p. 36). As both *Diadectes lentus* and *Diadectes carinatus* are retained as species of the genus *Diadectes* (Kissel, 2010, p. 84, 85), they are added in a polytomy with *Diadectes sideropelicus*.

Alpha taxonomy: *Tseajaia campi* (= *Tseajaia cf. campi* in Berman (1993) and Berman et al. (2015)) is also known from the El Cobre Canyon Formation of New Mexico (Berman et al., 1992;

Berman, 1993; Lucas, 2006; Berman et al., 2015). The stratigraphic range of the taxon is updated accordingly.

In his PhD thesis Kissel (2010, p. 72–74) assigned *Diadectes sanmiguelensis* to a new genus. Herein, the old genus name is still used, awaiting the formal erection of the new taxon. The assignment of specimens, however, follows Kissel (2010, p. 72–74).

Desmatodon hollandi is known from both Pennsylvania and New Mexico, but not from Illinois (Kissel, 2010, p. 74, 75). The taxon is recorded accordingly in the database.

Berman et al. (2014) treat *Diadectes absitus* as a valid taxon and it is therefore added to the database. In his PhD thesis Kissel (2010, p. 77) assigned the species to a new genus. Herein, the old genus name is used, awaiting the formal erection of the new genus name.

Diadectes tenuitectus (misspelled as *Diadectes tenuitectes*) is treated as a valid taxon by Kissel (2010, p. 80, 81). It is therefore added to the database. *Bolbodon tenuitectus* and *Diadectoides cretin* are considered junior synonyms of the taxon (Kissel, 2010, p. 80) and are treated accordingly.

Olson (1947, p. 8) reassigned *Animasaurus carinatus* to the genus *Diadectes* and this interpretation is also followed by Kissel (2010, p. 85). The taxon is treated accordingly and is added to the database.

Romer (1956b, p. 486) and Kuhn (1972, p. 55) treat *Metarmosaurus* as a junior synonym of *Diadectes*. Kissel (2010, p. 125) reports it as a taxon with “uncertain affinities”. Herein it is assumed that *Metarmosaurus fossatus* is a junior synonym of *Diadectes sideropelicus* and the taxon is treated accordingly.

Diadectes sideropelicus is also known from the Markley Formation but appears to be restricted to its Permian part (Kissel, 2010, p. 99; 121; see also Liu and Bever, 2015, fig. 2). The data row of *Diadectes sideropelicus* is updated accordingly.

Nothodon lentus is valid as *Diadectes lentus* (Kissel, 2010, p. 84) and is known from various quarries in the El Cobre Canyon Formation of New Mexico (Lucas et al., 2005a,b; Berman et al., 2015). The taxon is treated accordingly. Kuhn (1972, p. 59) reports *Diadectes* (*Bolbodon*) *lentus* for the Clear Fork Group/Formation. The description of *Bolbodon lentus* in Kuhn (1972, p. 59) appears to be an abbreviated translation of the description that Cope (1896, p. 134) gives for *Bolbodon tenuitectus*. The species name reported by Kuhn (1972, p. 59) was therefore probably just a mistake, and he actually meant *Bolbodon tenuitectus*. *Diadectes lentus*, however, is indeed a valid taxon (see above), that has been erected by Marsh (1878) as *Nothodon lentus*.

Kissel (2010, p. 82, 83) treats *Diasparactus zenos* as another species of the genus *Diadectes* but Liu and Bever (2015) still treat the genus name *Diasparactus* as valid. The taxon is therefore retained in the database as *Diasparactus zenos*.

Limnosceloides dunkardensis, *Limnosceloides brachycoles* and *Limnoscelops longifemur* are *nomina dubia* according to Wideman et al. (2005) and this interpretation is also followed by Lucas (2013b) and Pelletier (2014). The taxa are treated accordingly.

A.15 ‘Basal’ Synapsida

Phylogeny: The scaffold for basal, ‘pelycosaurian’-grade synapsids is provided by the reduced consensus tree of Brocklehurst et al. (2016a, fig. 10B), which is based on an expanded and modified character matrix of Reisz and Fröbisch (2014). The dataset of Reisz and Fröbisch (2014) is based on that provided by Benson (2012).

Alpha taxonomy: Reisz (2014) considers *Protoclepsydrops haplous* to be a ‘pelycosaur’-grade synapsid. The precise phylogenetic relationships are uncertain (Reisz, 2014) and indeed it has been suggested previously that it does not even represent a synapsid (Reisz, 1986, p. 84). Therefore, it is excluded from the database.

A.15.1 Caseasauria

Phylogeny: The scaffold of Caseidae is mainly based on the single most parsimonious tree of Brocklehurst et al. (2016b, fig. 2A), who used a modified dataset of Romano and Nicosia (2015). Note, however, the problematic position of *Angelosaurus greeni* and *Trichasaurus texensis* (Brocklehurst et al., 2016b). The latter is being added using a different phylogenetic analysis (see below).

The taxa *Eocasea martini*, *Callibrachion gaudryi*, *Datheosaurus macrourus*, and *Trichasaurus texensis* are added according to the reduced consensus tree of Brocklehurst et al. (2016a, fig. 10B), which provides the scaffold tree for ‘pelycosaurian’-grade synapsids (see section A.15).

Phreatophasma aenigmaticum is added according to the strict consensus tree of Brocklehurst and Fröbisch (2017, fig. 4b), which is based on an updated and expanded character matrix (missing data inferred using iterative imputation) of Brocklehurst et al. (2016b).

Alierasaurus ronchii is added according to the single most parsimonious tree of Romano et al. (2017, fig. 9.1), which is based on an expanded dataset of Romano and Nicosia (2015).

Alpha taxonomy: *Mycterosaurus smithae* is assigned to the new genus *Vaughnictis* (Brocklehurst et al., 2016a) and is treated accordingly.

Callibrachion gaudryi and *Datheosaurus macrourus* can be considered valid taxa (Spindler et al., 2016) and are therefore added to the database.

Phreatophasma aenigmaticum is considered a valid taxon (Brocklehurst and Fröbisch, 2017) and is treated accordingly in the database.

Benson (2012), Romano and Nicosia (2014), and Romano and Nicosia (2015) treat *Trichasaurus texensis* as a valid taxon and it is herein treated accordingly. Note, however, that the phylogenetic position of the taxon is uncertain. Benson (2012) recovers it among Caseidae while Romano and Nicosia (2015, fig. 1A) obtain a clade consisting of *Trichasaurus texensis* + *Angelosaurus greeni* and *Edaphosaurus pogonias*. Ignoring the unusual position of *Angelosaurus greeni* outside of Caseidae (but see Brocklehurst et al., 2016b), this could indicate that *Trichasaurus texensis* represents an edaphosaurid, as already suspected by Olson (1968). The “typical” caseid characters of *Trichasaurus texensis* as reported by Benson (2012) can also be found in non-caseid taxa according to Romano and Nicosia (2015). Brocklehurst et al. (2016a, fig. 16) recovers it again among Caseidae (based on an expanded character matrix of Benson, 2012). Similarly, Brocklehurst et al. (2016b) also recover the taxon as a member of Caseidae (but see their methodological discussions). Herein, *Trichasaurus texensis* is treated as a caseid, but it is acknowledged, that additional analyses are necessary to constrain the phylogenetic position of the taxon.

The specimens described by Ronchi et al. (2011) as *Cotylorhynchus* sp. are now considered to represent the new taxon *Alierasaurus ronchii* Romano and Nicosia (2014) and are therefore treated accordingly.

Casea halselli is a *nomen dubium* according to Romano and Nicosia (2015) and is therefore excluded from the database.

A.15.2 Varanopidae

Phylogeny: The inner relationships of Varanopidae are based on the strict consensus tree of Spindler et al. (2018, fig. 30).

Ford and Benson (2019, fig. 23) recover *Orovenator mayorum* as the earliest diverging member of Varanopidae and the clade itself as belonging to Diapsida. The authors, themselves, however, consider it necessary to further test this unexpected result (Ford and Benson, 2019, p. 232). The results of Ford and Benson (2019) are therefore not further considered herein.

Alpha taxonomy: *Archaeovenator hamiltonensis* is treated as a valid taxon by Berman et al. (2014), Pelletier (2014) and Reisz and Fröbisch (2014) and is therefore added to the database.

Heleosaurus scholtzi is known from the *Tapinocephalus* AZ (Day et al., 2015a, fig. 1) and is treated accordingly.

Anningia megalops is potentially valid (Spindler et al., 2018) and is treated accordingly in the database.

Benson (2012) includes *Basicranodon fortsillensis* as a separate OTU. Reisz et al. (1997) considered the taxon to be a junior synonym of *Mycterosaurus longiceps* and this interpretation was also followed by Maddin et al. (2006) and Brocklehurst et al. (2016a). The analyses of Benson (2012) are not inconsistent with this result. Therefore, *Basicranodon fortsillensis* is herein treated as a junior synonym of *Mycterosaurus longiceps*, even though a few differences can be noted between the two taxa (Benson, 2012).

Campione and Reisz (2010) provide additional evidence that the specimens form the Dolese Brothers Quarry (Fort Sill/Richard Spurs locality), initially described as *Varanops cf. brevirostris* (Maddin et al., 2006), do, indeed, belong to the species *Varanops brevirostris*. They are therefore included in the database.

Pelletier (2014) do not report *Ruthiromia elcobriensis* and *Nitosaurus jacksonorum* among the valid varanopid taxa. *Ruthiromia elcobriensis* is treated as a valid taxon and included in the phylogenetic analyses of Benson (2012). It is therefore retained in the database. The holotype of *Nitosaurus jacksonorum* is possibly a composite of skeletal elements of *Aerosaurus* and *Oedaleops* (Reisz, 1986, p. 84; Brink et al., 2013; Spindler et al., 2016). Due to the uncertain phylogenetic position of the taxon (Reisz, 1986; Benson, 2012; Spindler et al., 2016) it is excluded from the database.

A.15.3 Ophiacodontidae

Phylogeny: *Milosaurus mccordi* is added according to the strict consensus tree of Spindler et al. (2018, fig. 30) as the sister taxon of the genus *Varanosaurus*.

Clepsydrops is an early diverging member of Ophiacodontidae (Currie, 1977; Reisz, 1986, p. 67, 68). It is added to a polytomy consisting of *Echinerpeton intermedium*, *Archaeothyris florensis*, and the clade consisting of *Varanosaurus* and later diverging ophiacodontids, following Olson (1962, fig. 69) and Laurin and de Buffrénil (2016, fig. 6). *Clepsydrops vinslovii* might be a junior synonym of *Clepsydrops colletti* (Reisz, 1986, p. 67; Laurin and de Buffrénil, 2016). It is therefore added as its sister taxon. *Clepsydrops magnus* is added as the sister taxon of the clade *Clepsydrops colletti* + *Clepsydrops vinslovii*.

Stereorachis is an early diverging ophiacodontid (Reisz, 1986, p. 58, 68) and is therefore added to the above-mentioned polytomy of early diverging Ophiacodontidae. The two species of *Stereorachis* are assumed to be sister taxa. Note, however, that *Stereorachis blanziacensis* might represent a new genus (Falconnet, 2014).

The two species of *Varanosaurus* are assumed to be sister taxa. Indeed, *Varanosaurus wichitaensis* might be a junior synonym of *Varanosaurus acutirostris* (Berman et al., 1995).

Baldwinonus is closely related to *Stereophallodon* (Brinkman and Eberth, 1986; Lucas, 2013b). It is therefore added according to the cladogram of Brinkman and Eberth (1986, fig. 19) as the sister taxon of *Stereophallodon*. The two species of *Baldwinonus* are assumed to be sister taxa. Note, however, that the assignment of *B. dunkardensis* to the genus *Baldwinonus* is not certain (Reisz, 1986, p. 68; Lucas, 2013b).

Ophiacodon mirus, *Ophiacodon uniformis*, and *Ophiacodon hilli* are very similar to each other (Romer and Price, 1940, p. 242; see also p. 237, 238 and 241; Reisz, 1986, p. 69–71). A polytomy, consisting of these three taxa, is created by adding *Ophiacodon uniformis* and *Ophiacodon hilli* to the supertree. *Ophiacodon uniformis*, *Ophiacodon retroversus*, and *Ophiacodon major* possibly form a grade (Romer and Price, 1940, p. 230; Berman et al., 2013) and *Ophiacodon retroversus* and *Ophiacodon major* are added accordingly to the supertree. *Ophiacodon navajovicus* is a "primitive member of the genus, morphologically a short step below *O. mirus* and *O. uniformis*" (Romer and Price, 1940, p. 234) and is therefore added as a sister taxon to the clade consisting of the abovementioned polytomy and the grade.

Alpha taxonomy: *Echinerpeton intermedium* has been included in the phylogenetic analyses of Benson (2012) and is therefore included in the database. Note, however, that it acted as a 'wildcard' taxon in the analyses of Benson (2012) that couldn't be constrained to any major synapsid clades. Brocklehurst et al. (2016a, fig. 10B) recovered it as an ophiacodontid.

Clepsydrops magnus is listed among the synapsids used by Brocklehurst (2015, Appendix C: p. 236) for his diversity estimates. The taxon is therefore retained in the database.

Falconnet (2014) treats *Stereorachis blanziacensis* as valid (but it might represent a new genus; Falconnet, 2014) and it is therefore included in the database. Note, that the genus name *Stereorachis* Gaudry, 1880 is often found misspelled in the literature as *Stereorhachis* (e.g., Olson, 1962, p. 185, 192; Reisz, 1986, p. 68; Fröbisch et al., 2011, Supplementary online material; Benson, 2012).

Spindler et al. (2018) treat *Milosaurus mccordi* as valid. The taxon is treated accordingly in the database.

The referral of *B. dunkardensis* to the genus *Baldwinonus* is uncertain (Lucas, 2013b). It is listed among the synapsids used by Brocklehurst (2015, Appendix C: p. 232) for his diversity estimates. The taxon is therefore retained in the database.

The specimen of *Ophiacodon navajovicus* reported from the Cutler Formation of Colorado (Lewis and Vaughn, 1965; Harris et al., 2010) is incorporated in the database. Vaughn (1962) describes additional specimens from the Halgaito Formation/Halgaito "tongue" of the Cutler Formation (Vaughn, 1962; Harris et al., 2010) and Brocklehurst (2015, Appendix D: p. 251–252) lists the specimens as *Ophiacodon navajovicus*. Vaughn (1962), however, described those specimens as belonging to *Ophiacodon cf. navajovicus* and Brocklehurst (2015) did not try to further refine the taxonomy (N. Brocklehurst, pers. comm., 2015). Huttenlocker et al. (2018a) report new material of *Ophiacodon navajovicus* from the Halgaito Formation and consider the material described by Vaughn (1962) to belong to *Ophiacodon navajovicus* as well. The stratigraphic and palaeobiogeographic range of *Ophiacodon navajovicus* is updated accordingly.

Felice and Angielczyk (2014) consider *Ophiacodon hilli* to be a valid species and it is treated accordingly in the database.

A.16 'Basal' Haptodontiformes

Phylogeny: The phylogenetic analysis of 'basal' Sphenacodontia of Spindler (2015, fig. 6.7) is used to add early diverging Haptodontiformes and Sphenacomorpha (including Sphenacodontidae) to the supertree. The therapsid part of Spindler (2015, fig. 6.7) is not used, and instead the corresponding taxa are placed according to the reduced consensus tree of Brocklehurst et al. (2016a, fig. 10B), which provides the scaffold tree for 'pelycosaurian'-grade synapsids (see section A.15). This tree is also used to add the taxa *Secodontosaurus obtusidens*, *Cryptovenator hirschbergeri*, *Lupeosaurus kayi*, *Glaucosaurus megalops*, *Edaphosaurus novomexicanus*, and

Edaphosaurus boanerges.

Haptodus baylei and *Xyrospondylus ecordi* are added according to the majority rule consensus tree of Spindler (2015, fig. 4.3E). *Haptodus grandis* and *Palaeohatteria longicaudata* are added to the scaffold using the trees of Spindler (2015, fig. 6.8C) and Spindler (2015, fig. 6.8F), respectively (see also Spindler, 2016).

Alpha taxonomy: *Ianthodon schultzei* is a valid taxon (Spindler et al., 2015) and is therefore included in the database.

The specimen assignment of the genus *Haptodus* follows Spindler (2015, Chapter 4). The newly erected taxa *Hypselohaptodus grandis*, *Eohaptodus garnettensis*, *Tenuacaptor reiszi* and *Kenomagnathus scotti* (Spindler, 2015, Chapter 4) are, however, not included, awaiting the formal description in a peer-reviewed journal.

Palaeohatteria longicaudata, *Pantelosaurus saxonicus*, and *Cutleria wilmarthi* are valid species (Benson, 2012; Spindler, 2015, 2016) and are therefore included in the database. The specimen assignment of *Palaeohatteria longicaudata* and *Pantelosaurus saxonicus* follows Spindler (2015, Chapter 5). The specimen assignment of *Cutleria wilmarthi* follows Spindler (2015, Chapter 6).

A.16.1 Edaphosauridae

Phylogeny: *Edaphosaurus colohistion*, *Edaphosaurus cruciger*, and *Edaphosaurus pogonias* are added according to the strict consensus tree of Mazierski and Reisz (2010, fig. 5).

Edaphosaurus credneri is assumed to be a potential sister taxon of one of the *Edaphosaurus* species and is added accordingly in a polytomy with *Edaphosaurus novomexicanus* and the clade consisting of the other species of *Edaphosaurus*.

Alpha taxonomy: *Xyrospondylus ecordi* is incorporated in the phylogenetic analyses of Spindler (2015, Chapter 4: fig. 4.2A-C; fig. 4.3C-E), who recovers it as an edaphosaurid. It is therefore treated as a valid taxon in the database.

Edaphosaurus credneri is considered Edaphosauridae *incertae sedis* by Huttenlocker et al. (2011b, Table 1). Fröbisch et al. (2011, Supplementary Online Material: p. 2) list the taxon among the European pelycosaur-grade synapsids and it is also mentioned by Spindler (2015, p. 70), who reports the type to be a juvenile. Brocklehurst (2015, Appendix C: p. 236) uses the taxon in his diversity estimates. *Edaphosaurus credneri* is herein retained in the database.

Edaphosaurus colohistion is considered a valid species of *Edaphosaurus* by Huttenlocker et al. (2011b, Table 1) and is therefore included in the database.

Edaphosaurus cruciger is also known from the Belle Plains Formation (Romer and Price, 1940, p. 393, 394; Reisz, 1986, p. 73) and its stratigraphic range is updated accordingly.

Fröbisch et al. (2011, Supplementary Online Material: p. 3) list *Edaphosaurus mirabilis* among the European pelycosaur-grade synapsids and Brocklehurst (2015, Appendix C: p. 237) uses the taxon in his diversity estimates. Reisz and Berman (1986), however, considered *Edaphosaurus mirabilis* a *nomen dubium*. According to Modesto and Reisz (1990a) it might belong to *Ianthasaurus*. *E. mirabilis* is also not mentioned among the valid taxa of *Edaphosaurus* by Huttenlocker et al. (2011b, Table 1). *Edaphosaurus mirabilis*, which is only represented by a fragment of a dorsal vertebra (Reisz, 1986, p. 72), is therefore not included in the database.

Huttenlocker et al. (2011b, Table 1) report *Edaphosaurus raymondi* as Edaphosauridae *incertae sedis*, but Reisz and Berman (1986) considered it a *nomen dubium* and Modesto and Reisz (1990b) considered it a *nomen vanum*. Specimens referred to *Edaphosaurus aff. Edaphosaurus raymondi* are considered Edaphosauridae *incertae sedis* by Modesto and Reisz (1990b) and *Edaphosaurus raymondi* might actually represent *cf. Ianthasaurus* (Spindler, 2015, p. 114). The specimens mentioned by Modesto and Reisz (1990b) are possibly the ones that Huttenlocker et al. (2011b, Table 1) are referring to. Due to the surrounding taxonomic uncertainty *Edaphosaurus raymondi* is not further considered herein.

A.16.2 Sphenacodontidae

Phylogeny: The resolution within Sphenacodontidae is slightly improved for *Cryptovenator hirschbergeri* using the strict reduced consensus tree of Brocklehurst (2015, fig. 16B) (Benson (2012, fig. 2C) recovers the same topology for *Cryptovenator hirschbergeri*).

The strict consensus tree of Brink et al. (2015, fig. 6), which is based on the data matrix of Fröbisch et al. (2011) (with modifications of Brink and Reisz (2014) and Brink et al. (2014)), is used to add the taxa *Dimetrodon borealis* and *Dimetrodon grandis*. Spindler (2015, fig. 6.7) recovers *Dimetrodon* as paraphyletic, but this is possibly caused by "polarity issues, as well as tooth type variations" (Spindler, 2015, p. 257). Herein, a monophyletic *Dimetrodon* is preferred (as recovered in, e.g., Brink et al., 2015, fig. 6) and the position of *Dimetrodon milleri* is changed according to Brink et al. (2015, fig. 6).

Macromerion schwartzenbergii is a member of Sphenacodontinae (Currie, 1977; Currie, 1979; Reisz, 1986, p. 76; Štamberg and Zajíc, 2008, p. 190; Fröbisch et al., 2011; Falconnet, 2015), which is reported as being very similar to "*Dimetrodon* and related sphenacodonts of the Wichita and other American deposits" (Romer, 1945, p. 431). The subfamily Sphenacodontinae in Reisz (1986, p. 76) includes nearly all taxa that are included in the sphenacodontid part of the supertree, except for *Secodontosaurus obtusidens* (which is assigned to Secodontosaurinae; Reisz, 1986, p. 75, 76) and *Cryptovenator hirschbergeri* which has just been described in 2011 (Fröbisch et al., 2011). *Macromerion schwartzenbergii* is therefore added to a polytomy consisting of *Cryptovenator hirschbergeri* and the rest of Sphenacodontidae with more derived character states.

The size and proportions of the holotype of *Sphenacodon britannicus* are very similar to those of *Sphenacodon ferox* (Paton, 1974). *Sphenacodon britannicus* is therefore added as the sister taxon of *Sphenacodon ferox*.

Based on a suite of morphological characters Romer and Price (1940, p. 335) divided the known species of *Dimetrodon* into two series. Series A was represented by *Dimetrodon milleri*, *Dimetrodon booneorum*, *Dimetrodon limbatus* and *Dimetrodon grandis* (Romer and Price, 1940, p. 335). Series B was represented by *Dimetrodon natalis*, *Dimetrodon macrospondylus*, *Dimetrodon loomisi*, *Dimetrodon dollovianus* and *Dimetrodon giganhomogenes* (Romer and Price, 1940, p. 335). Olson (1962, p. 23) considered *Dimetrodon angelensis* to possibly be part of series B. These interpretations were also mentioned by Reisz (1986, p. 80) and are supported by the results of Shelton et al. (2013). *Dimetrodon natalis*, *Dimetrodon macrospondylus*, *Dimetrodon loomisi*, *Dimetrodon dollovianus* and *Dimetrodon giganhomogenes* are added as a clade as proposed by Romer and Price (1940, p. 335).

Dimetrodon booneorum is similar to *Dimetrodon limbatus* (Reisz, 1986, p. 80; Shelton et al., 2013) and is therefore added as its sister taxon. Similarly, *Dimetrodon angelensis* is similar to *Dimetrodon giganhomogenes* (Olson, 1962, p. 23) and is are herein treated as its sister taxon.

Dimetrodon occidentalis is most similar to *Dimetrodon milleri* (Berman, 1977; Cantrell et al., 2013) and is therefore added as its sister taxon. *Dimetrodon teutonis* is most similar to *Dimetrodon natalis* (Berman et al., 2004) and is therefore added as its sister taxon.

Alpha taxonomy: Reisz et al. (1992) recognise only one species of *Secodontosaurus*, *S. obtusidens*. Brocklehurst (2015, Appendix C) also lists only one species of *Secodontosaurus*. The genus is herein treated accordingly.

Ctenorhachis jacksoni is a valid taxon according to Falconnet (2015) and is indeed also coded in, e.g., the phylogenetic analyses of Benson (2012). It is added to the database.

Dimetrodon giganhomogenes is also known from the Vale, lower Choza, and Hennessey Formation (Olson, 1958; Olson, 1967; Olson and Mead, 1982; Brocklehurst et al., 2017, Supplementary Data) and its stratigraphic range is updated accordingly.

Bathygnathus borealis is now considered to represent another species of *Dimetrodon* (Brink et al., 2015) and it is treated accordingly. Including *Dimetrodon borealis*, Brink et al. (2015) recognise 13 valid species of *Dimetrodon*. They refer to Brink and Reisz (2012) for the number of taxa, which in turn refer to Berman et al. (2001) and Reisz (1986) for the species count. The only valid (according to Berman et al., 2001 and Reisz, 1986) *Dimetrodon* species that is not part of the previous version of the ETD (Benton et al., 2013c,a), *Dimetrodon dollovianus*, is added accordingly (excluding the doubtful *Dimetrodon kempae*; see Reisz, 1986). *Dimetrodon kempae* has not been formally synonymized with any other taxon, but was considered Sphenacodontidae *incertae sedis* by Reisz (1986, p. 82), a "questionable species" by Berman et al. (2001) and is indeed probably not valid (K. Brink, pers. comm., 2016). It is therefore not included in further analyses.

Neosaurus cynodus is a *nomen dubium* (Falconnet, 2015) and is therefore excluded from the database.

Falconnet (2015) mentions *Eosyodon hudsoni*, but it is a *nomen dubium* according to Kammerer (2011) and is treated accordingly.

Dimacrodon hottoni, *Driveria ponderosa*, *Steppesaurus gurleyi*, *Gorgodon minutus*, *Knoxosaurus niteckii*, and *Mastersonia driverensis* have previously been assigned to various therapsid groups (Olson, 1962; Olson and Chudinov, 1992; King, 1988; Sigogneau-Russell, 1989) while Sidor and Hopson (1995) considered those remains to represent caseid and sphenacodontid pelycosaurs. Further study of these specimens is necessary to clarify the relationships of these taxa (Falconnet, 2015) and they might all prove to be *nomina dubia* (C. A. Sidor, pers. comm., 2016). Herein they are excluded from further analyses.

A.17 'Basal' Therapsida

Phylogeny: The scaffold tree for basal therapsid relationships is provided by the 50% majority rule consensus tree of Brink et al. (2015, fig. 7B), which is based on the data matrix of Liu et al. (2009) and Amson and Laurin (2011).

The poorly known *Phthinosuchus discors*, a member of Phthinosuchidae (Sigogneau-Russell, 1989, p. 4; Battail, 2000; Kemp, 2005, p. 30), might be a biarmosuchian or a dinocephalian according to Kammerer (2009, p. 14). Ivakhnenko (2003, p. S399) proposed it to be a a junior synonym of *Dinosaurus*. Ivakhnenko (2008a) considers different gorgonopsian taxa as being closely related to Phthinosuchidae. Sigogneau-Russell (1989, p. 2), however, disagrees with a close position of *Phthinosuchus discors* to Gorgonopsia and considers a close relationship to *Biarmosuchus tener* possible (Sigogneau-Russell, 1989, p. 19). Herein, Phthinosuchidae is considered the sister taxon of Biarmosuchia as proposed by Sigogneau-Russell (1989, fig. 276; Table II) and *Phthinosuchus discors* is added accordingly to the supertree. It is acknowledged, however, that such a placement can only be tentative (Sigogneau-Russell, 1989, p. 117; Kemp, 2005, p. 30).

Niaftasuchus is the only member of the family Niaftasuchidae, which belongs to the suborder Niaftasuchida and the order Dinocephalia according to Ivakhnenko (2008a, p. 980, 981). Ivakhnenko (2008a, p. 980, 981) treats Niaftasuchida as the sister taxon of Dinocephalida, which represents all other dinocephalian taxa. Battail and Surkov (2000) and Battail (2000) retain Niaftasuchidae as a distinct family within Biarmosuchia. *Niaftasuchus zekkeli* is added as the sister taxon of Dinocephalia (= Dinocephalida *sensu* Ivakhnenko, 2008a, p. 980, 981), following the interpretations of Ivakhnenko (2008a, p. 980, 981). Note, however, that the current higher-level taxonomic assignments of *Niaftasuchus* and a few other Russian taxa are deemed as "extremely dubious" by Kammerer (2011, p. 276).

Ivakhnenko (2008a, p. 980, 981) assigns *Nikkasaurus* to the family Nikkasauridae, which forms the order Nikkasaurida together with the family Microuraniidae. The only member of Microuraniidae, *Microurania* is paraphyletic: *Microurania minima* probably represents a juvenile dinocephalian and *Microurania mikia* is probably a juvenile venyukovioid anomodont (Kammerer, 2011). The phylogenetic position of Microuraniidae is therefore herein considered to be irrelevant for the phylogenetic position of Nikkasauridae. Nikkasaurida is part of the superorder Nikkasauria, which forms the infraclass Dinomorpha together with Gorgodontia and Anomodontia (Ivakhnenko, 2008a, p. 979, 980). The superorder Gorgodontia consists of Dinocephalia and Gorgonopia (Ivakhnenko, 2008a, p. 980). Gorgonopia *sensu* (Ivakhnenko, 2008a, p. 984) contains the suborders Ictidorhinida, Gorgonopida, and Estemmenosuchida. *Ictidorhinus*, however, is a burnetiamorph (Kammerer, 2016c, fig. 8B), and *Estemmenosuchus* is a dinocephalian (Brink et al., 2015, fig. 7). *Nikkasaurus tatarinovi* is therefore added to a polytomy consisting of the clade *Phthinosuchus discors* + Biarmosuchia, Anomodontia, Eutheriodontia + Gorgonopsia, and *Niaftasuchus zekkeli* + Dinocephalia. Indeed, Golubev (2015, p. 1348) reports nikkasaurs among "primitive therapsids" and Ivakhnenko (2011, p. 1124) and Ivakhnenko (2015) also considers Nikkasauria as basal eotherapsids.

Reiszia is also a nikkasaurid (Ivakhnenko, 2008a, p. 981) and is therefore added as the sister taxon of *Nikkasaurus*. The two species of *Reiszia* are assumed to be sister taxa.

A.17.1 Biarmosuchia

Phylogeny: *Hipposaurus*, Ictidorhinidae, and Burnetiamorpha are added according to the single most parsimonious tree of Day et al. (2018a, fig. 10), which is based on an expanded character matrix of Day et al. (2016).

The two species of *Biarmosuchus* are assumed to be closely related and are therefore added as sister taxa. The species of *Hipposaurus* are also assumed to be sister taxa and are treated accordingly.

Wantulignathus gwembensis might be a bullacephalid (Day et al., 2016) and is added accordingly.

Ivakhnenko (2008a, p. 983, 984) assigns *Alrausuchus* to the family Alrausuchidae, which forms the infraorder Eotitanosuchina together with the family Eotitanosuchidae. Eotitanosuchidae *sensu* Ivakhnenko (2008a, p. 983, 984) is only represented by *Biarmosuchus*. *Alrausuchus tagax* has previously been assigned to the genus *Biarmosuchus* (Ivakhnenko, 2008a, p. 984). It is therefore added as the sister taxon of the genus *Biarmosuchus*. Note, however, that Jansen et al. (2013) report *Alrausuchus* (and *Niaftasuchus*) as members of Dinocephalia.

Biarmosuchoides and *Ustia* belong to Ictidorhinidae according to Ivakhnenko (2008a, p. 984). The family Ictidorhinidae also includes *Ictidorhinus* and *Rubidgina* according to Ivakhnenko (2008a, p. 984). *Ustia atra* is probably a burnetiamorph according to Day et al. (2016). *Biarmosuchoides romanovi* is therefore added to a polytomy which also includes Ictidorhinidae and Burnetiamorpha. *Ustia atra* is added to a polytomy among early diverging members of Burnetiamorpha.

Alpha taxonomy: Smith et al. (2012b) and Dias-da-Silva (2012) mention *Chthomaloporus lenocinator* and it is treated as a valid taxon by Battail and Surkov (2000) (sometimes misspelled as *Chthamaloporus*; King, 1988, p. 14; Modesto and Rybczynski, 2000; Rubidge, 2005; Day, 2013, p. 71). Sigogneau-Russell (1989, p. 19), however, reported the holotype (PIN 1758/17) of the species *Chthomaloporus lenocinator* for *Biarmosuchus tener* or alternatively for Biarmosuchidae indet. (Sigogneau-Russell, 1989, fig. 18, 28). *Chthomaloporus lenocinator* is only represented by a pelvic girdle and sacral vertebrae (Battail and Surkov, 2000) and is not mentioned in the systematic treatment of Anteosauria by Kammerer (2011). It is probably referable to *Biarmosuchus* (C. F. Kammerer, pers. comm., 2016) and is treated accordingly.

Ivakhnenko (1999) considered *Eotitanosuchus olsoni* a junior synonym of *Biarmosuchus tener*. Kemp (2005, p. 33) suggested *Eotitanosuchus olsoni* and *Biarmosuchus tener* to be at least cogeneric. Ivakhnenko (2008a, p. 869, 870, 944), Kammerer (2009, Table 9: p. 578), and Kammerer (2014a) treat *Eotitanosuchus olsoni* as a junior synonym of *Biarmosuchus tener*. The taxon is treated accordingly.

Ivantosaurus ensifer has also been considered a junior synonym of *Biarmosuchus tener* (Ivakhnenko, 1999) and is treated as such by Ivakhnenko (2003, p. S374), Ivakhnenko (2008c, p. 113–115), and Olroyd and Sidor (2017, Supplementary Information: Table 11). The taxon is treated accordingly.

Ivakhnenko (1999) described the new species *Biarmosuchus tchudinovi* and it is treated as valid by Ivakhnenko (2003, p. S374), Ivakhnenko (2008c, p. 115, 116), Brocklehurst et al. (2013a, Supplementary Table 1), and Olroyd and Sidor (2017, Supplementary Information: Table 11). The taxon is therefore added to the database.

Ictidorhinus martinsi is restricted to the Upper *Daptocephalus* AZ (Day et al., 2016, Supplementary Online Material: SOM 4) and is treated accordingly.

The stratigraphic range of *Lycaenodon longiceps* is updated according to Day et al. (2016, Supplementary Online Material: SOM 4).

Fröbisch (2014b, Appendix 18.1) reports *Lemurosaurus* only for the *Dicynodon* AZ. The taxon is known, however, from the *Cistecephalus* AZ (Kruger et al., 2015; Sidor, 2015; Day et al., 2016, Supplementary Online Material: SOM 4) and the reported occurrence from the *Dicynodon* AZ is probably wrong (see Sidor and Welman, 2003). The taxon is herein treated as stemming only from the *Cistecephalus* AZ.

The occurrence of *Lobalopex*? in the *Pristerognathus* AZ (Day et al., 2015a, fig. 1) is not included in the database, awaiting further identification of the specimen. Indeed, Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) do not report the taxon for the *Pristerognathus* AZ.

Paraburnetia is restricted to the *Cistecephalus* AZ (Fröbisch, 2014b, Appendix 18.1; Day et al., 2016, Supplementary Online Material: SOM 4) and is treated accordingly.

Rubidgina angusticeps is a *nomen dubium* and referred material of the taxon has been transferred to *Herpetoskylax hopsoni* (Sidor and Rubidge, 2006, p. 95; Kammerer, 2014b, p. 166; Sidor, 2015, Table 1; Day et al., 2016). The taxon is treated accordingly.

A.18 Dinocephalia

Phylogeny: The anteosaurian part of the supertree is based on the single most parsimonious tree of Liu (2013b, fig. 11), which is based on modified character matrices of Kammerer (2011) and Cisneros et al. (2012). This tree is also used to add the taxa *Tapinocaninus pamelae* and *Ulemosaurus svijagensis*.

Criocephalosaurus vanderbyli and *Moschops capensis* are added according to the cladogram of Sidor (2003, fig. 4A). This part of the cladogram is based on unpublished cladistic analyses of C. A. Sidor (Sidor, 2003, Appendix 1). The dinocephalian part of this cladogram is also used to resolve the relationships between *Tapinocaninus pamelae* and *Jonkeria truculenta*. Unlike the topology for *Criocephalosaurus vanderbyli* and *Moschops capensis*, this part of the cladogram of (Sidor, 2003, fig. 4A) is based on a compilation of phylogenetic analyses (Sidor, 2003, Appendix 1). Some of these analyses (Hopson and Barghusen, 1986; Rubidge, 1991, 1994; Rubidge and van den Heever, 1997) do not include a character matrix and a description of the employed (quantitative) methods. The cladogram of Sidor (2003, fig. 4A) also shows the two species of *Estemmenosuchus* as sister taxa, and they are placed accordingly. Note that Sidor (2003, fig. 4A) recovers *Estemmenosuchus* as more closely related to *Jonkeria truculenta* (and other tapinocephalians) than to *Styracocephalus platyrhynchus* while Brink et al. (2015, fig. 7B) (the scaffold tree for Therapsida) recovers *Estemmenosuchus* as the sister taxon of the clade consisting of *Styracocephalus* and *Jonkeria*. The result of Brink et al. (2015, fig. 7B) is given priority and the taxa are treated accordingly.

Ivakhnenko (2008a, p. 986, 987) unites *Phthinosaurus* with *Parabradysaurus* and *Rhopalodon* in the family Rhopalodontidae. *Parabradysaurus udmurticus* and *Rhopalodon wangenheimi* have been considered Dinocephalia *incertae sedis* (King, 1988, p. 36, 37; Lee, 2000, p. 83). The type of *Rhopalodon murchisonii* (= *Dinosaurus murchisonii*) belongs to *Brithopus priscus* (Kammerer, 2011). *Brithopus priscus* has been considered a *nomen dubium* by Kammerer (2011). Kemp (2005, p. 30) reports *Phthinosaurus* to be similar to *Estemmenosuchus* and such an interpretation is also mentioned in Battail (2000). The taxon is therefore tentatively added as sister taxon of the genus *Estemmenosuchus*.

The holotype of *Microurania minima* probably represents a juvenile dinocephalian and the one of *Microurania mikia* a juvenile venyukovioid anomodont (Kammerer, 2011). The taxa are treated accordingly in the database. *Microurania minima* might be close to estemmenosuchids (Battail, 2000) and indeed, Kemp (2005, p. 30) also noticed similarities between the postcanines of *Microurania minima* and those of *Estemmenosuchus uralensis* and considered it part of the group Rhopalodonta, to which *Phthinosaurus* had been assigned as well. *Microurania minima* is added accordingly, creating a polytomy consisting of *Phthinosaurus borissiaki*, *Microurania minima*, and the genus *Estemmenosuchus*.

Molybdopygus arcanus is an estemmenosuchid (King, 1988, p. 12; Battail, 2000; Battail and Surkov, 2000, p. 96; Day, 2013, p. 71) and is therefore added to the above-mentioned polytomy.

Titanosuchus ferox and *Jonkeria truculenta* form the family Titanosuchidae (Battail, 2000; Rubidge and Sidor, 2001; Smith et al., 2012b, p. 38; Day, 2013, p. 195). *Titanosuchus ferox* is therefore added as the sister taxon of *Jonkeria truculenta*.

Deuterosaurus biarmicus is a tapinocephalian (Kammerer, 2011) and Ivakhnenko (2008a, p. 982) regards it as a member of Deuterosauridae, together with *Tapinocaninus pamelae*. Indeed, Sidor (2001) also considers *Deuterosaurus biarmicus* and *Tapinocaninus pamelae* to be closely related. *Deuterosaurus biarmicus* is therefore added as the sister taxon of *Tapinocaninus pamelae*.

Riebeeckosaurus longirostris is a tapinocephalid that bears some similarity to *Tapinocaninus pamelae* (Güven et al., 2013). *Riebeeckosaurus longirostris* is therefore added as the sister taxon of the clade *Tapinocaninus pamelae* + *Deuterosaurus biarmicus*.

Riebeeckosaurus longirostris and *Tapinocaninus pamelae* are tapinocephalids according to Güven et al. (2013) and Atayman et al. (2009). Rubidge and van den Heever (1997, fig. 8) recover Titanosuchidae as the sister taxon of Tapinocephalidae. King (1988, p. 27–34) included *Avenantia* (= *Riebeeckosaurus longirostris*), *Criocephalosaurus*, *Delphinognathus*, *Moschops*, *Ulemosaurus*, *Keratocephalus*, *Mormosaurus*, *Phocosaurus*, *Tapinocephalus*, and *Struthionops* within Tapinocephalini. *Tapinocephalus atherstonei* is added accordingly.

Struthiocephalus whaitsi is added according to the cladogram of Sidor (2001, fig. 3A), which (similar to Sidor, 2003, fig. 4A) is based on a compilation of previous phylogenetic analyses. The dinocephalian part of the cladogram is based on Hopson and Barghusen (1986), Rubidge (1991), Rubidge (1994), and Rubidge and van den Heever (1997) (see above).

Keratocephalus moloch might be a junior synonym of *Struthiocephalus whaitsi* (Kammerer, 2009, p. 234, 235; Day, 2013, p. 205). It is therefore added as the sister taxon of *Struthiocephalus whaitsi*.

Struthiocephaloides duplessisi might be a junior synonym of *Struthiocephaloides cavifrons* (Day, 2013, p. 214). Both *Struthiocephaloides cavifrons* and *Struthiocephaloides duplessisi* have been suggested to be junior synonyms of *Struthiocephalus whaitsi* (Kammerer, 2009, p. 234–236), with *Struthiocephaloides cavifrons* potentially representing a separate taxon (Kammerer, 2009, p. 236). *Struthiocephaloides duplessisi* is added as the sister taxon of *Struthiocephaloides cavifrons* and the resulting clade is added in a polytomy with *Struthiocephalus whaitsi* and *Keratocephalus moloch*.

Taurocephalus lerouxi is a junior synonym of *Mormosaurus seeleyi* according to Kammerer (2009, p. 223, 224). *Phocosaurus megischion* might also be synonymous with *Mormosaurus seeleyi* (Day, 2013, p. 212). A polytomy consisting of *Taurocephalus lerouxi*, *Phocosaurus megischion*, and *Mormosaurus seeleyi* is therefore created.

Mormosaurus seeleyi is very similar to *Struthiocephalus* (Kammerer, 2009, p. 223, 224). The trichotomy *Mormosaurus seeleyi* + *Taurocephalus lerouxi* + *Phocosaurus megischion* is therefore added as sister taxon to the clade *Struthiocephalus whaitsi* + *Keratocephalus moloch*.

The two species of *Ulemosaurus* are assumed to be sister taxa.

Struthionops intermedius might be conspecific with *Moschognathus whaitsi* (Kammerer, 2009, p. 227; Boos et al., 2015). It is therefore added as the sister taxon of *Moschognathus whaitsi*.

The specimens assigned to *Delphinognathus conocephalus* might represent juvenile individuals of *Moschops* (Day, 2013, p. 205). This has also been suggested by Boonstra (1969, p. 42) while Kammerer (2009, p. 222) considered it a *nomen dubium*. *Delphinognathus conocephalus* is herein added as the sister taxon of *Moschops capensis*.

Boonstra (1969, p. 42) suggested *Moschognathus* to be a synonym of *Moschops*. This interpretation has been followed by King (1988, p. 29) and Wyllie (2003, Appendix) and mentioned by Day (2013, p. 209). Kammerer (2009, p. 227, 228) questioned this synonymy, but did not suggest alternative relationships except for the synonymy of *Struthionops intermedius* with *Moschognathus whaitsi*. Boos et al. (2015) also reported differences between *Moschognathus* and *Moschops*. Boos et al. (2015) implicitly accepted *Moschognathus* and *Moschops* to be similar, as they described a new specimen that is most similar to these two taxa. The clade *Struthionops intermedius* + *Moschognathus whaitsi* is therefore added as the sister taxon of the clade *Delphinognathus conocephalus* + *Moschops capensis*.

Alpha taxonomy: Both Kammerer (2011) and Liu (2013b) consider *Stenocybus acidentatus* to be a junior synonym of *Sinophoneus yumenensis* (but see Jiang and Ji, 2014) and the taxon is treated accordingly.

Paranteosaurus primus is a junior synonym of *Anteosaurus magnificus* (Kammerer, 2011) and is treated accordingly.

Syodon efremovi is a junior synonym of *Syodon biarmicum* (Kammerer, 2011) and it is treated accordingly.

Battail and Surkov (2000) considered *Anoplosuchus tenuirostris*, *Zopherosuchus luceus*, and *Estemmenosuchus uralensis* to be separate taxa, albeit mentioning the close similarity between *Zopherosuchus luceus* and *Anoplosuchus tenuirostris* (Battail and Surkov, 2000, p. 96). The taxa were treated accordingly in Gorsky et al. (2003) and Day (2013, p. 71). Ivakhnenko (2000) considered *Anoplosuchus tenuirostris* and *Zopherosuchus luceus* to be junior synonyms of *Estemmenosuchus uralensis*. Ivakhnenko (2008a, p. 870; fig.60) and Ivakhnenko (2008c, p. 150, 151) followed these conclusions. Kammerer (2009, Table 9: p. 599) also reassigns the holotype of *Anoplosuchus tenuirostris* to *Estemmenosuchus uralensis*. These interpretations are followed herein and both *Anoplosuchus tenuirostris* and *Zopherosuchus luceus* are treated as junior synonyms of *Estemmenosuchus uralensis*.

Kammerer (2009, p. 220) considers *Dinosphageus haughtoni* (and therefore also *Jonkeria haughtoni*), *Jonkeria parva*, and *Jonkeria rossouwi* as synonyms of *Jonkeria truculenta*. They are treated accordingly.

Avenantia kruisvleiensis is reported by Fröbisch (2014b, Appendix 18.1) for the *Tapinocephalus* AZ, but it is a junior synonym of *Riebeeckosaurus longirostris* (Kammerer, 2009, p. 232, 233; Güven et al., 2013) and is treated accordingly.

Keratocephalus moloch is treated as a valid taxon by Atayman et al. (2009), Fröbisch (2014b), Jirah and Rubidge (2014), and Day et al. (2015a) and is therefore retained in the database.

Struthiocephaloides duplessisi has been suggested to represent a junior synonym of *Struthiocephalus whaitsi* (Kammerer, 2009, p. 235) or *Struthiocephaloides cavifrons* (Day, 2013, p. 214). Kammerer (2009, p. 234) also considered *Struthiocephaloides cavifrons*, the type species of *Struthiocephaloides*, to be a junior synonym of *Struthiocephalus whaitsi*, but also mentioned, that it might represent a distinct taxon. Indeed, both Day et al. (2015a) and Fröbisch (2014b) treat the genus as valid. Therefore, *Struthiocephaloides cavifrons* is retained in the database as a valid taxon. *Struthiocephaloides duplessisi* is also retained in the database as a separate species, awaiting further studies that possibly confirm one of the proposed synonymies.

Taurocephalus lerouxi is treated as a valid species by Day et al. (2015a) and Fröbisch (2014b) and is therefore retained in the database. Note, that Kammerer (2009, p. 224) considers it to be a synonym of .

Day et al. (2015a) and Fröbisch (2014b) treat *Phocosaurus megischion* as a valid taxon (Kammerer (2009, p. 221) considered it a *nomen dubium*). It is therefore retained in the database.

Atayman et al. (2009) report only *Ulemosaurus svijagensis* among the valid tapinocephalid taxa, but Ivakhnenko (2008a) also treats *Ulemosaurus gigas* as a valid species, suggesting that it might even belong to a different genus (Ivakhnenko, 2008a, p. 982). *Ulemosaurus gigas* is therefore retained in the database.

The tapinocephalid genus name *Criocephalus* has been replaced with *Criocephalosaurus* (Kammerer and Sidor, 2002) and the species *Criocephalosaurus vanderbyli* is herein treated accordingly.

Delphinognathus conocephalus is mentioned by both Day et al. (2015a, fig. 1) and Boos et al. (2015) and is therefore herein considered to be valid. Boos et al. (2015) note, that its holotype might represent a juvenile.

Kammerer (2009, p. 229) considers *Pnigalion oweni* (and therefore also *Moschops oweni* and *Moschops koupensis*) to be junior synonyms of *Moschops capensis*. This view is followed herein. Note, however, that Atayman et al. (2009) still report the taxa as being separate species.

Kammerer (2009, p. 227) considers *Moschops whaitsi* as belonging to the genus *Moschognathus*, which was (implicitly) accepted by Boos et al. (2015). This view is followed herein. Kammerer (2009, p. 227) also considers *Struthionops intermedius* to be a junior synonym of *Moschognathus whaitsi*. Due to missing overlapping material, this hypothesis is difficult to test (Boos et al., 2015) and therefore the taxa are retained herein separately.

Olroyd and Sidor (2017, Supplementary Information: Table 6) mention *Criocephalosaurus* *gunyankaensis*, but all the specimens referred to the taxon have been lost (Güven et al., 2012; Day et al., 2015b) and the taxon is considered a *nomen nudum* (Day, 2013, p. 74). Therefore this species is not added to the database.

Eccasaurus priscus is a *nomen dubium* (Kammerer, 2011) and is treated accordingly.

Titanophoneus rugosus was provisionally considered a *nomen dubium* (Kammerer, 2011) and is treated accordingly.

Admetophoneus kargalensis is a *nomen dubium* (Kammerer, 2011) and is treated accordingly in the database.

Brithopus priscus, *Brithopus bashkyricus*, and *Brithopus ponderus* are considered *nomina dubia* by Kammerer (2011) and are treated accordingly. *Brithopus fischeri* is based on very fragmentary remains (Battail and Surkov, 2000), making its validity as a species uncertain as indicated by the question mark on p. 14 of King (1988). Its is therefore also excluded from further analyses.

Parabradysaurus silantjevi is known from several specimens (Brocklehurst et al., 2017), but the diagnosis of the species (Ivakhnenko, 1996a) was based on fragmentary material. The genus *Parabradysaurus* had initially been considered a pareiasaur but was later reassigned to Dinocephalia (Lee, 2000, p. 83). Due to the surrounding uncertainty of the taxon, *Parabradysaurus silantjevi* is excluded from further analyses.

Kammerer (2009, p. 219) considers *Jonkeria vanderbyli*, *Dinophoneus ingens* (and therefore also *Jonkeria ingens*), *Jonkeria koupensis*, *Jonkeria boonstrai*, *Titanosuchus cloetei*, and *Dinocynodon dubius* (and therefore also *Titanosuchus dubius*) to be *nomina dubia*. They are treated accordingly.

Phreatosaurus and *Phreatosuchus* are mentioned by Brocklehurst and Fröbisch (2017) and are also listed in Olroyd and Sidor (2017, Supplementary Information: Table 10). Both taxa, however, are based on very fragmentary material (Battail and Surkov, 2000, p. 102) that makes their relationships difficult to determine (Modesto and Rybczynski, 2000, p. 20). The two genera are therefore not included in further analyses.

Ivakhnenko (2012) considered *Novocynodon kutorgai* to belong to Cynodontia, but it probably represents a juvenile dinocephalian or anomodont (Kammerer, 2014b, 2016a). Due to the uncertainty in the systematic assignment of the taxon, it is excluded from the database.

A.19 Gorgonopsia

Phylogeny: The scaffold tree for Gorgonopsia is provided by the consensus tree of Kammerer and Masyutin (2018b, fig. 10), which is based on an expanded character matrix of Kammerer (2017). The latter is based on a revised data matrix of Kammerer (2016b).

Aloposaurus gracilis, *Cyonosaurus longiceps*, and *Aelurosaurus felinus* are added according to the strict consensus tree of Gebauer (2007, fig. 52).

The species of *Aloposaurus* are assumed to be sister taxa and a corresponding polytomy is created.

Kamagorgon ulanovi might be a "basal gorgonopsian" (Kemp, 2006, p. 1240). It is added accordingly.

Cyonosaurus broomianus shares some similarities with *Cyonosaurus kitchingi* (Gebauer, 2007, p. 79) and these species are treated as sister taxa. *Cyonosaurus longiceps* is similar to *Cyonosaurus rubidgei* (Gebauer, 2007, p. 85, 86) and these species are also treated as sister taxa. The resulting clades and *Cyonosaurus tenuirostris* are assumed to be sister taxa and are placed in a corresponding polytomy.

The species of *Aelurosaurus* are assumed to be sister taxa.

Alpha taxonomy: Gebauer (2007) recognizes three valid species within the genus *Aloposaurus*, *A. gracilis*, *A. tenuis*, and *A. watermeyeri*. The taxa are treated accordingly.

Viatkogorgon ivakhnenkoi is treated as a valid taxon by several authors (Kümmell and Frey, 2012; Benton et al., 2012; Tsuji et al., 2012; Kümmell and Frey, 2014; Gebauer, 2014; Cisneros et al., 2015b). It is therefore retained in the database.

Gebauer (2007) recognizes *Cyonosaurus broomianus* and *Cyonosaurus tenuirostris* as valid species. The taxa are added to the database.

Gebauer (2007) considers only *Aelurosaurus felinus* and *Aelurosaurus wilmanae* as valid species of the genus *Aelurosaurus*. *Aelurosaurus watermeyeri* (Broom, 1940) is assigned to *Aloposaurus watermeyeri* (Gebauer, 2007) and specimens referred to *Aelurosaurus watermeyeri* (Sigogneau, 1970, p. 70–76; Sigogneau-Russell, 1989, p. 72) or *Aelurosaurus* sp. (Sigogneau-Russell, 1989, p. 72) are considered junior synonyms of *Aelurosaurus felinus* (Gebauer, 2007). *Aelurosaurus whaitsi* and *Aelurosaurus polyodon* are *nomina dubia* and specimens previously referred to *Aelurosaurus whaitsi* are now considered to belong to *Aelurosaurus felinus* (Gebauer, 2007). The taxa are treated accordingly.

Gebauer (2007) regarded *Cerdorhinus parvidens* as Gorgonopsia indet. and this view is followed herein.

The current preparation of the type specimen does not allow to determine *Cerdodon tenuidens* as a definite gorgonopsian (Kammerer, 2014a). It is therefore excluded from the dataset.

Gebauer (2007, p. 94) considered *Aelurosauroides watsoni* to be Gorgonopsia gen. et sp. indet. but it might be a junior synonym of *Aelurosaurus felinus* (Sigogneau-Russell, 1989, p. 71). The holotype of *Aelurosauroides watsoni* is known from the *Tapinocephalus* or *Pristerognathus* AZ (Kammerer, 2014a; Kammerer et al., 2015a), not the *Cistecephalus* AZ as reported in (Sigogneau-Russell, 1989, p. 71). It would therefore considerably expand the stratigraphic range of *Aelurosaurus felinus*, if the synonymy could be confirmed. As the specimen is poorly preserved (Kammerer, 2014a) *Aelurosauroides watsoni* is excluded from the database.

A.19.1 Gorgonopsidae

Phylogeny: *Dixeya nasuta* is added according to the strict consensus tree of Gebauer (2007, fig. 52), which has also been used to add a few non-gorgonopsid gorgonopsians (section A.19). Note, that Gebauer (2007, fig. 52) uses the newly erected genus name of Gebauer (2007, p. 155) for *Dixeya nasuta*. The strict consensus tree of Gebauer (2007, fig. 52) is also used to improve the resolution of the tree for *Lycaenops* and *Arctognathus curvimola*.

The strict consensus tree of Kammerer (2016b, fig. 74) is used to improve the resolution of the tree for the clade *Arctops willistoni* + *Smilesaurus ferox*.

The species of *Sauroctonus* are assumed to be sister taxa.

The species of *Inostrancevia* are assumed to be sister taxa and are placed in a corresponding polytomy.

Scylacops capensis is very similar to *Gorgonops* (Gebauer, 2007, p. 133) and, indeed, Gebauer (2007, p. 137) created the new combination *Gorgonops capensis*. *Scylacops capensis* is therefore added as the sister taxon of *Gorgonops*.

Gorgonops eupachygnathus might be conspecific with *Gorgonops torvus* (Gebauer, 2007, p. 127) and is therefore treated as its sister taxon.

Gorgonops whaitsi is very similar to *Gorgonops torvus* (Gebauer, 2007, p. 123, 125) and Sigogneau-Russell (1989, p. 89) even considers *Gorgonops whaitsi* as just "being somewhat more evolved". *Gorgonops whaitsi* is therefore treated as the sister taxon of the clade *Gorgonops torvus* + *Gorgonops eupachygnathus*. *Gorgonops kaiseri* and *Gorgonops dixeyi* are placed in a polytomy with the clade consisting of *Gorgonops whaitsi*, *Gorgonops eupachygnathus*, and *Gorgonops torvus*.

The species of *Lycaenops* are assumed to be sister taxa and placed in a corresponding polytomy.

Alpha taxonomy: ?*Aelurognathus parringtoni* was referred to the genus *Sauroctonus* (Gebauer, 2007, 2014) and is treated accordingly.

Suchogorgon golubevi is treated as a valid taxon by Gebauer (2014) and is therefore retained in the database.

Arctops watsoni and *Arctops kitchingi* are junior synonyms of *Arctops willistoni* (Kammerer, 2016b, 2017) and are treated accordingly. *Arctops watsoni* is restricted to the *Cistecephalus* AZ (Kammerer, 2017) and its stratigraphic range is updated accordingly in the database.

Eoarctops vanderbyli, *Scylacognathus parvus*, and *Galesuchus gracilis* are junior synonyms of *Eriphostoma microdon* (Kammerer et al., 2015a; Kammerer, 2016b) and are treated accordingly.

Gebauer (2007) considered *Scylacops bigendens* a junior synonym of *Scylacops capensis* and referred *Scylacops capensis* to the genus *Gorgonops* with the exception of MZC 885 (which was assigned to a new genus and species; see below). Sidor et al. (2010) and Gebauer (2014) still treat *Scylacops capensis* as a valid taxon. Therefore, *Scylacops capensis* is retained in the database, but the material of *Scylacops bigendens* is referred to *Scylacops capensis*.

Gorgonops dixeyi is considered a valid species by Gebauer (2007, p. 128), but might be synonymous with *Gorgonops torvus* (Kammerer et al., 2015a). It is retained in the database, awaiting a complete revision of the genus *Gorgonops* (see also Kammerer et al., 2015a). The stratigraphic range of *Gorgonops torvus* is expanded to the *Pristerognathus* and *Tropidostoma* AZ as reported in Day et al. (2015a, Dataset S1).

Kammerer et al. (2015a) implicitly accept the assignment of *Pachyrhinos kaiseri* to the genus *Gorgonops*. The taxon is therefore retained as *Gorgonops kaiseri*. It stems from either the *Tapinocephalus* AZ or the *Pristerognathus* AZ (Kammerer, 2014a; Kammerer et al., 2015a) with the *Pristerognathus* AZ being more likely (Kammerer et al., 2015a; C. F. Kammerer, pers. comm., 2016). The stratigraphic range of the taxon is treated accordingly.

Gorgonops whaitsi is treated as a valid taxon by, e.g., Wyllie (2003), Gebauer (2007, p. 139) (as *Gorgonops*? *whaitsi*), and Gebauer (2014) (implicitly, as an almost complete postcranial skeleton is reported for *Gorgonops cf. G. whaitsi*). Kammerer (2016b) implicitly accepts the referral of *Scymnognathus whaitsi* to the genus *Gorgonops*. Therefore, the taxon is retained in the database as *Gorgonops whaitsi*, accepting that a thorough revision of the taxon is needed (see also Kammerer, 2014a).

Gorgonops longifrons is a junior synonym of *Gorgonops torvus* (Gebauer, 2007) and is treated accordingly.

Gorgonops eupachygnathus is possibly valid, although its relationships can be considered "dubious" (Gebauer, 2007, p. 127). It's therefore retained in the database.

The referred specimens of *Dixeya quadrata* from Tanzania are probably conspecific with *Dixeya nasuta* (Kammerer, 2015) and are treated accordingly. Gebauer (2007) assigned the holotype of (= *Dixeya quadrata*) from Malawi to the genus *Lycaenops*. Kammerer (2016b) doesn't seem to agree with this assignment but does not provide an alternative. Therefore, *Lycaenops quadrata* is retained in the database, including the referred Zambian specimens (Gebauer, 2007).

Arctognathoides breviceps (and therefore also *Arctognathus breviceps*) is a junior synonym of *Arctognathus curvimola* (Kammerer, 2015). *A. nasuta* does not belong to the genus *Arctognathus* (Kammerer, 2015), which is therefore not known from Tanzania. Instead, Kammerer et al. (2015a) suggest to treat the taxon as '*Dixeya*' *nasuta* (the new genus name proposed by Gebauer (2007) is not used, awaiting the formal erection of the taxon). The taxa are treated accordingly.

Gebauer (2007) excluded *Aelurognathus sollasi* and ?*Aelurognathus parringtoni* from the genus *Aelurognathus*. This view was followed by Kammerer (2016b). Gebauer (2007) assigned *Aelurognathus sollasi* to the genus *Lycaenops* and this view is followed herein. Gebauer (2007) also considered *Lycaenops minor* to be a junior synonym of *Lycaenops sollasi*, but Kammerer (2016b) considers *Lycaenops minor* to possibly be conspecific with *Lycaenops microdon* and this view is followed herein. Note, that the generic assignment of *Lycaenops microdon* is slightly uncertain (Kammerer, 2016b).

Lycaenops is also reported for the *Tropidostoma* AZ (Fröbisch, 2014b, Appendix 18.1; Roopnarine and Angielczyk, 2015b, Supplementary Material: Table S1). Indeed, Sidor and Smith (2007) also report *Lycaenops ornatus* for the *Tropidostoma* AZ. Therefore, the reported occurrences of *Lycaenops* are assumed to represent the species *L. ornatus* and are added to the database.

Arctops? *ferox* as reported by Sigogneau-Russell (1989) is now again part of *Smilesaurus ferox* (Kammerer, 2016b) and is treated accordingly.

Aelurognathus tigriceps is the only valid species of the genus *Aelurognathus* (Kammerer, 2016b). *Aelurognathus serratidens*, *Lycaenops kingwilli*, *Leontocephalus cadlei*, *Prorubidgea maccabei*, *Prorubidgea brinki*, *Prorubidgea alticeps*, *Prorubidgea brodiei*, and *Arctops*? *minor* are junior synonyms of *Aelurognathus tigriceps* (Kammerer, 2016b). The taxa are treated accordingly.

The Zambian specimen reported as *Prorubidgea* sp. by Sigogneau-Russell (1989, p. 107) is now referred to *Aelurognathus tigriceps* (Kammerer, 2016b; C. F. Kammerer, pers. comm., 2016).

The holotype of *Lycaenops kingoriensis* (and therefore also the type of *Sycosaurus kingoriensis* and *Cephalicustriodus kingoriensis*; see Maisch, 2002) is referred to *Sycosaurus nowaki* (Kammerer, 2016b) and is treated accordingly. Another specimen, previously referred to *Cephalicustriodus kingoriensis* (for which Maisch, 2002 erected the new taxon *Ruhuhucerberus terror*), is now considered to belong to *Ruhuhucerberus haughtoni* (Kammerer, 2016b) and is treated accordingly. Kammerer (2016b) considered *Ruhuhucerberus terror* a junior synonym of *Aelurognathus haughtoni* and created the new combination *Ruhuhucerberus*, containing *Aelurognathus haughtoni* (and therefore also *Leontocephalus haughtoni*). The taxa are treated accordingly.

Leontocephalus intactus is a junior synonym of *Sycosaurus nowaki* (Kammerer, 2016b) and is treated accordingly.

Kammerer (2016b) reinstates *Leontosaurus vanderhorsti* as a valid taxon with the synonyms *Sycosaurus vanderhorsti* and *Rubidgea platyrhina*. The taxa are treated accordingly.

Titanogorgon maximus, *Broomicephalus laticeps*, and *Rubidgea majora* are junior synonyms of *Rubidgea atrox* (Kammerer, 2016b) and are treated accordingly.

Clelandina scheepersi and *Dinogorgon pricei* are junior synonyms of *Clelandina rubidgei* (Kammerer, 2016b) and are treated accordingly.

Broomisaurus planiceps is a *nomen dubium*, but might be referable to *Eriphostoma microdon* (Kammerer et al., 2015a). Herein, it is treated as a *nomen dubium*.

Gebauer (2007) erects a new genus with two species based on the holotypes GPIT/RE/7118 and UMZC 885. The taxa are not included, awaiting the formal erection of the genus and the species.

Paragalerhinus rubidgei is considered *Lycaenops* sp. by Gebauer (2007) and is therefore not further considered in this analysis.

Kammerer (2016b) considers the holotype of *Broomisaurus rubidgei* (and thus also of *Leontocephalus rubidgei*) to be a problematic specimen, that probably does not belong to Rubidgeinae and requires further study. Gebauer (2007) regarded this specimen as *Sycosaurus* sp., but Kammerer (2016b) considers it not to be part of the genus *Sycosaurus*. Due to the taxonomic uncertainty, *Leontocephalus rubidgei* is excluded from further analyses.

A.20 Anomodontia

Phylogeny: The strict consensus tree of Angielczyk and Kammerer (2017b, fig. 6), which is based on a modified character matrix of Angielczyk et al. (2018), forms the anomodont part of the synapsid subtree. The single most parsimonious tree of Olroyd et al. (2017, fig. 7), which is based on a modified character matrix of Kammerer et al. (2013), is used to add the taxon *Abajudon kaayai* and to improve the resolution of the anomodont tree for *Sangusaurus parringtonii*.

Parasuminia ivakhnenkoi is similar to *Suminia getmanovi* (Kurkin, 2017) and is therefore added as its sister taxon.

Venyukovia and *Otsheria* form together the family Venyukoviidae (Ivakhnenko, 2008a, p. 987). *Venyukovia prima* is therefore added as sister taxon of *Otsheria netzvetajevi*. Note, however, that Kammerer and Angielczyk (2009, p. 4) consider it “premature” to define familial and subfamilial taxa within Venyukovioidea. *Microurania mikia* is possibly a juvenile venyukovioid anomodont (Kammerer, 2011) and is placed accordingly in a polytomy with the clade *Suminia getmanovi* + *Parasuminia ivakhnenkoi* and the clade consisting of *Otsheria netzvetajevi* + *Venyukovia prima* and *Ulemica*.

The two species of *Ulemica* are assumed to be closely related and are treated accordingly. Indeed, Angielczyk and Kammerer (2017a, Continuous character database) use both *Ulemica invisa* and *Ulemica efremovi* specimens to code their OTU *Ulemica*.

Palemydops platysoma is possibly closely related to *Pristerodon mackayi*, but more research is needed to confirm this relationship (Boos et al., 2016). Kammerer (2009, Table 9: p. 569) assigns a specimen, that previously had been assigned to *Palemydops minor*, to *Pristerodon mackayi*. Herein, *Palemydops* is treated as the sister taxon of . The different species of *Palemydops* are assumed to be sister taxa.

The material known for *Endothiodon mahalanobisi* could potentially represent subadult individuals of *Endothiodon bathystoma* (Cox and Angielczyk, 2015). *Endothiodon bathystoma* is therefore added as the sister taxon of *Endothiodon bathystoma*.

The two species of *Delectosaurus* are assumed to be sister taxa.

Alpha taxonomy: *Ulemica efremovi*, based on a skull previously referred to *Venyukovia prima* (Ivakhnenko, 1996b), is treated as a valid species by Ivakhnenko (2008c, p. 155), Surkov and Benton (2008, Table 1), Fröbisch (2009), Liu et al. (2010), Fröbisch and Reisz (2011), and Olroyd and Sidor (2017, Supplementary Information: Table 12). The species is therefore added to the database.

Galepus is known from the *Tapinocephalus* AZ according to Fröbisch (2014b, Appendix 18.1), while Day et al. (2015a, fig. 1) report it for the *Pristerognathus* and/or *Tropidostoma* AZ. The holotype, which was initially assigned to the *Cistecephalus* AZ possibly occurs in the *Pristerognathus*

AZ (Day, 2013, p. 228, 229). The stratigraphic range of *Galepus* is updated according to Day et al. (2015a, fig. 1).

All specimens of *Eodicynodon* are known from the *Eodicynodon* Assemblage Zone, above the Ecca-Beaufort Group contact (Jinnah and Rubidge, 2007; Day, 2013, p. 247). Indeed, Fröbisch (2009) and Fröbisch (2014b, Appendix 18.1) only reports the taxon for the *Eodicynodon* Assemblage Zone. It is treated accordingly in the database.

Lanthanostegus moholi probably stems from the *Eodicynodon* AZ rather than the *Tapinocephalus* AZ (Day, 2013, p. 253). Indeed, Day et al. (2015a, fig. 1) do not report the taxon for the *Tapinocephalus* AZ. *Lanthanostegus moholi* is treated accordingly.

Brachyprosopus broomi is a valid taxon and *Chelydontops altidentalis* is its junior synonym (Angielczyk et al., 2016). The taxa are treated accordingly. *Brachyprosopus broomi* is probably restricted to the *Tapinocephalus* AZ, with a possible range extension into the uppermost *Eodicynodon* and the lowermost *Pristerognathus* AZ (Angielczyk et al., 2016). In the database the stratigraphic range of *Brachyprosopus broomi* is therefore restricted to the *Tapinocephalus* AZ.

Fröbisch (2009) reports *Pristerodon mackayi* as the only valid species of the genus and it is treated accordingly, also taking into account the reported stratigraphic and palaeobiogeographic range (Fröbisch, 2009; Angielczyk et al., 2014b; Kammerer et al., 2016a).

Emyduranus platyops and *Emyduranus gracilis* have been sunk into the genus *Pristerodon* by King and Rubidge (1993) which is accepted by Wyllie (2003) and, indeed, Fröbisch (2009) does not include the genus *Emyduranus* in his list of Anomodontia. This view is followed herein.

Brachyuraniscus merwevillensis is a junior synonym of *Pristerodon mackayi* (Angielczyk et al., 2016) and is treated accordingly.

Fröbisch (2009) didn't include the three species of *Palemydops* in his analysis, considering them as poorly represented and of uncertain taxonomic status. Both Nicolas and Rubidge (2010) and Smith et al. (2012b), however, treat the genus in their analyses as valid and it is therefore retained in the database with its three species as reported by King (1988, p. 114).

Cox and Angielczyk (2015) only recognise three species of the genus *Endothiodon* as valid, namely *E. bathystoma*, *E. mahalanobisi*, and *E. tolani*. *Endothiodon uniseries* and *Endothiodon whaitsi* are considered junior synonyms of *Endothiodon bathystoma*, giving the species a wide distribution in Brazil, India, Malawi, Mozambique, South Africa, Tanzania, and Zambia (Cox and Angielczyk, 2015). This view is followed herein and the taxa and their occurrences are treated accordingly. Therefore, the Brazilian specimen described as *Endothiodon* sp., which resembles *E. bathystoma*, *Endothiodon uniseries*, and *Endothiodon whaitsi* more than *E. mahalanobisi* (Boos et al., 2013), can now be referred to the single species *Endothiodon bathystoma*. For the same reason, the specimens from Malawi referred to *Endothiodon cf. Endothiodon bathystoma* (Jacobs et al., 2005), the specimens from Zambia referred to *Endothiodon* sp. (Angielczyk et al., 2014b) and the specimens from Mozambique (Fröbisch, 2009; Castanhinha et al., 2013; Boos et al., 2013) are herein considered an occurrence of *Endothiodon bathystoma*. The stratigraphic range of *Endothiodon bathystoma* in South Africa encompasses the *Pristerognathus*, *Tropidostoma*, and *Cistecephalus* AZ (Fröbisch, 2009, Appendix A; Day, 2013, p. 244, 245; Day et al., 2015a, fig. 1). The database is updated accordingly. *Pachytegos stockleyi* is also considered to be a junior synonym of *Endothiodon bathystoma* (Cox and Angielczyk, 2015) and is treated accordingly.

The occurrence of *cf. Katumbia parringtoni* from the Zambian Upper Madumabisa Mudstone (Angielczyk et al., 2014b) is not included, awaiting further confirmation of the presence of *Katumbia parringtoni* in Zambia.

A.20.1 Alpha Taxonomy of *Dicynodon*

The alpha taxonomy of *Dicynodon* follows the comprehensive taxonomic revision of Kammerer et al. (2011), which considers *Dicynodon lacerticeps* and *Dicynodon huenei* to be the only valid species of the genus *Dicynodon*. To ease comparison, synonyms that have not already been mentioned in Benton et al. (2013a) and/or which change the stratigraphic/palaeobiogeographic range as reported in Benton et al. (2013a) are reported here and incorporated in the database.

Dicynodon microrhynchus (and therefore also *Pristerodon microrhynchus*), *Dicynodon pygmaeus*, *Dicynodon raniceps*, *Dicynodon swierstrai*, *Dicynodon trigoniceps* are junior synonyms of *Pristerodon mackayi* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon feliceps is valid as *Diictodon feliceps* (Kammerer et al., 2011) and is treated accordingly. *Dicynodon antjiesfonteinensis*, *Dicynodon broomi*, *Dicynodon broilii*, *Dicynodon gamkaensis*, *Dicynodon grimbeeki*, *Dicynodon grossarthi*, *Dicynodon haughtonianus*, *Dicynodon huenei* Broili and Schröder, 1937, *Dicynodon ictidops*, *Dicynodon jouberti*, *Dicynodon macrorhynchus*, *Dicynodon nanus* (and therefore also *Diictodon nanus*), *Dicynodon parvidens*, *Dicynodon psittacops*, *Dicynodon rubidgei*, *Dicynodon sollasi*, *Dicynodon testudirostris*, *Dicynodon tienshanensis*, *Dicynodon vanderhorsti* are junior synonyms of *D. feliceps* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon schroederi is a junior synoynm of *Robertia broomiana* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon clarencei, *Dicynodon duvenhagei*, *Dicynodon gracilis*, *Dicynodon howardi* are junior synonyms of *Dicynodontoides recurvidens* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon nowacki is valid as *Dicynodontoides nowacki* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon allani, *Dicynodon andrewsi*, *Dicynodon bolorhinus*, *Dicynodon brachyrhynchus*, *Dicynodon breviceps*, *Dicynodon brevirostris*, *Dicynodon corstorphinei*, *Dicynodon curtus*, *Dicynodon cyclops*, *Dicynodon euryceps*, *Dicynodon glaucops*, *Dicynodon graaffi*, *Dicynodon greyii*, *Dicynodon halli*, *Dicynodon helenae*, *Dicynodon kolbei*, *Dicynodon latirostris* Broom, 1932, *Dicynodon luangwanensis* (and therefore also *Oudenodon luangwanensis*), *Dicynodon lutriceps*, *Dicynodon maccabei*, *Dicynodon marlothi*, *Dicynodon megalops*, *Dicynodon milletti*, *Dicynodon* *moutonae*, *Dicynodon mustoi*, *Dicynodon nesemanni*, *Dicynodon parabreviceps*, *Dicynodon planus*, *Dicynodon platyceps*, *Dicynodon platyfrons*, *Dicynodon prognathus*, *Dicynodon richardi*, *Dicynodon robertsi*, *Dicynodon robustus*, *Dicynodon schwarzi*, *Dicynodon truncatus*, *Dicynodon vanderbyli*, *Dicynodon wellwoodensis*, *Dicynodon wilmanae* are junior synonyms of *Oudenodon bainii* (Kammerer et al., 2011) and are treated accordingly. *Oudenodon bainii* is also known from Malawi (Botha and Angielczyk, 2007; Sidor et al., 2013, Table S1) and is treated accordingly.

Dicynodon grandis is possibly valid as *Oudenodon grandis* (Kammerer et al., 2011; Angielczyk et al., 2014b) and is retained as such in the database.

Dicynodon dubius is valid as *Tropidostoma dubium* (Kammerer et al., 2011) and is treated accordingly. *Dicynodon microtrema*, *Dicynodon acutirostris*, *Dicynodon cavifrons*, *Dicynodon dunnii*, *Dicynodon rogersi*, *Dicynodon validus* are junior synonyms of *Tropidostoma dubium* (Kammerer et al., 2011) and are treated accordingly. The oldest occurrences of *Tropidostoma dubium* are found in the *Tropidostoma* AZ (Day et al., 2015a, fig. 1) and the taxon is treated accordingly.

Dicynodon bainii is valid as *Aulacephalodon bainii* (Kammerer et al., 2011) and is treated accordingly. *Dicynodon bolorhinoides*, *Dicynodon laticeps*, *Dicynodon tigriceps* are junior synonyms of *Aulacephalodon bainii* (Kammerer et al., 2011) and are treated accordingly. *Aulacephalodon bainii* is also known from the lower and upper *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1) and is treated accordingly.

Dicynodon roberti is a junior synonym of *Syops vanhoepeni* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon scheepersi is a junior synonym of *Rhachiocephalus magnus* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon sidneyi is a junior synonym of *Pelanomodon moschops* (Kammerer et al., 2011, 2016b) and is treated accordingly.

Dicynodon duffianus, *Dicynodon huxleyanus*, *Dicynodon juddianus* are junior synonyms of *Gordonia traquairi* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon calverleyi, *Dicynodon microdon*, *Dicynodon weatherbyi* are junior synonyms of *Basilodon woodwardi* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon aetorhamphus, *Dicynodon cadlei*, *Dicynodon dutoiti*, *Dicynodon kitchingi*, *Dicynodon pardiceps*, *Dicynodon taylori*, *Dicynodon trigonocephalus* are junior synonyms of *Dicynodon lacerticeps* (Kammerer et al., 2011) and are treated accordingly in the database.

Dicynodon huenei Haughton, 1932 is a valid species of *Dicynodon* (Kammerer et al., 2011) and is therefore retained in the database. A nearly complete specimen from Zambia, that was assigned to '*Dicynodon trigonocephalus*' (King, 1981), is considered to belong to *Dicynodon huenei* (Kammerer et al., 2011) and is treated accordingly. Angielczyk et al. (2014a) also report *Dicynodon huenei* for the upper tetrapod-bearing horizon of the Ruhuhu Formation. The range of the taxon is expanded accordingly in the database.

Dicynodon annae, *Dicynodon rossicus*, *Dicynodon venyukovi* are junior synonyms of *Vivaxosaurus trautscholdi* (Kammerer et al., 2011) and are treated accordingly. Kurkin (2012) erected the new genus *Fortunodon* for the holotype of *Vivaxosaurus trautscholdi* without mentioning the new combination created by Kammerer et al. (2011). Herein, the interpretation of Kammerer et al. (2011) is followed and the taxon is retained in the database as *Vivaxosaurus trautscholdi*. The same applies to the new combination *Peramodon amalitzkii* proposed by Kammerer et al. (2011). Kurkin (2012) erected *Fortunodon amalitzkii* for its holotype. Herein, the interpretation of Kammerer et al. (2011) is followed and the taxon is retained in the database as *Peramodon amalitzkii*.

Dicynodon anneae, *Dicynodon galecephalus*, *Dicynodon macrodon* are junior synonyms of *Dinanomodon gilli* (Kammerer et al., 2011) and are treated accordingly. The stratigraphic range of *Dinanomodon gilli* is updated according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1).

Dicynodon daptocephaloides, *Dicynodon leontocephalus*, *Dicynodon leontops*, *Dicynodon lissops*, *Dicynodon osborni*, *Dicynodon watsoni* are junior synonyms of *Daptocephalus leoniceps* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon taoshuyuanensis is a junior synonym of *Jimusaria sinkianensis* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon sunanensis is a junior synonym of *Turfanodon bogdaensis* (Kammerer et al., 2011) and is treated accordingly.

Dicynodon copei, *Dicynodon orientalis*, *Dicynodon verticalis* are junior synonyms of *Lystrosaurus murrayi* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon declivis is valid as *Lystrosaurus declivis* (Kammerer et al., 2011) and is treated accordingly. *Dicynodon alfredi*, *Dicynodon depressus*, *Dicynodon latirostris* Owen, 1860 are junior synonyms of *Lystrosaurus declivis* (Kammerer et al., 2011) and are treated accordingly.

Dicynodon curvatus is valid as *Lystrosaurus curvatus* (Kammerer et al., 2011). It is treated accordingly and its stratigraphic range is modified according to Viglietti et al. (2016).

Dicynodon simocephalus is valid as *Kannemeyeria simocephalus* (Kammerer et al., 2011) and is treated accordingly. *Dicynodon latifrons* and *Dicynodon pachyrhynchus* are junior synonyms of *Kannemeyeria simocephalus* (Kammerer et al., 2011) and are treated accordingly (the taxon was misspelled as *Kannemeyeria simocephala* by Kammerer et al., 2011; see Kammerer et al., 2013).

The taxonomic status of *Dicynodon hartzenbergi* is “uncertain” (Kammerer et al., 2011, p. 38) and the taxon is therefore excluded from further analyses.

A.20.2 Pylaecephalidae & Emydopoidea

Phylogeny: *Emydops oweni* and *Kombuisia antarctica* are added to the supertree according to the strict consensus tree of Fröbisch and Reisz (2011, fig. 15), which is based on an updated dataset of Fröbisch (2007) with modifications of Fröbisch and Reisz (2008) and Fröbisch et al. (2010).

King (1988, p. 123) considers *Diictodontoides skaios* a member of the subfamily Diictodontinae (within Robertiidae). Indeed, Kammerer (2009, Table 9: p. 531) referred the holotype of *Diictodontoides skaios* to *Diictodon feliceps*. *Diictodontoides skaios* is therefore added as the sister taxon of *Diictodon feliceps*.

Cluver and Hotton III (1981) assigned *Emydorhynchus palustris* to the genus *Diictodon* (Sullivan and Reisz (2005) questioned this assignment, but did not provide an alternative). *Emydorhynchus formosus* might also belong to *Diictodon* (King, 1988, p. 123, 123) and is therefore added to a polytomy consisting of *Emydorhynchus formosus*, *Diictodontoides skaios*, and *Diictodon feliceps*.

King (1988, p. 118, 119) assigns *Aulacocephalus pithecops* to Robertiidae *incertae sedis* and mentions one feature found in both *Aulacocephalus pithecops* and *Robertia*. *Aulacocephalus pithecops* is therefore added to a polytomy consisting of early diverging pylaecephalids.

The OTU '*Emydops* sp.', represented by specimens described by Kammerer et al. (2011) and Angielczyk et al. (2014b), is added to a polytomy consisting of all species of *Emydops*.

Cryptocynodon simus is possibly an emydopoid (Castanhinha et al., 2013; Angielczyk and Cox, 2015) and kingoriid mandibles described by Angielczyk and Cox (2015) could potentially belong to *Cryptocynodon simus*. *Cryptocynodon simus* is therefore added to the polytomy among early diverging members of Emydopoidea. Note, however, that the phylogenetic relationships of *Cryptocynodon simus* and similar taxa are still difficult to resolve (Angielczyk et al., 2016).

Dicynodontoides nowacki is assumed to be the sister taxon of *Dicynodontoides recurvidens* and added accordingly. The Indian specimen described as *Dicynodontoides* sp. (Ray and Bandyopadhyay, 2003; Angielczyk et al., 2009) is added in a polytomy with the other species of *Dicynodontoides*.

Phylogenetic analyses of Kammerer et al. (2012) recover *Emydorhinus sciuroides* as the sister taxon of *Myosaurus*. Indeed, King (1988, p. 116, 117) considered *Myosaurus gracilis* and *Myosauroides minnaari* (a junior synonym of *Emydorhinus sciuroides*; Viglietti et al., 2016, Supplementary data: mmc1; C. F. Kammerer, pers. comm., 2016) to be the sole members of Myosaurini. *Emydorhinus sciuroides* is therefore added as the sister taxon of *Myosaurus gracilis*.

Alpha taxonomy: *Diictodon feliceps* is the only valid species (including *Diictodon galeops* and *Diictodon tienshanensis*) of the genus (Angielczyk and Sullivan, 2008; Fröbisch, 2009) and is treated accordingly. The stratigraphic and palaeobiogeographic range is updated according to Viglietti et al. (2016) and Angielczyk et al. (2014b).

Emydorhynchus formosus is retained in the database as the only valid species of the genus (Wyllie, 2003) but it might belong to *Diictodon* (King, 1988, p. 123). Fröbisch (2009) does not mention the taxon.

Aulacocephalus pithecops and *Diictodontoides skaios* are retained in the database. Note, however, that Fröbisch (2009) excluded them from his analysis, considering them to belong to a number of taxa " based on poor material and whose taxonomic status is questionable" Fröbisch (2009, p. 122).

Aulacocephalus pithecops has been erected by Seeley (1898). Note, however, that the genus name *Aulacocephalus* has already been used by Temminck and Schlegel (1842, p. 15) for a perciform grouper fish. Therefore, a new genus name needs to be created for *Aulacocephalus pithecops*.

Robertia broomiana is also known from the *Pristerognathus* AZ (Rubidge and Angielczyk, 2009; Olroyd and Sidor, 2017, Supplementary Information: Table 3) and the stratigraphic range of the taxon is updated accordingly.

Fröbisch and Reisz (2008) recognize two species of *Emydops*, *E. arctatus* and *E. oweni*, with *E. minor* being the junior synonym of *E. arctatus*. This view is implicitly followed by Angielczyk et al. (2014b). The taxa are treated accordingly in the database.

The specimen from the upper *Tapinocephalus* or *Pristerognathus* AZ, mentioned by King (1988, p. 116) as *Emydops* sp. and redescribed by Angielczyk et al. (2005), is referred to *Emydops arctatus* by Fröbisch and Reisz (2008, Appendix 2). The stratigraphic range of *Emydops arctatus* is expanded accordingly. *Emydops arctatus* is also known from the lowermost part of the *Dicynodon* AZ (Roopnarine and Angielczyk, 2015b, Supplementary Material: Table S1), which corresponds to the lowermost part of the lower *Daptocephalus* AZ *sensu* Viglietti et al. (2016). Viglietti et al. (2016, fig. 2; Supplementary data: mmc1) report the taxon for both the lower and upper *Daptocephalus* AZ. The corresponding stratigraphic range extension is incoporated into the database. *Dicynodon ictinops* is a junior synonym of *Emydops arctatus* (Kammerer et al., 2011) and is treated accordingly.

Emydops platyceps is either a *nomen dubium* or a junior synonym of *Emydops arctatus* (Fröbisch and Reisz, 2008). Herein, it is treated as a synonym of *Emydops arctatus*. Note, however, that the specimens from India reported for *Emydops platyceps* (Ray, 2001; Ray and Bandyopadhyay, 2003; Sidor et al., 2013, Supporting Information) have been reassigned to the the new taxon *Sauroscaptor* (Kammerer et al., 2016a). They are treated accordingly.

Dicynodon megalorhinus is now considered to represent a specimen of *Emydops* sp. (Kammerer et al., 2011) and it is retained in the database due to its importance for the stratigraphical range of the taxon. The same applies to *Dicynodon pseudojouberti* (Kammerer et al., 2011). The specimens from the Upper Madumabisa Mudstone of Zambia described as *Emydops* sp. (Angielczyk et al., 2014b) are also retained due to their palaeobiogeographic importance.

Compsodon helmoedi is treated as a valid taxon by Castanhinha et al. (2013), Sidor et al. (2013, Table S1), Angielczyk et al. (2014b), Angielczyk and Cox (2015), Kammerer et al. (2015b), and Angielczyk and Kammerer (2017b) and is therefore included in the database. Its stratigraphic range is updated according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1). It is also known from the Upper Madumabisa Mudstone of Zambia (Angielczyk et al., 2014b) and this occurrence is added to the database.

According to Day (2013, p. 281) *Cryptocynodon* is restricted to the *Pristerognathus* AZ. Indeed, Codron et al. (2017, Supporting Information: Table S1) report *Cryptocynodon simus* only for the *Pristerognathus* AZ. Possible occurrences from the *Tapinocephalus* AZ have been mentioned elsewhere (Castanhinha et al., 2013; Day, 2013, p. 236, 237; Angielczyk et al., 2016) and in Day et al. (2015a, Dataset S1) the respective specimen belongs to either the uppermost *Tapinocephalus* or the *Pristerognathus* AZ (see also Day, 2013, fig. 38, 39, 42). Indeed, Olroyd and Sidor (2017, Supplementary Information: Table 2) report *Cryptocynodon simus* only for the *Tapinocephalus* AZ, citing hereby Day (2013). Day (2013, p. 237) mentions that this specimen "straddles the boundary of the Abrahamskraal and Teekloof formations", which would therefore belong to the uppermost part of the *Tapinocephalus* AZ (Day et al., 2015a, fig. 1). In agreement with Day et al. (2015a, Dataset S1) *Cryptocynodon simus* is retained in the database for the uppermost *Tapinocephalus* and the *Pristerognathus* AZ. Note, however, that a redescription of the genus appears necessary (Castanhinha et al., 2013).

The Indian specimen described as *Dicynodontoides* sp. (Ray and Bandyopadhyay, 2003; Angielczyk et al., 2009) is retained herein due to its palaebiogeographical importance.

The Zambian specimen described as *Dicynodontoides cf. D. nowacki* (Angielczyk et al., 2014b) is added to the database due to its palaeobiogegraphic importance. It is herein retained within *Dicynodontoides nowacki*. Sidor et al. (2013, Supporting Information: Table S1) report *Dicynodontoides nowacki* from the Chiweta Beds of Malawi, which are probably the specimens mentioned by Angielczyk et al. (2009). The taxon is treated accordingly.

Digalodon rubidgei is valid species (Kammerer et al., 2015b). It is added to the database and its stratigraphic range is updated according to Kammerer et al. (2015b, fig. 2; Supplementary data: mmc1).

Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) report *Myosauroides* also for the *Dicynodon* AZ. Viglietti et al. (2016, fig. 2), however, do not report *Myosauroides* at all from their *Daptocephalus* AZ (~*Dicynodon* AZ). Viglietti et al. (2016, Supplementary data: mmc1), however, report the holotype RC 54 of *Myosauroides minnaari* Broom, 1941 (often misspelled as *Myosauroides minaari*; e.g., King, 1988, p. 117; Fröbisch, 2009; Sidor et al., 2013, Table S1; Angielczyk et al., 2014b, Table 7.4; Angielczyk and Cox, 2015) for the *Cistecephalus* AZ. Viglietti et al. (2016, Supplementary data: mmc1) assign RC 54 to *Emydorhinus sciuroides* which would make *Myosauroides minnaari* a junior synonym of the latter taxon. Indeed, *Myosauroides minnaari* is a junior synonym of *Emydorhinus sciuroides* (C. F. Kammerer, pers. comm., 2016) and is treated accordingly. Viglietti et al. (2016, fig. 2; Supplementary data: mmc1) report *Emydorhinus sciuroides* for the *Cistecephalus*, lower *Daptocephalus* and upper *Daptocephalus* AZ. Fröbisch (2009) considered *Emydorhinus sciuroides* to be of questionable taxonomic status, but it is treated as a valid taxon by Nicolas and Rubidge

(2010), Kammerer et al. (2012), Fröbisch and Kammerer (2014) and Viglietti et al. (2016, fig. 2). This view is followed herein and the taxon is treated accordingly.

Material from India, that previously had been assigned to *Cistecephalus microrhinus* (Kutty, 1972; Ray, 2001; Angielczyk et al., 2014b) is now considered to belong to the species *Sauroscaptor* (Kammerer et al., 2016a). The occurrences are treated accordingly.

Cistecephalus is also reported from the *Tropidostoma* AZ of South Africa (Nasterlack et al., 2012; Fröbisch, 2014b, Appendix 18.1; Roopnarine and Angielczyk, 2015b, Supplementary Material: Table S1). The stratigraphic range of *Cistecephalus microrhinus* is updated accordingly (see also Retallack et al., 2006, fig. 8).

Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) report *Cistecephaloides* only for the *Dicynodon* AZ, but Angielczyk et al. (2014b) report it for the *Cistecephalus* AZ and Viglietti et al. (2016, fig. 2) do not report the taxon for their *Daptocephalus* AZ (˜*Dicynodon*AZ). Therefore, *Cistecephaloides* is herein retained only for the *Cistecephalus* AZ.

A.20.3 'Cryptodontia'

Phylogeny: The different species of *Oudenodon* are assumed to be sister taxa and are placed in a corresponding polytomy.

The two species of *Australobarbarus* are also assumed to be sister taxa and are treated accordingly. The same applies to the two species of *Rhachiocephalus*.

Alpha taxonomy: Fröbisch (2014b, Appendix 18.1) reports *Keyseria* only for the *Dicynodon* AZ (now *Daptocephalus* AZ *sensu* Viglietti et al., 2016. According to Angielczyk et al. (2014b, Table 7.4) *Keyseria benjamini* might also be present in the *Cistecephalus* AZ, but Angielczyk et al. (2014b, Table 7.4: p. 131) also note that the stratigraphic range is "not well-constrained". Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) report the taxon for both the *Cistecephalus* and the *Dicynodon* AZ (see also Kammerer et al., 2015b). It is treated accordingly.

Odontocyclops whaitsi is known from both South Africa and Zambia (Angielczyk et al., 2014b) and is treated accordingly.

It is not certain, whether *Oudenodon grandis* is a valid species (Botha and Angielczyk, 2007), but it is included in the faunal list of Angielczyk et al. (2014b, Table 7.4) and is therefore retained in the database. According to Day et al. (2018b, fig. 1) *Oudenodon grandis* is restricted to the Tropidostoma AZ. The stratigraphic range of the taxon is updated accordingly. *Oudenodon sakamenensis* is also retained in the database, following Fröbisch (2009). Note, however, that Kurkin (2011) considers diagnostically important parts of the skull of *Oudenodon sakamenensis* to be missing.

Keyser (1973b) and Botha and Angielczyk (2007) considered *Cteniosaurus platyceps* a junior synonym of *Tropidostoma microtrema* (contra Cluver and King (1983, p. 218) and King (1988, p. 82, 83)). This interpretation is followed herein. *Tropidostoma microtrema* is now considered a junior synonym of *Tropidostoma dubium* (Kammerer et al., 2011, p. 65). *Cteniosaurus platyceps* is therefore treated as a junior synonym of *Tropidostoma dubium*. Indeed, also Kammerer (2009, Table 9: p. 476) treats the taxon as a junior synonym of *Tropidostoma dubium*. King (1988, p. 83) reports *Cteniosaurus platyceps* for the *Cistecephalus* AZ, but Kammerer (2009, Table 9: p. 476) reports the same specimens from the *Tropidostoma* AZ. The stratigraphic range of *Cteniosaurus platyceps* (= *Tropidostoma dubium*) is therefore restricted to the *Tropidostoma* AZ.

The taxonomy and stratigraphic ranges of *Rhachiocephalus* are mainly based on Fröbisch (2009) and updated with Angielczyk et al. (2014b) and Viglietti et al. (2016). Therefore *Rhachiocephalus magnus* is not recorded for the Madumabisa Mudstone of Zambia (Angielczyk et al., 2014b). *Rhachiocephalus behemoth* is restricted to Tanzania (Angielczyk et al., 2014b) and is treated accordingly.

Kitchinganomodon crassus is a valid taxon (Angielczyk et al., 2014b; Kammerer et al., 2015b, 2016b) and is therefore included in the database, including its Zambian (Angielczyk et al., 2014b) and Malawian occurrence (Sidor et al., 2013, Table S1). Its stratigraphic range is updated according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1).

Pelanomodon moschops is the only valid species of the genus *Pelanomodon* and *Pelanomodon rubidgei* is interpreted as being only a sexual dimorph of the taxon (Kammerer et al., 2016b). *Propelanomodon* is a juvenile morphotype of *Pelanomodon moschops* (Kammerer et al., 2016b). These taxa are treated accordingly in the database.

Pelanomodon tuberosus is a junior synonym of *Geikia locusticeps* (Maisch and Gebauer, 2005) and is treated accordingly in the database.

A.20.4 Lystrosauridae

Phylogeny: The strict consensus tree of Kammerer and Smith (2017, fig. 18), which is based on an updated character matrix of Kammerer et al. (2011) with modifications of Castanhinha et al. (2013), Kammerer et al. (2013), Kammerer et al. (2015b), Kammerer et al. (2016a), Angielczyk et al. (2016), and Boos et al. (2016), is used to add the taxon *Kwazulusaurus shakai*.

Lystrosaurus georgi is added according to the strict consensus tree of Surkov et al. (2005, fig. 10A). *Lystrosaurus robustus* and *Lystrosaurus shichanggouensis* are added according to the majority-rule consensus tree of Liu et al. (2002, fig. 3).

Alpha taxonomy: *Euptychognathus bathyrhynchus* is also known from the *Cistecephalus* AZ of South Africa (Kammerer et al., 2011; Angielczyk et al., 2014b) and this occurrence is added to the database.

The taxonomy of *Lystrosaurus* follows Grine et al. (2006) and Fröbisch (2009) for the South African species and Fröbisch (2009) for the other species of *Lystrosaurus*. The stratigraphic range of the taxa is updated with Viglietti et al. (2016) where applicable. Therefore the species *Lystrosaurus curvatus*, *Lystrosaurus declivis*, *Lystrosaurus murrayi*, *Lystrosaurus maccaigi*, *Lystrosaurus georgi*, *Lystrosaurus hedini*, *Lystrosaurus robustus*, and *Lystrosaurus shichanggouensis* are included in the database. *Lystrosaurus youngi* is treated as a junior synonym of *Lystrosaurus curvatus*, *Lystrosaurus rajurkari*, and *Lystrosaurus broomi* as junior synonyms of *Lystrosaurus murrayi* and *Lystrosaurus latifrons* as junior synonym of *Lystrosaurus robustus* (Ray, 2005; Grine et al., 2006; Fröbisch, 2009). Note, however, that the Chinese *Lystrosaurus* species might be oversplit (Camp, 2010; see also Kammerer et al., 2011) and their taxonomy is currently being revised (J. A. Miller-Camp, pers. comm., 2016).

Thackeray (2018) suggests that *Lystrosaurus declivis* is a junior synonym of *Lystrosaurus murrayi*, but this assessment is only based on a comparison of basal skull lengths and further analyses are necessary to evaluate this hypothesis.

The stratigraphic range of *Lystrosaurus curvatus* is modified according to Viglietti et al. (2016).

A.20.5 Kannemeyeriiformes

Phylogeny: The subtree of Kammerer (2018, fig. 21), which is based on an expanded character matrix of Angielczyk and Kammerer (2017b), is used to add the taxon *Pentasaurus goggai*.

The single most parsimonious tree of Liu and Li (2003, fig. 5) is used to add the taxa *Parakannemeyeria ningwuensis*, *Parakannemeyeria youngi*, *Parakannemeyeria shenmuensis*, *Sinokannemeyeria yingchiaoensis*, and *Sinokannemeyeria sanchuanheensis*.

The strict consensus tree of Maisch and Matzke (2014, fig. 3), based on the updated data matrices of Maisch (2001) and Vega-Dias et al. (2004), is used to add the taxon *Sungeodon kimkraemerae*.

The three species of *Vinceria* are assumed to be sister taxa and are placed in a corresponding polytomy.

All species of *Shansiodon* are assumed to be closely related. *Shansiodon wupuensis* might be conspecific with *Shansiodon* (Li and Sun, 2008, p. 394) and is therefore added as its sister taxon. *Shansiodon shaanbeiensis* might be conspecific with *Shansiodon wuhsiangensis* (Li and Sun, 2008, p. 395) and is therefore added as its sister taxon. Due to its palaeobiogeographic importance the South African specimen described as *Shansiodon* sp. (Hancox et al., 2013) is added to the database as a separate taxon. It is particularly similar to *Shansiodon wuhsiangensis* (Hancox et al., 2013) and is therefore added as the sister taxon of the clade *Shansiodon wuhsiangensis* + *Shansiodon shaanbeiensis*.

Shaanbeikannemeyeria buerdongia might be a synonymous with *Shaanbeikannemeyeria xilougoensis* (Kammerer et al., 2013) and is added as the sister taxon of *Shaanbeikannemeyeria* *xilougoensis*.

Angielczyk et al. (2014b) consider the referral of *Kannemeyeria latirostris* to *Dolichuranus* (Keyser, 1973a; Keyser and Cruickshank, 1979) as currently unwarranted and retain it as "*Kannemeyeria*" *latirostris*. This view is followed herein. It is added to a polytomy including the clade *Kannemeyeria simocephalus* + *Rabidosaurus cristatus* and the clade *Kannemeyeria lophorhinus* + *Wadiasaurus indicus*.

Rhadiodromus mariae is assumed to be the sister taxon of *Rhadiodromus klimovi* and is added accordingly.

Sinokannemeyeria baidaoyuensis could also be a larger specimen of *Sinokannemeyeria sanchuanheensis* (Liu, 2015) and is therefore added as the sister taxon of *Sinokannemeyeria sanchuanheensis*.

According to Kammerer et al. (2013) *Elephantosaurus jachimovitschi* might fall outside of Stahleckeriidae. An alternative position within Kannemeyeriiformes, however, is not reported (Kammerer et al., 2013) and it has previously been suggested, that *Elephantosaurus* might be a junior synonym of *Stahleckeria* (Lucas, 2010). *Elephantosaurus jachimovitschi* is therefore added as the sister taxon of *Stahleckeria impotens*.

Sangusaurus edentatus is assumed to be the sister taxon of *Sangusaurus parringtonii*.

A description of the *Ischigualastia*-like form from Poland (Dzik et al., 2008) is currently in progress (Kammerer et al., 2013). It is retained herein as *Ischigualastia* sp. and is added to the phylogeny as a sister taxon of *Ischigualastia jenseni*.

The two species of *Jachaleria* are assumed to be sister taxa.

Alpha taxonomy: The South African specimens described as *Angonisaurus* sp. (Hancox et al., 2013) are retained in the database entry of *Angonisaurus cruickshanki* (see also Fröbisch, 2009). *Angonisaurus* sp. is also known from the upper Fremouw Formation of Antarctica (Hancox et al., 2013; Sidor et al., 2013, Table S2; Sidor et al., 2014b) and this occurrence is also added to the database.

Following the considerations of Renaut and Hancox (2001), Fröbisch (2009) treated *Kannemeyeria argentinensis* as *Vinceria argentinensis*. Domnanovich and Marsicano (2012) erected the new species *Vinceria vieja* for a specimen that Renaut and Hancox (2001) had considered to be referable to *Kannemeyeria argentinensis*/*Vinceria argentinensis*. Domnanovich and Marsicano (2012) do not further explain the relationship of *Vinceria vieja* and *Vinceria argentinensis*. The species *K. argentinensis* is a valid taxon (C. A. Marsicano, pers. comm., 2016) and it is herein referred to the genus *Vinceria* following the analyses of Renaut and Hancox (2001).

Dinodontosaurus pedroanum is the only valid species of the genus *Dinodontosaurus* (Langer et al., 2007; Fröbisch, 2009; Kammerer et al., 2011; Dassie, 2014, p. 28), with *Dinodontosaurus brevirostris* and *Dinodontosaurus platyceps* being junior synonyms of *Dinodontosaurus pedroanum* (Lucas and Harris, 1996; Langer et al., 2007). The taxon is treated accordingly.

Fröbisch (2009) accepts the synonymy of *Shaanbeikannemeyeria* with *Kannemeyeria* as argued elsewhere (Cox, 1991; Lucas, 1993; Rubidge, 2005). Liu (2015) and Kammerer et al. (2013, f), however, treat them as separate taxa. This view is followed herein.

The stratigraphic range of *Kannemeyeria simocephalus* in the Karoo Basin is restricted to subzone B of the *Cynognathus* Assemblage Zone (Hancox et al., 1995; Govender et al., 2008; Smith et al., 2012b; Hancox et al., 2013). Indeed, Sidor et al. (2014b) report *Kannemeyeria* and *Angonisaurus* to not co-occur in subzone C of the *Cynognathus* Assemblage Zone. The stratigraphic range of *Kannemeyeria simocephalus* is treated accordingly in the database. Note, that *Kannemeyeria simocephalus* is also known from the Kingori Sandstone or the lowermost portion of the Lifua Member in the Ruhuhu Basin (see Hancox et al., 2013; Wynd et al., 2018; Smith et al., 2018; Kammerer et al., 2018; Butler et al., 2018). The stratigraphic range of *Kombuisia frerensis* is also restricted to subzone B of the *Cynognathus* Assemblage Zone (Hancox et al., 2013) and is treated accordingly.

Kannemeyeria wilsoni is a junior synonym of *Kannemeyeria simocephalus* according to Renaut (2000, p. 124, 136). Indeed, the taxon is not mentioned by Fröbisch (2009) and is also not incorporated in the supertree analysis of Brocklehurst et al. (2015, Supplementary Information) (see also Brocklehurst, 2015, Appendix M: p. 438). Cruickshank (1975) already speculated that the two taxa might be sexual dimorphs of the same species, but kept them separate in his analysis and described the specimen ELM 1 as *Kannemeyeria wilsoni*. When re-evaluating the postcranial skeleton of *Kannemeyeria simocephalus* Govender et al. (2008) considered the same specimen to be different enough to warrant exclusion of the specimen from the referred material of *Kannemeyeria simocephalus*. Govender et al. (2008), however, did not resurrect *Kannemeyeria wilsoni* but followed Renaut (2000) in considering *Kannemeyeria simocephalus* the only valid species of the genus. Instead they considered ELM 1 a chimera. *Kannemeyeria wilsoni* is herein treated as a junior synonym of *Kannemeyeria simocephalus*.

Renaut et al. (2003) erected the new species *Kannemeyeria lophorhinus* for two specimens from Africa that were previously referred to *Rechnisaurus cristarhynchus* (Crozier, 1970) and later to *Rechnisaurus* '*cristarhynchus*' (Keyser and Cruickshank, 1979). This view is followed herein (see also Angielczyk et al., 2014b). The Indian species *Rechnisaurus cristarhynchus* is retained as a valid taxon (Renaut et al., 2003; Angielczyk et al., 2014b).

Xiyukannemeyeria brevirostris is treated as a valid taxon by Kammerer et al. (2013) and Liu and Abdala (2015). Maisch and Matzke (2014) include the taxon in their phylogenetic analysis. It is therefore included in the database.

Fröbisch (2009) recognizes five species of *Parakannemeyeria*, namely *P. dolichocephala*, *P. ningwuensis*, *P. youngi*, *P. shenmuensis*, and *P. chengi*. All species, except for *P. chengi*, are treated as mentioned in Fröbisch (2009). *Parakannemeyeria chengi* probably does not belong to the genus *Parakannemeyeria* (Liu and Abdala, 2015) but might be a synonym of *Sungeodon kimkraemerae* (J. Liu, pers. comm., 2016) and is treated accordingly.

Edaxosaurus edentatus is considered a junior synonym of *Uralokannemeyeria vjuschkovi* (Kammerer et al., 2013) and is treated accordingly.

Rhadiodromus mariae is treated as a valid species by Fröbisch (2009) and it is also included in the analyses of Sookias et al. (2012b, Supplement 1) and of Pearson et al. (2013, Appendix S1). The alpha taxonomy of the species has not changed so far (C. F. Kammerer, pers. comm., 2016) and the taxon is therefore added to the database.

Lucas and Hunt (1993) considered *Placerias gigas* to be a junior synonym of *Placerias hesternus* and this view was followed by Fröbisch (2009) and Green et al. (2010). The taxon is treated accordingly. Note, however, that according to Irmis (2005b) no one has explicitly shown that the holotype of *Placerias hesternus* represents a specimen that warrants a species diagnosis.

Lucas and Wild (1995) considered *Moghreberia nmachouensis* to be a member of the genus *Placerias*. This was accepted by Fröbisch (2009) but it was also mentioned that the type material of *Placerias nmachouensis* needed to be restudied to confirm the presence of the genus *Placerias* in Morocco. Indeed, Kammerer et al. (2013) code the taxon *Moghreberia* separately from *Placerias* in their phylogenetic analyses. Therefore, *P. nmachouensis* is retained in the database within the genus *Moghreberia*.

Stahleckeria impotens is a junior synonym of *Stahleckeria potens* (Vega-Dias et al., 2005; Fröbisch, 2009) and is treated accordingly.

Sangusaurus parringtonii is treated as a valid taxon by various authors (Fröbisch, 2009; Hancox et al., 2013; Sidor et al., 2013; Nesbitt et al., 2014; Angielczyk et al., 2014b) and is therefore included in the database.

Eubrachiosaurus browni, which had previously been assigned to *Placerias hesternus* (Lucas and Hunt, 1993; Fröbisch, 2009), is a valid taxon according to Kammerer et al. (2013) and is treated accordingly.

Putillosaurus sennikovi is mentioned by Sennikov (2015) but it is probably a *nomen dubium* according to Fröbisch (2009) and is therefore excluded from the database.

Dicynodon tener and *Dicynodon turpior* (and therefore also *Dinodontosaurus tener* and *Dinodontosaurus turpior*) are *nomina dubia* (Kammerer et al., 2011) and are treated accordingly.

Cox (1968) described *Dinodontosaurus platygnathus*, which was referred to the genus *Jachaleria* by Keyser and Cruickshank (1979). The reassignment was accepted by Fröbisch and Reisz (2009). Domnanovich and Marsicano (2009), however, reassigned the specimen to *Dinodontosaurus platygnathus* and Morato (2006, p. 13) considered the taxon to be a *nomen dubium*. Due to the taxonomic uncertainty of *Jachaleria platygnathus*, it is herein treated as a *nomen dubium*, following Morato (2006).

A.21 Therocephalia

Phylogeny: The therocephalian part of the synapsid subtree is based on the majority rule consensus tree of Liu and Abdala (2017a, fig. 7: right), whose data matrix is based on a modified version of Huttenlocker and Sidor (2016), which is itself based on Huttenlocker et al. (2015). The conservative topology of Huttenlocker and Smith (2017, fig. 9), which is also based on a modified character matrix of Huttenlocker and Sidor (2016), is used to improve the resolution within Bauriidae and to resolve the polytomy consisting of the clade *Regisaurus jacobi* + *Urumchia lii*, Lycideopidae, and Bauriamorpha. Following the strict parsimony consensus tree of Huttenlocker and Smith (2017, Online Supplementary Information: Appendix S3), Therocephalia is added as sister taxon of Cynodontia, forming the clade Eutheriodontia (see also Kammerer, 2014b). Eutheriodontia is then added as sister taxon of Gorgonopsia, forming a monophyletic Theriodontia as recovered in the preferred cladogram of Sidor and Hopson (1998, fig. 2) and proposed by Rubidge and Sidor (2001, fig. 3). Theriodontia is still generally recognized (Kammerer, 2014b) and most recent studies favour the sister-taxon relationship of Gorgonopsia with Eutheriodontia (e.g., Amson and Laurin, 2011; Liu and Abdala, 2017a; see also Benoit et al., 2016, fig. 7; Benoit et al., 2017, fig. 1; Button et al., 2017, fig. 2).

Gorynychus masyutinae is added according to the strict consensus tree of Kammerer and Masyutin (2018a, fig. 12), which is based on an expanded character matrix of Huttenlocker and Smith (2017).

Abdala et al. (2014a) recognize *Simorhinella baini* and *Lycosuchus vanderrieti* as valid species within Lycosuchidae. *Simorhinella baini* is therefore added as the sister taxon of *Lycosuchus vanderrieti*.

Lycosuchidae consists of *Porosteognathus* and *Lycosuchus* according to Ivakhnenko (2011, p. 1016). A trichotomy consisting of *Porosteognathus efremovi*, *Lycosuchus vanderrieti*, and *Simorhinella baini* is therefore created.

Cynariognathus platyrhinus is a scylacosaurid according to Wyllie (2003, Appendix) and Huttenlocker (2013, Appendix 10: UCMP 42667). Cys (1967) and Fröbisch (2008b, p. 92) report it as a pristerognathid. Indeed, Broom (1912) had initially described this taxon as *Pristerognathus platyrhinus* (Cys, 1967). *Cynariognathus platyrhinus* is therefore added to a polytomy including *Pristerognathus polyodon* and *Glanosuchus macrops*.

Polycynodon elegans is a member of Scaloposauridae according to Haughton and Brink (1954, p. 144) and Haughton (1965, p. 7) (Romer (1956a, p. 701) reports it as Bauriamorpha *incertae sedis*). Additional to *Polycynodon elegans*, Scaloposauridae *sensu* Haughton and Brink (1954) also contains *Choerosaurus*, *Cyrbasiodon* (= *Procynosuchus*; Kammerer and Abdala, 2009), *Ericiolacerta*, *Icticephalus*, *Ictidognathus*, *Ictidostoma*, *Ictidosuchops*, *Nanictidops*, *Nanictocephalus* (an indeterminate basal member of Baurioidea according to Kammerer, 2009, Table 9: p. 624), *Pelictosuchus* (a synonym of *Akidnognathus*; Wyllie, 2003, Appendix), *Scalopocephalus*, *Scaloporhinus*, *Scaloposaurus*, *Scaloposuchus* (an indeterminate basal member of Baurioidea according to Kammerer, 2009, Table 9: p. 627; see also Huttenlocker and Sidor, 2016), *Silpholestes*, and *Tetracynodon*. Disregarding *Cyrbasiodon*, whose scaloposaurid affinities were already doubted by Haughton and Brink (1954, p. 142), *Polycynodon elegans* can therefore be placed in a polytomy with the clade Akidnognathidae + Chthonosauridae and the clade consisting of Whaitsioidea and Baurioidea. It is added accordingly.

Alpha taxonomy: *Lycosuchus vanderrieti* is known from both the *Pristerognathus* and *Tapinocephalus* AZ (Abdala et al., 2014a; Day et al., 2015a, fig. 1) and is treated accordingly.

Simorhinella baini is restricted to the *Tapinocephalus* AZ (Abdala et al., 2014a; Day et al., 2015a, fig. 1) and is treated accordingly.

Alopecodon is treated as a valid taxon by Fröbisch (2014b, Appendix 18.1), Day et al. (2015a, fig. 1), and Huttenlocker et al. (2015), with the only valid species being *A. priscus* (Wyllie, 2003, Appendix; Abdala et al., 2008, Table 1; Day, 2013, p. 264, 265). The species is added to the database.

Pardosuchus whaitsi is a valid taxon (Wyllie, 2003, Appendix; Day, 2013, p. 271, 272; Fröbisch, 2014b, Appendix 18.1; Day et al., 2015a, fig. 1) and is therefore added to the database.

Glanosuchus macrops is also known from the *Pristerognathus* AZ (Fröbisch, 2014b, Appendix 18.1; Day et al., 2015a, fig. 1) and is treated accordingly.

The holotype (SAM-PK-3415) of *Pristerognathoides minor* (and thus also *Pristerognathus minor*; Broom, 1932, p. 56) is now assigned to *Glanosuchus* (Day, 2013, p. 266; Day et al., 2015a, Dataset S1) and is treated accordingly.

Alopecognathus angusticeps is considered a junior synonym of *Glanosuchus macrops* (Wyllie, 2003, Appendix) and this view is followed by Huttenlocker (2013, Table 1.1). Indeed, Day (2013, p. 266) and Day et al. (2015a, Dataset S1) report the holotype of *Alopecognathus angusticeps* (AMNH 5559) for *Glanosuchus*. The taxon is treated accordingly herein. Note, however, that Kammerer (2009, Table 9: p. 619) considered the species *Alopecognathus angusticeps* to be valid and Brocklehurst (2015, Appendix C: p. 239) also treats it as a valid taxon.

Kammerer (2009, Table 9: p. 626) assigned the holotype of *Ptomalestes avidus* to *Glanosuchus macrops*, while Huttenlocker (2013, p. 28; Appendix 1: 330; Appendix 10: p. 396) followed van den Heever (1994) in assigning it to *Pristerognathus polyodon*. Day (2013, p. 272) also assigns the holotype (SAM-PK-11942) of *Ptomalestes avidus* to *Pristerognathus polyodon*. It is treated herein accordingly. This increases the stratigraphic range of *Pristerognathus polyodon* to the *Tapinocephalus* AZ. Indeed, Fröbisch (2014b, Appendix 18.1) also reports *Pristerognathus polyodon* for both *Tapinocephalus* AZ and *Pristerognathus* AZ. Note, that Day et al. (2015a, fig. 1) report *Pristerognathus polyodon* only for the *Tapinocephalus* AZ but not for the *Pristerognathus* AZ, following therefore Day (2013), who writes: “Ironically, no securely identified specimens of the genus *Pristerognathus* are found in the assemblage zone that bears its name” (Day, 2013, p. 273). Awaiting further confirmation, the taxon *Pristerognathus polyodon* is for now not removed from the *Pristerognathus* AZ, but occurrences from the *Tapinocephalus* AZ are added to the database.

Scylacosaurus sclateri is known from both *Tapinocephalus* and *Pristerognathus* AZ (Day et al., 2015a, fig. 1) and is treated accordingly. *Therioides* is a junior synonym of *Scylacosaurus* (Huttenlocker, 2013, p. 28; Appendix 1: p. 330) and is treated accordingly. Indeed, Day (2013, p. 274) reports the holotype specimen of *Therioides cyniscus* (SAM-PK-11888) among the referred specimens of *Scylacosaurus sclateri* (see also Day et al., 2015a, Dataset S1).

Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) treat *Polycynodon* as a valid taxon and report it for the *Dicynodon* AZ. Brocklehurst et al. (2017, Supplementary Data) report the taxon for the *Cistecephalus* AZ, but this record is probably based on an older dataset, which identified specimens down to genus level (Nicolas and Rubidge, 2010; see Irmis et al., 2013b, Appendix A: Supplementary Data A). A first-hand examination of specimens with identification down to species level Irmis et al. (2013b, Appendix A: Supplementary Data B) recovers the taxon only in the *Dicynodon* AZ. Wyllie (2003, Appendix) also considers the species *Polycynodon elegans* to be valid and it is therefore added to the database. Note, however, that the taxon is rather poorly known (Crompton, 1955a).

Zinnosaurus paucidens, *Scymnosaurus major*, *Trochosuchus acutus*, and *Trochosuchus major* are considered Lycosuchidae *incertae sedis* (Abdala et al., 2014a) and are therefore not further considered in the analyses.

Trochosaurus dirus is a valid taxon according to Wyllie (2003), but Kammerer (2009, p. 247) considered it a junior synonym of *Lycosuchus vanderrieti*. This interpretation is also mentioned by Huttenlocker (2013, p. 27). Both *Trochosuchus acutus* and *Trochosuchus major* were referred to *Lycosuchus vanderrieti* by Kammerer (2009, p. 247) and, as mentioned before, are now considered Lycosuchidae *incertae sedis* (Abdala et al., 2014a). At least *T. major* is clearly better preserved than *T. dirus* (see Broom, 1936a and Abdala et al., 2014a). Therefore, herein it is assumed that *Trochosaurus dirus* can also be considered Lycosuchidae *incertae sedis*. *Trochosaurus dirus* is therefore also excluded from further analyses.

Ivakhnenko (2011) treats *Scylacoides ferox* as a valid taxon but it is not mentioned among the synapsid genera of the Karoo Basin as presented by Fröbisch (2014b, Appendix 18.1). *Scylacoides ferox* is referred to Pristerognathidae by Boonstra (1935), who considers, among others, *Alopecodon priscus*, *Alopecognathus angusticeps* (= *Glanosuchus macrops*; Wyllie, 2003, Appendix; Day et al., 2015a, Dataset S1), *Cynariognathus platyrhinus*, and *Scylacosaurus sclateri* to belong to Pristerognathidae. All these taxa are recovered as scylacosaurids by Huttenlocker and Sidor (2016, fig. 5: right). Haughton (1924a, p. 77), Haughton and Brink (1954, p. 7, 133), and Romer (1956a, p. 697) also report *Scylacoides ferox* as a member of Pristerognathidae. The holotype is very poorly preserved (van den Heever, 1994) and Broom (1915) already mentioned that it was impossible to refer the species confidently to either Therocephalia or Gorgonopsia. Indeed, van den Heever (1987, p. 441–443) reinterpreted the holotype as Gorgonopsia *incertae sedis*. This interpretation is also mentioned by Wyllie (2003, Appendix), but Kammerer (2009, Table 8: p. 461) still list the taxon as a therocephalian. Due to the uncertain status of the species *Scylacoides* *ferox* is excluded from further analyses.

A.21.1 Akidnognathidae & Chthonosauridae

Phylogeny: The species of *Annatherapsidus* are assumed to be sister taxa and are added accordingly.

Nanictidops kitchingi is an akidnognathid according to Botha-Brink and Modesto (2011) and is therefore added in a polytomy with *Shiguaignathus* and the clade consisting of the other members of Akidnognathidae.

Nanictidops and *Purlovia* are the only members of the family Nanictidopidae according to Ivakhnenko (2011).*Purlovia maxima* is therefore added as a sister taxon of *Nanictidops kitchingi*.

Zorillodontops gracilis is an akidnognathid according to Kammerer (2009, Table 9: p. 631) and Huttenlocker (2013, Appendix 10). It is added in a polytomy with *Shiguaignathus wangi*, *Purlovia maxima* + *Nanictidops kitchingi*, and the other members of Akidnognathidae.

Yikezhaogia megafenestrala is similar to *Olivierosuchus* (Huttenlocker, 2013, p. 35) and is therefore added as its sister taxon. Note, however, that Li and Sun (2008, p. 407, 408) refer the taxon to Therocephalia *incertae sedis*.

Alpha taxonomy: Huttenlocker and Sidor (2016) and Huttenlocker et al. (2015) treat *Perplexisaurus foveatus* (see also Huttenlocker and Sidor, 2016, Supplementary Data 2: R1) as a valid taxon, but consider it to be "problematic" (Huttenlocker and Sidor, 2016, p. e1111897-10) and "enigmatic" (Huttenlocker et al., 2015, p. e969400-8). *Perplexisaurus foveatus* is herein treated as a valid taxon. *Chlynovia serridentatus* is a junior synonym of *Perplexisaurus foveatus* (Ivakhnenko, 2011) and is treated accordingly.

Ivakhnenko (2011) erects the new taxon *Purlovia maxima* and assigns an incomplete skull, that previously had been referred to *Hexacynodon purlinensis*, to the new taxon. Abdala et al. (2014a) treat *Purlovia maxima* as valid and this view is followed herein. *Purlovia maxima* is added to the database.

Wyllie (2003, Appendix), Fröbisch (2014b, Appendix 18.1), and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) treat *Nanictidops* as a valid taxon. Viglietti et al. (2016, Supplementary data: mmc1) report *Nanictidops kitchingi* from the lower *Daptocephalus* AZ. The taxon is treated accordingly. Note, however, that Kammerer (2009, Table 9: p. 624) considered the holotype of *Nanictidops kitchingi* to be indeterminate.

Akidnognathus parvus is treated as a valid taxon by Huttenlocker et al. (2011a), Huttenlocker and Sidor (2012), Fröbisch (2014b, Appendix 18.1), Huttenlocker et al. (2015), Huttenlocker and Abdala (2015). It is therefore included in the database and its stratigraphic range is updated according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1).

The stratigraphic range of *Promoschorhynchus platyrhinus* is modified according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1). Note, that the occurrence from the *Lystrosaurus*

AZ is based on the specimen described as *Promoschorhynchus cf. P. platyrhinus* (Huttenlocker et al., 2011a; Huttenlocker and Smith, 2017). *Promoschorhynchus platyrhinus* is also known from Madagascar (Huttenlocker and Sidor, 2016, Supplementary Data 2: R1) and is treated accordingly.

Notaelurodon is treated as a valid taxon by Botha-Brink and Modesto (2011), Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1), but Huttenlocker and Smith (2017, Table 2) do not list it among the valid African Permo-Triassic therocephalians. The taxon is only poorly preserved (Huttenlocker et al., 2011a) and a determination down to genus and species (*Notaelurodon kitchingi*) level might not be possible (van den Heever, 1987, p. 336, 337; 530; 539; Wyllie, 2003, Appendix). Indeed, Roopnarine and Angielczyk (2015b, Supplementary Material: Materials and Methods) treat *Notaelurodon* as synonymous with *Promoschorhynchus*. Codron et al. (2017, Supporting Information: Table S1) report the holotype of *Notaelurodon kitchingi* as another specimen of *Promoschorhynchus platyrhinus*. *Notaelurodon kitchingi* is therefore herein treated as a junior synonym of *Promoschorhynchus platyrhinus*. Fröbisch (2014b, Appendix 18.1) reports *Notaelurodon kitchingi* (and therefore *Promoschorhynchus platyrhinus*) for the *Cistecephalus*, *Dicynodon*, and *Lystrosaurus* AZ's, but Viglietti et al. (2016, fig. 2; Supplementary data: mmc1) restrict it to the Upper *Daptocephalus* AZ and the lower *Lystrosaurus* AZ. Herein, the stratigraphic range as reported in Viglietti et al. (2016, fig. 2; Supplementary data: mmc1) is used for *Promoschorhynchus platyrhinus*.

Cerdops burgheri is treated as a valid taxon by Abdala et al. (2008), Huttenlocker et al. (2011a), Huttenlocker and Sidor (2012), Sigurdsen et al. (2012, Appendix 2) and Brocklehurst et al. (2015, Supplementary Information) and is possibly restricted to the upper *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1). *Cerdops burgheri* was considered a junior synonym of *Cerdosuchoides brevidens* (Wyllie, 2003, Appendix; Huttenlocker, 2013, p. 57; Appendix 2: p. 328). Indeed, Fröbisch (2014b, Appendix 18.1) does not report the occurrence of *Cerdops* for the *Dicynodon* AZ, but does report *Cerdosuchoides* for the *Dicynodon* AZ. The taxa are treated accordingly.

Wyllie (2003) reports the species *Moschorhinus kitchingi*, *Moschorhinus minor*, *Moschorhinus warreni* and *Moschorhinus esterhuyseni* as being synonymous with *Tigrisuchus simus*. Indeed, Mendrez (1974b), Mendrez (1974a) and Kammerer (2008) considered the genus *Moschorhinus* to be synonymous with *Tigrisuchus*. Botha-Brink and Modesto (2011) and Botha-Brink et al. (2014) report the synonymization attempt of Mendrez (1974a) and the accepted synonymy in the abstract of Kammerer (2008) as well. Kammerer (2009, Table 9: p. 623) identified the holotype of *Moschorhinus natalensis* as *Tigrisuchus simus*.

Fröbisch (2014b, Appendix 18.1) implicitly accepts the synonymy as only *Tigrisuchus* is reported among the synapsid genera of the South African Karoo Basin, while *Moschorhinus* is not mentioned.

Moschorhinus kitchingi, however, is still treated as a valid taxon in recent publications (e.g., Huttenlocker et al., 2015; Viglietti et al., 2016) and Kammerer (2016b) mentions the genus *Moschorhinus*, thus implicitly accepting its validity. Herein, the taxon is treated as follows. All reported species of *Moschorhinus* are assumed to belong to the single species *Moschorhinus kitchingi* as they have previously been united in the single taxon *Tigrisuchus simus*. Instead of the genus *Tigrisuchus*, the genus *Moschorhinus* is retained. In the database *Moschorhinus* is therefore monospecific, with the only species *M. kitchingi* being retained. The stratigraphic range of *Moschorhinus kitchingi* is updated according to Viglietti et al. (2016).

Ivakhnenko (2011) erected the new species *Perplexisaurus lepusculus*. This species is based on very fragmentary remains (Ivakhnenko, 2011; Huttenlocker, 2013, p. 31) and might represent a different genus (Ivakhnenko, 2011). Indeed, Huttenlocker and Smith (2017, Table 3) consider it invalid or based on non-diagnostic material. It is therefore excluded from further analyses.

Blattoidealestes gracilis appears in the datasets of Codron et al. (2017, Supporting Information: Table S1) and Olroyd and Sidor (2017, Supplementary Information: Table 2), but Kammerer (2009, Appendix 5: Table 9) lists the holotype as indeterminate and Day (2013, p. 276) considers its validity dubious. Ivakhnenko (2011) treats the taxon as valid and potentially related to Perplexisauridae but also considers it as “insufficiently investigated” (Ivakhnenko, 2011, p. 1124). Huttenlocker and Smith (2017, Table 2) also treat the taxon as invalid. *Blattoidealestes gracilis* is therefore excluded from further analyses.

A.21.2 Whaitsioidea

Phylogeny: *Gorochovetzia* and *Hofmeyria* are the only members of Hofmeyriidae according to Ivakhnenko (2011, p. 1030). *Gorochovetzia sennikovi* is therefore added as the sister taxon of *Hofmeyria atavus*.

Ictidognathus hemburyi has been reassigned to *Ictidostoma* (Wyllie, 2003, Appendix) and Brink (1961, p. 171) considers the difference of *Ictidostoma hemburyi* from *Ictidognathus parvidens* “anything but substantial”. *Ictidognathus parvidens* is therefore added as the sister taxon of *Ictidostoma hemburyi*.

Megawhaitsia patrichae is a whaitsiid (Ivakhnenko, 2008d). Another whaitsiid, *Moschowhaitsia vjuschkovi*, is known from the same locality (Ivakhnenko, 2011, p. 1001; Lebedev et al., 2015; Niedźwiedzki et al., 2016). *Megawhaitsia patrichae* is therefore assumed to be the sister taxon of *Moschowhaitsia vjuschkovi*.

Alpha taxonomy: Fröbisch (2014b, Appendix 18.1) reports *Hofmeyria atavus* for the *Pristerognathus* and the *Tropidostoma* Assemblage Zones. Kammerer (2009, Table 9: p. 621) and Huttenlocker (2013, p. 220) report the taxon also for the *Cistecephalus* Assemblage Zone and it is treated accordingly.

Fröbisch (2014b, Appendix 18.1) reports *Ictidostoma hemburyi* only for the *Cistecephalus* Assemblage Zone and the taxon is treated accordingly herein. Boos et al. (2013, Appendix S2) also report occurrences of this taxon from the *Tropidostoma* Assemblage Zone, but currently only the holotype from the *Cistecephalus* Assemblage Zone can be confidently assigned to the species (J. Fröbisch, pers. comm., 2016).

Ictidognathus parvidens is a valid taxon according to Wyllie (2003) and is also mentioned by Fourie (2013, Table 1). It is thus retained in the database.

Ictidochampsa platyceps is a valid taxon according to Wyllie (2003) and is treated as such by Huttenlocker (2013), Fröbisch (2014b, Appendix 18.1), and Huttenlocker and Abdala (2015). It is incorporated into the database and its stratigraphic range is updated according to Viglietti et al. (2016, fig. 2; Supplementary data: mmc1).

The stratigraphic and palaeobiogeographic range of *Theriognathus microps* is updated according to Huttenlocker and Abdala (2015) and Viglietti et al. (2016).

Ivakhnenko (2011) assigns the holotype (and referred material) of *Hexacynodon purlinensis* to *Moschowhaitsia vjuschkovi*. This view is followed herein, and the respective taxa are treated accordingly.

A.21.3 Baurioidea

Phylogeny: *Silphoictidoides ruhuhuensis* is added according to the strict consensus tree of Maisch (2017, fig. 6), which is based on an expanded data matrix of Huttenlocker and Sidor (2016).

Icticephalus polycynodon is an ictidosuchid (Wyllie, 2003, Appendix). It is added to the polytomy consisting of *Ictidosuchus primaevus*, *Ictidosuchops rubidgei*, *Ictidosuchoides longiceps*, and the rest of Baurioidea.

Ivakhnenko (2011, p. 1026) assigns *Scalopodontes* to Ictidosuchidae, together with *Ictidosuchus*, *Ictidosuchoides*, and *Ictidosuchops*. *Scalopodontes kotelnichi* is therefore added to the polytomy among early diverging members of Baurioidea.

Liu and Abdala (2017b) hypothesize a phylogenetic relationship between the eutherocephalian *Dalongkoua fuae* and *Urumchia lii*. *Dalongkoua fuae* is therefore treated as the sister taxon of *Urumchia lii*.

Scaloporhinus might belong to the family Karenitidae and is similar to *Karenites* according to Ivakhnenko (2011, p. 1079). A trichotomy consisting of *Scaloporhinus angulorugatus*, *Karenites ornamentatus*, and *Mupashi migrator* is therefore created.

Ivakhnenko (2011, p. 1079) treats *Scalopodon tenuisfrons* as a junior synonym of *Karenites ornamentatus*. It is therefore added as the sister taxon of *Karenites ornamentatus*. Note, however, that it might be more closely related to other taxa previously assigned to Scaloposauridae (Huttenlocker and Sidor, 2016).

Ivakhnenko (2011, p. 1137) assigns *Scalopolacerta* and *Scaloposaurus* to the subfamily Scaloposaurinae. *Scalopolacerta hoffmanni* is therefore added as the sister taxon of *Scaloposaurus* *constrictus*. There have been suggestions, however, that *Scaloposaurus constrictus* might represent a juvenile *Regisaurus* (Huttenlocker, 2013, p. 47).

The species of *Ordosiodon* are assumed to be sister taxa and are added accordingly.

The species of *Nothogomphodon* are assumed to be sister taxa and are added accordingly.

Dongusaurus schepetovi is a bauriid (Ivakhnenko, 2011; Niedźwiedzki et al., 2016) and is added accordingly as an early diverging member of the clade to the supertree.

Antecosuchus boreus is assumed to be the sister taxon of *Antecosuchus ochevi* and is added accordingly.

Alpha taxonomy: *Ictidosuchus primaevus* is only known from the *Tropidostoma* Assemblage Zone (Day, 2013, p. 275; Huttenlocker, 2013, Appendix 6: p. 386; Day et al., 2015a, fig. 1) and is treated accordingly.

Ictidosuchops rubidgei is known from both the upper *Cistecephalus* and the lower *Daptocephalus* AZ (Huttenlocker, 2013, p. 40–42; Viglietti et al., 2016, fig. 2; Supplementary data: mmc1) and is treated accordingly. *Ictidosuchops* is also known from the *Tropidostoma* AZ (Fröbisch, 2014b, Appendix 18.1; Day et al., 2015a, fig. 1) and is treated accordingly.

Silphoictidoides ruhuhuensis is a valid taxon (Maisch, 2017) and is therefore added to the database.

Ictidosuchops intermedius is probably a junior synonym of *Ictidosuchoides longiceps* (Huttenlocker, 2013, p. 41) and is also known from the *Dicynodon* AZ (Kammerer, 2009, Table 9: p. 622, 623). Viglietti et al. (2016, fig. 2; Supplementary data: mmc1) restrict the resulting range of *Ictidosuchoides longiceps* to the lower *Daptocephalus* AZ. The taxon is treated accordingly. *Ictidosuchoides longiceps* is also known from the *Pristerognathus* and the *Tropidostoma* AZ (Day et al., 2015a, fig. 1; Day, 2013, p. 274; Huttenlocker, 2013, p. 234, 235) and its stratigraphic range is recorded accordingly.

Smith and Botha (2005), Botha and Smith (2006), Abdala (2007), and Fröbisch (2014b, Appendix 18.1) report *Ictidosuchoides* for the *Lystrosaurus* AZ. Specimens previously considered to belong to *Ictidosuchoides* sp. from the *Lystrosaurus* AZ, represent, however, misidentified remains of juvenile baurioids (Kammerer, 2008; Kammerer, 2009, Table 9: p. 622) and of *Promoschorhynchus cf. P. platyrhinus* (Huttenlocker et al., 2011a). According to Botha-Brink et al. (2014) *Ictidosuchoides longiceps* is probably not part of the *Lystrosaurus* AZ. This view is followed herein. The specimens of *Ictidosuchoides* previously referred to the *Lystrosaurus* AZ are herein considered to belong to *Scaloposaurus constrictus* (Kammerer, 2009, Table 9: p. 622) and *Promoschorhynchus cf. P. platyrhinus* (Huttenlocker et al., 2011a) and are treated accordingly. *Ictidosuchoides longiceps* is also known from tetrapod assemblages equivalent to the *Cistecephalus* AZ from Tanzania and Zambia (Huttenlocker and Sidor, 2016). These occurrences are added to the database.

Ivakhnenko (2011) assigns the holotype (PIN 2212/97) of *Scalopodon tenuisfrons* to *Karenites ornamentatus* and this interpretation is followed by Huttenlocker (2013, p. 44). Kammerer (2009,

Table 9: p. 626) also considers the holotype of *Scalopodon tenuisfrons* as being referable to *Karenites ornamentatus*. New phylogenetic analyses (Huttenlocker and Sidor, 2016) suggest, however, that the two taxa might not be synonymous. Therefore, *Scalopodon tenuisfrons* is retained in the database as a separate taxon.

Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) treat *Scaloporhinus* as a valid taxon and report it for the *Dicynodon* AZ. It is incorporated into the database. Note, however, that Kammerer (2009, Table 9: p. 626) considered the holotype to be indeterminate.

Lycideops longiceps is also known from the *Tropidostoma* AZ (Day et al., 2015a, fig. 1) and the *Dicynodon* AZ (Huttenlocker, 2013, Appendix 6: p. 387; Fröbisch, 2014b, Appendix. 18.1) and is treated accordingly. Note that Viglietti et al. (2016, fig. 2) report the genus only for the upper *Daptocephalus* AZ but also state that the range of the taxon could not be verified in their study.

Choerosaurus dejageri is treated as a valid taxon by Sigurdsen et al. (2012) and Fröbisch (2014b, Appendix 18.1) and is therefore added to the database. Note, that Abdala et al. (2008, Table 1) and Huttenlocker (2013, Appendix 6) report the taxon from the *Tropidostoma* AZ, while Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1) report it for the *Cistecephalus* AZ. Herein, it is treated as a *Cistecephalus* AZ occurrence.

Scaloposaurus constrictus is only known from the (lower and upper portion of the) *Lystrosaurus* AZ (Botha and Smith, 2006, fig. 7; Abdala et al., 2008, Table 1; Kammerer, 2009, Table 9; Botha-Brink and Modesto, 2011, text-fig. 9; Huttenlocker, 2013, p. 46–48; Fröbisch, 2014b, Appendix 18.1; Roopnarine and Angielczyk, 2015b, Supplementary Material: Table S1) and is treated accordingly.

Scalopolacerta hoffmanni, initially described as *Scaloposaurus hoffmanni* (Crompton, 1955b), might be a juvenile *Regisaurus* (Huttenlocker, 2013, p. 47). Indeed, Kammerer (2009, Table 9) assigned specimens of *Scalopolacerta hoffmanni* (including the holotype), to *Regisaurus hoffmanni*. According to (Huttenlocker, 2013, p. 47) a formalized synonymy needs additional material and therefore *Scalopolacerta hoffmanni* is retained in the database.

Colbert and Kitching (1981) assigned the Antarctic specimens AMNH FARB 9550 and AMNH FARB 9542 to *Ericiolacerta parva*. AMNH FARB 9550 is now considered Eutherocephalia indet. and AMNH FARB 9542 is assigned to *cf. Ericiolacerta parva* (Huttenlocker and Sidor, 2012). Herein, AMNH FARB 9542 is assumed to represent an occurrence of *Ericiolacerta parva* in Antarctica and is treated accordingly.

Hazhenia concava is recognised as a valid taxon by Nesbitt et al. (2011), Sidor et al. (2014b) and Liu and Abdala (2015) and is incoroporated in the phylogenetic analyses of Huttenlocker (2013, fig. 1.7). It is therefore included in the database. Note, that Ivakhnenko (2011) considers the taxon to be insufficiently described.

Sesamodontoides pauli (and therefore also *Sesamodon pauli*) is a junior synonym of *Bauria* *cynops* (Abdala et al., 2014b) and is treated accordingly. The stratigraphic range of *Bauria cynops* is restricted to *Cynognathus* Assemblage Zone B as reported by Abdala et al. (2014b) and Huttenlocker (2013, p. 53).

Ivakhnenko (2011, p. 1003, 1004, 1111) reassigns the holotype of *Neotrirachodon expectatus* and other material that previously had been referred to this taxon (Tatarinov, 2008, p. 216) to *Antecosuchus ochevi*. Indeed, both taxa have been considered bauriid therocephalians (Abdala and Smith, 2009; Sues and Hopson, 2010; Liu and Abdala, 2014). Huttenlocker (2013, p. 14, 53) also treats *Neotrirachodon* as a junior synonym of *Antecosuchus*. Herein, the interpretation of Ivakhnenko (2011) is followed and *Neotrirachodon expectatus* is treated as a junior synonym of *Antecosuchus ochevi*.

Scalenodon boreus is a bauriid therocephalian (Sues and Hopson, 2010; Liu and Abdala, 2014) that is now referred to the genus *Antecosuchus* (Ivakhnenko, 2011). The taxon is treated accordingly.

Watsoniella breviceps, *Sesamodon browni* and *Herpetogale marsupialis* are junior synonyms of *Microgomphodon oligocynus* (Abdala et al., 2014b) and are treated accordingly. Abdala et al. (2014b) also provides the stratigraphic range of the taxon. The genus name *Microgomphodon* is misspelled as *Mircrogomphodon* in Fröbisch (2014b, Appendix 18.1) and Roopnarine and Angielczyk (2015b, Supplementary Material: Table S1).

The holotype of *Crapartinella* had previously been assigned to *Icticephalus*, but was subsequently deemed to be sufficiently different to warrant the erection of a new genus (Mendrez-Carroll, 1979, p. 188). Huttenlocker and Smith (2017, Table 2) treat it as a taxon that is either not valid or based on non-diagnostic material. *Crapartinella croucheri* is therefore excluded from further analyses.

Abdala et al. (2008) considered the taxonomic status of *Malasaurus germanus* as uncertain and it is therefore not part of further analyses (see also Huttenlocker and Smith, 2017, Table 3). Ivakhnenko (2011) erected the new taxon *Muchia microdenta*, but it is based on even less complete material than *Malasaurus germanus* and its assignment to Scaloposauridae is uncertain (Ivakhnenko, 2011). It is therefore also excluded from further analyses.

Nanicticephalus is a *nomen dubium* according to Huttenlocker (2013, p. 47) and is treated accordingly.

Pedaeosaurus parvus and *Rhigosaurus glacialis* are *nomina dubia* (Huttenlocker and Sidor, 2012) and are treated accordingly.

Smith et al. (2012b, Table 2.3) mention *Macroscelesaurus* for the *Cistecephalus* AZ and it is also treated as a valid taxon by Botha-Brink and Modesto (2011) and Müller et al. (2010, Supporting Information: 1. Data set of vertebral count numbers). Watson and Romer (1956, p. 76) assigned the taxon, which is mainly represented by postcranial remains (Haughton, 1918), to Bauriamorpha *incertae sedis*. Fröbisch (2014b, Appendix 18.1) did not include the taxon in a comprehensive list of South African synapsid taxa of the Karoo Basin and it can be considered a *nomen dubium* (J. Fröbisch, pers. comm., 2016). *Macroscelesaurus* is therefore excluded from further analyses.

Huttenlocker and Smith (2017, Table 3) consider *Scalopognathus multituberculatus* to be invalid or based on non-diagnostic material. The taxon is therefore excluded from further analyses.

A.22 'Basal' Cynodontia

Phylogeny: The early diverging part of the Cynodontia subtree is based on the majority rule consensus tree of Van den Brandt and Abdala (2018, fig. 11) which uses an updated data matrix of Kammerer (2016a), which is itself based on Botha et al. (2007).

Bolotridon frerensis is added according to the Adams consensus tree of Sidor and Smith (2004, fig. 7).

The strict consensus tree of Martinelli et al. (2017c, fig. 7) is used to add non-mammaliaform Eucynodontia, focusing on non-mammaliaform probainognathians (section A.23).

The single most parsimonious tree of Ruta et al. (2013, fig. 1), which is used to add Tritheledontidae (section A.23), is also used to improve the resolution for Charassognathidae, *Cynosaurus suppostus*, and *Traversodon stahleckeri* (subsection A.22.1). This tree is also used to modify the position of *Nanictosaurus kitchingi*, which is herein treated as a sister taxon of *Thrinaxodon liorhinus* in accordance with the results of the phylogenetic analysis of Kammerer (2016a, fig. 6). Ivakhnenko (2012) also considers *Nanictosaurus kitchingi* a member of Thrinaxodontidae.

Procynosuchus vladimiriensis is assumed to be closely related to *Procynosuchus delaharpeae* and is added as its sister taxon.

Tatarinov (2005) describes *Madysaurus sharovi* as a basal procynosuchian cynodont, which he assigns to the newly created family Madysauridae. Shcherbakov (2008, p. 116) mentions it as a "primitive cynodont". Voigt et al. (2006) and Kogan et al. (2009) report the taxon as a procynosuchid cynodont. Herein, *Madysaurus sharovi* is added to a polytomy consisting of *Procynosuchus* and other (potential) members of Procynosuchidae.

Sludica bulanovi is a procynosuchid according to Ivakhnenko (2012) and is added accordingly to a polytomy consisting of *Procynosuchus* and other (potential) members of Procynosuchidae.

Thrinaxodon bengalensis is assumed to be a sister taxon of *Thrinaxodon liorhinus* and is added accordingly.

Battail (2000) consider *Nanocynodon seductus* as a possible thrinaxodontid, and it is treated as such also by Battail (1991, p. 39), Battail and Surkov (2000), and Ivakhnenko (2012). Kammerer (2016a) also mentions it as a potential thrinaxodontid and Battail and Surkov (2000) argue against an affinity to Procynosuchidae. *Nanocynodon seductus* is therefore added in a polytomy with *Thrinaxodon* and *Nanictosaurus* (which, e.g., Ivakhnenko (2012) also considers a member of Thrinaxodontidae). Ivakhnenko (2012) argues against a procynosuchid affinity of *Uralocynodon tverdokhlebovae* and considers it a member of Thrinaxodontidae that is closer to *Nanictosaurus*.

Kammerer (2016a) also reports it as a possible thrinaxodontid. *Uralocynodon tverdokhlebovae* is therefore added as the sister taxon of *Nanictosaurus*.

Hwanghocynodon multienspidus is similar to *Nanocynodon*, *Thrinaxodon*, and *Nanictosaurus* (Liu et al., 2014b) and is added accordingly to the above-mentioned polytomy within Thrinaxodontidae.

Alpha taxonomy: *Procynosuchus delaharpeae* is now also reported for the *Tropidostoma* Assemblage Zone (Botha-Brink and Abdala, 2008; Viglietti et al., 2016). This occurrence, however, represents another taxon (*Abdalodon diastematicus*; Kammerer, 2016a, and is treated accordingly. Therefore, *Procynosuchus delaharpeae* is known in South Africa only from the upper *Cistecephalus* and *Daptocephalus* AZ (Kammerer, 2016a) and the respective database entries are updated accordingly.

The occurrences of *Procynosuchus delaharpeae* from the Madumbasia Mudstone Formation of Zambia and from the Usili (= Kawinga) Formation of Tanzania (Weide et al., 2009; Kammerer and Abdala, 2009) are added. *Parathrinaxodon proops* is a subjective junior synonym of *Procynosuchus delaharpeae* (Abdala and Allinson, 2005; Weide et al., 2009; Kammerer and Abdala, 2009; Ivakhnenko, 2012) and is treated accordingly. *Scalopocynodon gracilis* is a synonym of *Procynosuchus delaharpeae* according to Hopson and Kitching (1972) and this view was followed by Botha et al. (2007) and Ivakhnenko (2012). It is treated accordingly in the database.

The specimen from the lower Zechstein of Germany described as *Procynosuchus* sp. (Sues and Boy, 1988) is retained in the database due to its palaeobiogeographic importance. Brocklehurst et al. (2017, Supplementary Data) treat the specimen as another occurrence of *Procynosuchus delaharpeae* and Sues and Boy (1988, p. 524) also describe it as being “virtually identical” to this species. The specimen is therefore treated as another occurrence of *Procynosuchus delaharpeae*.

Botha-Brink et al. (2012) consider *Uralocynodon* and *Nanocynodon* to be junior synonyms of *Procynosuchus*, but Ivakhnenko (2012) and Kammerer (2016a) treat them as separate valid taxa. They are retained accordingly in the database.

Kammerer and Abdala (2009) and Botha-Brink et al. (2012) considered *Cyrbasiodon vladimiriensis* as *Procynosuchus* sp., while Ivakhnenko (2012) created the new combination *Procynosuchus vladimiriensis* (misspelled as *Procynosuchus vladimirense*). Herein, the interpretation of Ivakhnenko (2012) is followed and *Cyrbasiodon vladimiriensis* is retained as *Procynosuchus vladimiriensis*.

Cynosuchoides is a synonym of *Cynosaurus* and *Cynosuchoides whaitsi* a synonym of *Cynosaurus suppostus* according to Hopson and Kitching (1972). This view is also followed by Wyllie (2003), Benoit et al. (2015), and Van den Brandt and Abdala (2018). Indeed, only *Cynosaurus suppostus* is mentioned by Viglietti et al. (2016) in their description of the (new) *Daptocephalus* Assemblage Zone. The taxon is treated accordingly in the database.

Thrinaxodon putterilli is considered to be synonymous with *Thrinaxodon liorhinus* (Hopson and Kitching, 1972; van Heerden, 1972; Colbert and Kitching, 1977; Wyllie, 2003) and is treated accordingly in the database.

Thrinaxodon bengalensis is treated as a valid taxon by Bandyopadhyay (1999), Abdala and Ribeiro (2010), and Ray (2015) and is therefore included in the database.

van Heerden and Rubidge (1990) recognise *Nanictosaurus kitchingi* as the only valid species of the genus and consider *Nanictosaurus rubidgei* to be a junior synonym of *Nanictosaurus kitchingi*. This view is followed by Wyllie (2003). Indeed, Viglietti et al. (2016) only report *Nanictosaurus kitchingi* when describing the (new) *Daptocephalus* Assemblage Zone. *Nanictosaurus* is treated accordingly in the database. Note, however, that Sidor and Smith (2004) regarded the four specimens (including the holotype of *Nanictosaurus kitchingi*, *Nanictosaurus*, *Nanictosaurus*, and a referred specimen of *Nanictosaurus*) attributed by van Heerden and Rubidge (1990) to *Nanictosaurus kitchingi* as juvenile individuals of *Cynosaurus*.

Liu et al. (2014b) consider *Hwanghocynodon multienspidus* to be a valid cynodont taxon. It is therefore included in the database.

A.22.1 Cynognathia

Phylogeny: The Cynodontia subtree is augmented with the strict consensus tree of Pavanatto et al. (2018, fig. 10) for Cynognathia. This analysis uses an expanded character matrix of Liu and Abdala (2014) with the modifications proposed by Melo et al. (2015) and Melo et al. (2017). The resolution of this tree is improved for *Santacruzodon hopsoni*, *Massetognathus ochagaviae*, *Massetognathus pascuali*, and *Dadadon isaloi* using the strict consensus tree of Gaetano and Abdala (2015, Supporting Information: fig. S3), which is based on an expanded character matrix of Melo et al. (2015).

The phylogenetic relationships of Trirachodontidae and Sinognathinae are modified according to the strict consensus tree of Sidor and Hopson (2018, fig. 11), which is based on a modified character matrix of Hopson and Kitching (2001) with data added from Abdala et al. (2006), Gao et al. (2010b), and Liu and Abdala (2014). The resolution of the tree is improved for the genus *Cricodon* following the comments of Sidor and Hopson (2018).

Exaeretodon argentinus, *Exaeretodon riograndensis*, *Exaeretodon statisticae*, and *Ruberodon roychowdhurii* are added according to the strict consensus tree of Ray (2015, fig. 7).

Cynognathus sp. from the upper Fremouw Formation (Hammer, 1995) is assumed to be closely related to *Cynognathus crateronotus* and is added as its sister taxon.

Titanogomphodon crassus is a diademodontid (Abdala and Smith, 2009; Martinelli et al., 2009; Smith et al., 2012b), that previously has been suggested to be synonymous with *Diademodon* (Grine et al., 1978). It is therefore added as a sister taxon to *Diademodon tetragonus*.

The position of *Habayia halbardieri*, *Maubeugia lotharingica*, *Microscalenodon nanus*, and *Rosieria delsatei* as members of Traversodontidae is uncertain (Liu and Abdala, 2014), but they are retained in the database, as no alternative systematic assignment is proposed by Liu and Abdala (2014). Note, however, that also Hopson and Sues (2006, p. 125) are not convinced of their traversodontid affinities. *Rosieria delsatei*, *Maubeugia lotharingica*, and *Microscalenodon nanus* are added according to the phylogeny hypothesized by Godefroit and Battail (1997, fig. 26). Therefore, *Rosieria delsatei* and *Maubeugia lotharingica* are added as a grade to *Mandagomphodon* and later diverging traversodontids (note that Godefroit and Battail (1997) still treat *Scalenodon charigi* as valid taxon, which is now considered a junior synonym of *Mandagomphodon attridgei*; Liu and Abdala, 2014). *Microscalenodon nanus* is added in a polytomy with *Scalenodontoides macrodontes*, *Siriusgnathus niemeyerorum*, and the clade consisting of *Exaeretodon* and *Ruberodon roychowdhurii*. *Habayia halbardieri*, *Maubeugia lotharingica*, and *Rosieria delsatei* are more similar to each other than to *Microscalenodon nanus* (Godefroit, 1999, p. 392). Therefore, *Habayia halbardieri* is added in a polytomy with *Rosieria delsatei* and the clade consisting of *Maubeugia lotharingica* and later diverging traversodontids.

Boreogomphodon herpetairus is assumed to be the sister taxon of *Boreogomphodon jeffersoni* and is placed accordingly.

Alpha taxonomy: The South American *Cynognathus minor* is synonymous with the South African *Cynognathus crateronotus* according to Abdala (1996). Indeed, Martinelli et al. (2009), Kammerer et al. (2010), Abdala and Ribeiro (2010), Abdala and Ribeiro (2012, Tabela 1), Krapovickas et al. (2013), and Ottone et al. (2014) report the occurrence *Cynognathus crateronotus* for South America, therefore treating the two species as synonymous. This view is followed herein and *Cynognathus minor* is treated accordingly in the database.

Due to its palaeobiogeographic importance the specimen from the upper Fremouw Formation described by Hammer (1995) as *Cynognathus* sp. is retained in the database and treated as a separate taxon.

Hopson and Kitching (1972) and Kammerer (2009, Table 9: p. 587) consider *Gomphodontoides megalops* a junior synonym of *Diademodon tetragonus*. Indeed, Hopson and Sidor (2015) do not report the species among the valid trirachodontids. The stratigraphic range of *Gomphodontoides megalops* is restricted to the *Cistecephalus* AZ (Haughton and Brink, 1954; Romer, 1967; Hopson and Kitching, 1972; Kammerer, 2009, Table 9: p. 587). Huttenlocker (2013, Appendix 10) reports the holotype BP/1/2097 of *Gomphodontoides megalops* for *Diademodon tetragonus* and thus implicitly accepts the synonymy of the two taxa. The specimen is reported for the *Cistecephalus* AZ B/C. The taxon is herein treated accordingly.

Diademodon tetragonus is also known from the Upper Omingonde Formation (Abdala and Ribeiro, 2012, Tabela 2) and this occurrence is added to the database. The occurrence of *Diademodon* in the Lifua Member in Tanzania (Abdala and Ribeiro, 2012, Tabela 2) is not included, as it was just determined to genus level and is only represented by poorly preserved remains (Crompton, 1955b; Abdala and Ribeiro, 2010).

Hopson and Kitching (1972) and Kammerer (2009, Table 9: p. 598) considered *Trirachodon kannemeyeri* to be synonymous with *Trirachodon berryi*. Hopson and Sidor (2015) recognise *Trirachodon kannemeyeri* as a separate valid species and it is treated as such also by Sidor et al.

(2013, Table S2). Sidor and Hopson (2018) finally treat the taxon as another species of the genus *Cricodon*. The taxon is treated accordingly and is added to the database. Both *Trirachodon berryi* and *Cricodon kannemeyeri* (probably) do not belong to the *Cistecephalus* AZ A (J. A. Hopson, pers. comm., 2016) and are treated accordingly.

The specimens reported as *Cynognathus* sp. and *Trirachodon* for the lower and middle levels of the upper Omingonde Formation (Keyser, 1973a; Smith and Swart, 2002; Abdala et al., 2013b) are herein treated as occurrences of the species *Cynognathus crateronotus* and *Trirachodon berryi*. Indeed, Abdala and Ribeiro (2010) and Abdala and Ribeiro (2012, Tabela 2) report *Cynognathus crateronotus* and *Trirachodon berryi* for the upper Omingonde Formation.

Cricodon metabolus is also known from the Luangwa Basin of Zambia (Sidor et al., 2013, Table S2; Hopson and Sidor (2015); Hendrickx et al., 2016; Sidor and Hopson, 2018). This occurrence is added to the database.

Scalenodon charigi is a junior synonym of *Scalenodon attridgei* (Liu and Abdala, 2014). It is treated accordingly. *Scalenodon attridgei* and *Scalenodon hirschsoni* are placed in the separate genus *Mandagomphodon* following Hopson (2014) and Liu and Abdala (2014).

Massetognathus teruggii, *Massetognathus major* and *Megagomphodon oligodens* are synonyms of *Massetognathus pascuali* (Liu and Abdala, 2014) and are treated accordingly. *Massetognathus pascuali* is possibly also present in the Brazilian Santa Maria Formation (Liu et al., 2008; Liu and Abdala, 2014) and this occurrence is added to the database.

Liu and Abdala (2014) recognize *B. herpetairus* (initially described as *Plinthogomphodon herpetairus*) as another valid species of *Boreogomphodon*. It is treated accordingly.

Exaeretodon frenguelli is a junior synonym of *Exaeretodon argentinus* (Liu and Abdala, 2014) and it is treated accordingly. *Ischignathus sudamericanus* is a junior synonym of *Exaeretodon argentinus* (Liu and Abdala, 2014) and it is treated accordingly.

According to Liu and Abdala (2014) *Exaeretodon statisticae* does not have clear diagnostic characters and is therefore treated as *Exaeretodon* sp. Ray (2015) does consider the taxon to be distinct from the other species of *Exaeretodon* and also Liu and Abdala (2014) consider it to be possibly a different species. Therefore *E. statisticae* is retained in the database as *Exaeretodon statisticae*.

Sidor et al. (2013, Table S2) report *Diademodon tetragonus* for the upper Fremouw Formation of Antarctica (see also Kammerer et al., 2010), but Sidor et al. (2014b, Table 1) report only Diademodontidae indet. among the vertebrate taxa known from the formation and thus this occurrence is not included in the database.

Spielmann and Lucas (2012, p. 96) consider the tooth taxon *Redondagnathus hunti* a trirachodontid but according to Abdala et al. (2006) and Sidor and Hopson (2018) the corresponding specimens cannot confidently be assigned to Trirachodontidae. Furthermore, the stratigraphic range of the Late Triassic taxon (Spielmann and Lucas, 2012, p. 96) does not match that of other members of Trirachodontidae, which are mainly known from the Early and Middle Triassic (Sidor and Hopson, 2018). Due to the uncertain relationships of the taxon it is excluded from further analyses.

Theropsodon njalilus and *Colbertosaurus muralis* are *nomina dubia* (Liu and Abdala, 2014) and are therefore excluded from further analyses.

A.23 'Basal' Probainognathia

Phylogeny: The strict consensus tree of Martinelli et al. (2017c, fig. 7), based on an updated dataset of Liu and Olsen (2010) (with modifications of Martinelli et al. (2016b)), is used to add non-mammaliaform Eucynodontia (section A.22), focusing on Probainognathia.

The strict consensus tree of Stefanello et al. (2018, fig. 9), based on an updated dataset of Martinelli et al. (2016b), is used to add the taxa *Trucidocynodon riograndensis* and *Diegocanis elegans* and improve the resolution for the taxon *Platycraniellus elegans* (in accordance with the results of Van den Brandt and Abdala, 2018, fig. 11).

Aleodon is added according to the strict consensus tree of Martinelli et al. (2017b, fig. 18), which is based on an expanded character matrix of Ruta et al. (2013).

Alemoatherium huebneri is added according to the strict consensus tree of Martinelli et al. (2017a, fig. 7A), which is based on an updated dataset of Liu and Olsen (2010) with modifications of Martinelli et al. (2016b).

Charruodon tetracuspidatus and *Santacruzgnathus abdalai* are added according to the strict consensus tree of Martinelli et al. (2017a, fig. 7C).

The clade Tritheledontidae is added according to the single most parsimonious tree of Ruta et al. (2013, fig. 1).

Tritheledon riconoi and *Irajatherium hernandezi* are added according to the single most parsimonious tree of de Oliveira et al. (2011, fig. 9), which is based on an expanded character matrix of Martinelli and Rougier (2007).

Battail (1991) referred *Cistecynodon parvus* to Chiniquodontidae, but Abdala (1996) argued against the inclusion in Chiniquodontidae. Kammerer (2009, Table 9: p. 581) reported the taxon as a basal probainognathian and, indeed, Chiniquodontidae *sensu* Battail (1991, p. 49, 50) also included *Probainognathus*. *Cistecynodon parvus* is therefore added to the supertree as an early diverging member of Probainognathia.

Cromptodon mamiferoides (Abdala, 2000; Fröbisch, 2009; Kammerer et al., 2010; Abdala and Ribeiro, 2010; Gaetano et al., 2012; Martinelli et al., 2017b) is similar to *Aleodon* and is therefore added as its sister taxon.

The Namibian specimen *Chiniquodon* sp. (Abdala and Smith, 2009) is more similar to *Chiniquodon theotonicus* and *Chiniquodon sanjuanensis* than to *Chiniquodon kalanoro* (Kammerer et al., 2010). Therefore, *Chiniquodon sanjuanensis* and *Chiniquodon* sp. are placed in a polytomy with *Chiniquodon theotonicus* and *Chiniquodon kalanoro* is added as a sister taxon to this clade.

Godefroit and Battail (1997) classified *Meurthodon gallicus* as a potential member of Dromatheriidae. Sigogneau-Russell and Hahn (1994) considered *Meurthodon gallicus* to be most closely related to *Therioherpeton cargnini*, but this interpretation was questioned by Shapiro and Jenkins (2001). According to Shapiro and Jenkins (2001) *Mitredon cromptoni* is probably closely related to *Meurthodon gallicus*, but is not a member of Therioherpetidae because it possesses bifurcate postcanine tooth roots (but see the discussion in subsection A.23.1) and a non-alternate pattern of tooth replacement. Instead, *Mitredon cromptoni* was reported as a possible chiniquodontid (Shapiro and Jenkins, 2001) and this interpretation was (implicitly) followed by Martinelli et al. (2005). Therefore, *Mitredon cromptoni* is added as an early diverging member of Chiniquodontidae, in a polytomy with *Chiniquodon* and the clade *Aleodon* + *Cromptodon mamiferoides*. *Meurthodon gallicus* is then added as the sister taxon of *Mitredon cromptoni*. Note, however, that Abdala and Giannini (2002) excluded *Aleodon brachyrhamphus* and *Cromptodon mamiferoides* from Chiniquodontidae.

The type specimen of *Minicynodon maieri* had initially been considered as a juvenile of *Brasilitherium riograndensis* (Bonaparte, 2013). It is therefore added as a sister taxon of *Brasilitherium riograndensis*. Indeed, *Brasilitherium riograndensis* and *Minicynodon maieri* might be junior synonyms of *Brasilodon quadrangularis* (A. G. Martinelli, pers. comm., 2016; Liu and Olsen (2010) already suggested that *Brasilitherium riograndensis* was a junior synonym of *Brasilodon quadrangularis*).

Alpha taxonomy: Abdala and Ribeiro (2012), Sidor et al. (2013, Table S2), and Fröbisch (2014b, Appendix 18.1) treat *Cistecynodon parvus* as a valid taxon. It is therefore added to the database.

Aleodon is treated as a valid taxon by several authors (Hopson, 2014; Abdala et al., 2013b; Gaetano et al., 2012; Nesbitt et al., 2013d) and is treated accordingly in the database. The Namibian specimen of *Aleodon* sp. (Abdala and Smith, 2009) was tentatively referred to *Aleodon cromptoni* (Martinelli et al., 2017b). It is treated accordingly in the database.

Cromptodon mamiferoides is treated as a valid taxon by various authors (Abdala and Ribeiro, 2010; Gaetano et al., 2012; Krapovickas et al., 2013) and is therefore retained in the database.

The specimen assigned to *Chiniquodon* sp. reported for the *Santacruzodon* Assemblage Zone of the Santa Maria Formation (Abdala and Giannini, 2002; Abdala and Ribeiro, 2010, 2012) is retained in the database within the data row of *Chiniquodon theotonicus* due to its stratigraphic importance.

Probelesodon kitchingi, *Probelesodon lewisi*, and *Probelesodon minor* are junior synonyms of *Chiniquodon theotonicus* (Abdala and Giannini, 2002; Martínez et al., 2012) and are treated accordingly.

The Namibian specimen reported by Abdala and Smith (2009) as *Chiniquodon* sp. is retained in the database as a separate taxon due to its palaeobiogeographic and stratigraphic importance.

Bonaparte and Barberena (2001) assigned *Thrinaxodon brasiliensis* to the new genus *Prozostrodon* and Abdala et al. (2013a) accept this assignment. It is treated accordingly.

Shubin et al. (1991) report *Pachygenelus cf.. monus* from the Canadian McCoy Brook Formation. The specimens cannot be distinguished from *Pachygenelus monus* (Shubin et al., 1994; Sues and Olsen, 2015) and are therefore retained in the database for *P. monus*.

Diarthrognathus broomi is also known from the Upper Elliot Formation (Gow, 1994; Sidor and Hancox, 2006, Table 1; Sciscio et al., 2017, fig. 9). The stratigraphic range of the taxon is updated accordingly.

Bonaparte (2013) interpreted *Panchetocynodon damodarensis* as a brasilodontid but added it as the sister taxon of *Protheriodon estudianti* in his tentative cladogram (Bonaparte, 2013, fig. 10). Recent phylogenetic analyses do not recover *Protheriodon estudianti* as a brasilodontid (Martinelli et al., 2016b, 2017a; Pacheco et al., 2018). Das and Gupta (2012) already noted similarities between *Panchetocynodon damodarensis* and *Thrinaxodon liorhinus* and, indeed, *Panchetocynodon damodarensis* might be a thrinaxodontid (A. G. Martinelli, pers. comm., 2017). Such an early diverging position of *Panchetocynodon damodarensis* on the supertree would be more consistent with its stratigraphic range. Considering the uncertainty in the phylogenetic relationships of the taxon, *Panchetocynodon damodarensis* is excluded from further analyses, awaiting future re-study of the material (A. G. Martinelli, pers. comm., 2017). Indeed, in Bonaparte and Crompton (2018), who consider Brasilodontidae a junior synonym of Therioherpetidae, *Panchetocynodon damodarensis* is only "tentatively" assigned to Therioherpetidae "because of its fragmentary condition" (Bonaparte and Crompton, 2018, p. 176).

A.23.1 Dromatheriidae

Phylogeny: Due to the poor preservation of many specimens, Sues (2001) considered Dromatheriidae to be difficult to diagnose and referred the included taxa to Eucynodontia *incertae sedis*. Clemens and Martin (2014) accepted this interpretation and classified *Tricuspes* in their study as Eucynodontia *incertae sedis*. Conversely, Datta et al. (2004) treat Dromatheriidae as a valid family-level taxon and Bonaparte et al. (2005) consider Dromatheriidae to be tentatively valid. Therefore, *Dromatherium*, *Microconodon*, *Pseudotriconodon wildi*, *Tricuspes*, and *Rewaconodon tikiensis* are herein considered to be members of Dromatheriidae as proposed by Datta et al. (2004). Battail (1991, p. 88, 89) considered *Therioherpeton cargnini* to be the sister taxon of Dromatheriidae and recovered it as such in his phylogenetic analysis of Cynodontia (Battail, 1991, fig. 8). A recent phylogenetic analysis (Martinelli et al., 2017a, fig. 7B, C) recovers the dromatheriid *Microconodon* in a polytomy with several other early diverging prozostrodontians, among others also *Therioherpeton* and *Prozostrodon*. *Microconodon tenuirostris* is added according to the strict consensus tree of Martinelli et al. (2017a, fig. 7C) and its position is used to add Dromatheriidae in a polytomy with *Prozostrodon brasiliensis*, *Santacruzgnathus abdalai*, *Alemoatherium huebneri*, and the clade consisting of *Therioherpeton cargnini* and later diverging members of Prozostrodontia. It is accepted, however, that the phylogenetic relationships of Dromatheriidae are poorly known (Sues, 2001; Liu and Olsen, 2010).

Following Datta et al. (2004) *Tricuspes* is treated as a member of Dromatheriidae. It is added as an early diverging member of the clade. *Tricuspes tuebingensis* differs slightly from *Tricuspes sigogneauae* and *Tricuspes tapeinodon* (Sues, 2001). *Tricuspes tuebingensis* is therefore added as sister taxon to the clade consisting of *Tricuspes sigogneauae* and *Tricuspes tapeinodon*.

Rewaconodon tikiensis is considered to be a dromatheriid that is most similar to *Therioherpeton*, *Tricuspes*, and *Microconodon* (Datta et al., 2004). *Rewaconodon tikiensis* is added accordingly as an early diverging member of Dromatheriidae.

Hahn and Wouters (1987) referred *Lepagia gaumensis* to Chiniquodontidae and considered it to be similar to *Probainognathus*, a view that was also upheld by Sigogneau-Russell and Hahn (1994), who referred it to Probainognathidae or Chiniquodontidae. Battail (1991, p. 89) considered such an affinity as unlikely and the precise phylogenetic position of *Lepagia gaumensis* was deemed impossible to resolve (Battail, 1991, p. 89; Sues, 2001). Godefroit and Battail (1997) also argued against a close relationship between *Lepagia gaumensis* and *Probainognathus* and considered the species as being more similar to Dromatheriidae. A precise determination of the relationships of *Lepagia gaumensis* within Cynodontia, however, was also regarded impossible (Godefroit and Battail, 1997, p. 596), as the root of the postcanine teeth was not found to be subdivided in *Lepagia gaumensis* as in Dromatheriidae. An undivided root has also been found in other members of Dromatheriidae (e.g., *Pseudotriconodon wildi*; Cuny, 2004). Fröbisch and Fröbisch (2006, p. 1086) also refer to the specimens of *Lepagia gaumensis* as "'dromatheriid' teeth". Therefore, *Lepagia gaumensis* is herein treated as a member of Dromatheriidae and is added accordingly in a polytomy with other early diverging members of Dromatheriidae.

Polonodon woznikiensis is a dromatheriid (Sulej et al., 2018) and is therefore added to the polytomy including other early diverging members of Dromatheriidae.

A lower jaw, that initially had been assigned to *Dromatherium sylvestre*, was made the holotype of *Microconodon tenuirostris* (Osborn, 1886; Sues, 2001). The two species are therefore treated as sister taxa.

Pseudotriconodon is most similar to *Microconodon* (Sigogneau-Russell and Hahn, 1994). Kielan-Jaworowska et al. (2004, p. 22) follow the interpretation of Sigogneau-Russell and Hahn (1994) and report *Pseudotriconodon* as potentially being similar to *Microconodon* and *Dromatherium*. The genus *Pseudotriconodon* is therefore added as a sister taxon of the clade consisting of *Microconodon tenuirostris* and *Dromatherium sylvestre*. *Pseudotriconodon chatterjeei* is assumed to be the sister taxon of *Pseudotriconodon wildi*. Note, however, that the referral of *Pseudotriconodon chatterjeei* to Cynodontia might require additional material (Sues, 2001).

Godefroit and Battail (1997) referred *Hahnia obliqua* to Cynodontia *incertae sedis*, but noted a close similarity with *Pseudotriconodon*. Godefroit and Battail (1997) refrained from assigning *Hahnia obliqua* to Dromatheriidae, because the root of the posterior postcanines is not subdivided in *Hahnia obliqua*, while it supposedly represents a diagnostic character of Dromatheriidae (Godefroit and Battail, 1997). This subdivision of the root (see Shapiro and Jenkins (2001) for a general discussion of this feature), however, is also rare in *Pseudotriconodon* (Godefroit and Battail, 1997) and indeed, Cuny (2004) assigns a tooth from the Holwell Quarries (United Kingdom) to *Pseudotriconodon wildi*, which also lacks a bipartite root (Cuny (2004) accepts the assignment of *Pseudotriconodon wildi* to Dromatheriidae). An undivided root is therefore also found in other members of Dromatheriidae. Therefore, herein *Hahnia obliqua* is assumed to belong to Dromatheriidae and added in a polytomy with *Gaumia*, *Deccanodon maleriensis*, and the clade consisting of *Pseudotriconodon* and *Microconodon tenuirostris* + *Dromatherium sylvestre*. It should be noted, however, that comparable teeth with a (partially) undivided root are similar to those of Triassic pterosaurs (Dalla Vecchia, 2013). Godefroit and Battail (1997) erected *Hahnia obliqua*. The genus name *Hahnia*, however, has already been used by Koch (1841, p. 61–64) for a dwarf sheet spider. Therefore, a new genus name needs to be erected for *Hahnia obliqua*.

Hahn and Wouters (1987) do not assign *Gaumia* to a family and Battail (1991, p. 89) regards its systematic position as uncertain. Godefroit and Battail (1997) consider it to be similar to *Pseudotriconodon*, but exclude it from Dromatheriidae due to the missing bipartition of the root (but see the previous discussion of this feature). Godefroit and Battail (1997) consider *Pseudotriconodon* Cynodontia *incertae sedis*. Sigogneau-Russell and Hahn (1994) also consider *Gaumia* to be similar to *Pseudotriconodon* and assign it to Chiniquodontoidea, possibly belonging to Chiniquodontidae. According to Sigogneau-Russell and Hahn (1994) it is not closely related to *Dromatherium*, *Microconodon*, and *Therioherpeton* as the tooth root is undivided (see above). Following Sigogneau-Russell and Hahn (1994), Kielan-Jaworowska et al. (2004, p. 22) also report the taxon as a chiniquodontoid. Herein - reflecting the closer relationship of *Gaumia* to *Pseudotriconodon* than to other dromatheriid taxa (Godefroit and Battail, 1997; Sigogneau-Russell and Hahn, 1994) -, *Gaumia longiradicata* is added in a polytomy with *Hahnia obliqua*, *Deccanodon maleriensis*, and the clade consisting of *Pseudotriconodon* and *Microconodon tenuirostris* + *Dromatherium sylvestre*.

Abdala and Ribeiro (2010), Das and Gupta (2012), Ray (2015), and Kammerer et al. (2016c, fig. 2) treat *Deccanodon maleriensis*, which is based on an isolated postcanine tooth (Nath and Yadagiri, 2007), as a valid taxon. It is added to the database. The "Systematic Palaeontology" section of Nath and Yadagiri (2007) reports the taxon as a member of Chiniquodontidae, the text refers to it as member of Chiniquodontoidea and it is reported to closely resemble *Microconodon*. Ray (2015) also reports it as a chiniquodontid, probably just citing Nath and Yadagiri (2007). Conversely, Das and Gupta (2012) consider the taxon to represent a dromatheriid or "a *Microconodon*" (Das and Gupta, 2012, p. 179). Such an assessment is more in line with Nath and Yadagiri's (2007) description of *Deccanodon maleriensis* as being similar to *Microconodon*. Herein, *Deccanodon maleriensis* is treated as a dromatheriid with affinities to *Microconodon*. It is therefore added to the above-mentioned polytomy with *Hahnia obliqua*, *Gaumia longiradicata*, and the clade consisting of *Pseudotriconodon* and *Microconodon tenuirostris* + *Dromatherium sylvestre*.

Alpha taxonomy: An occurrence in Switzerland is reported in the abstract of Clemens and Martin (2014) for *Tricuspes tuebingensis*. This is a mistake in the abstract (W. A. Clemens, pers. comm., 2016) as the corresponding specimen represents either *Tricuspes cf. tuebingensis* or *Tricuspes sigogneauae* (Clemens and Martin, 2014; W. A. Clemens, pers. comm., 2016). Herein it is considered to represent *Tricuspes sigogneauae* and is added accordingly to the database.

Abdala and Ribeiro (2010), Liu and Olsen (2010), Mukherjee et al. (2012), Das and Gupta (2012), Ray (2015), and Kammerer et al. (2016c, fig. 2) treat the dromatheriid *Rewaconodon tikiensis* as a valid taxon. It is therefore added to the database.

Pseudotriconodon wildi is known from Luxembourg, France (Godefroit and Battail, 1997), and the United Kingdom (Cuny, 2004). The occurrences from Luxembourg and the United Kingdom are added to the database.

A.23.2 Tritylodontidae

Phylogeny: Tritylodontidae are added according to the strict consensus tree (but see the comments in Panciroli et al., 2017) of Velazco et al. (2017, fig. 16).

All species of *Oligokyphus* (including *Oligokyphus* sp. from the Kayenta Formation; Sues, 1985) are assumed to be sister taxa and are placed in a corresponding polytomy.

Eoraetia siegerti is considered to have potential mammalian affinities (Kuhn, 1939, p. 260; Romer, 1956a, p. 696; Sander, 1992; Lucas and Hunt, 1994, p. 337; Clemens and Martin, 2014). Hopson and Kitching (1972) refers the taxon to Cynodontia *incertae sedis*, Carroll (1988, p. 624) refers it to Chiniquodontoidea *incertae sedis*. Appleby et al. (1967, p. 724) refer *Eoraetia siegerti* to Tritylodontidae and Ruta et al. (2013, Supplementary Datasets S1-S12 Final) also treat it as a member of Tritylodontidae. *Eoraetia siegerti* is therefore added to a polytomy consisting of *Oligokyphus* and the clade including *Tritylodon* and later diverging members of Tritylodontidae. Note, however, that *Eoraetia siegerti* is only known from a fragmentary ulna (Lucas and Hunt, 1994, p. 337), which makes this assignment uncertain. It is also not mentioned by Velazco et al. (2017) among the currently recognized genera of tritylodontids.

All species of *Tritylodon* are assumed to be sister taxa and are placed accordingly.

It has been suggested that *Bienotherium magnum* is a larger individual of *Bienotherium yunnanense* and that *Bienotherium minor* belongs to *Lufengia delicata* (Luo and Wu, 1994). *Bienotherium magnum* is therefore added as the sister taxon of *Bienotherium yunnanense* and *Bienotherium minor* is added as the sister taxon of the resulting clade.

Alpha taxonomy: The specimens from the Kayenta Formation (USA) described as *Oligokyphus* sp. (Sues, 1985) are retained in the database due to their stratigraphic and palaeobiogeographic importance. Sues (1985) did not consider *Oligokyphus minor* to be a valid species, as it may represent a sexual dimorph of *Oligokyphus major*. Indeed, Fedak et al. (2015) also include *Oligokyphus minor* within *Oligokyphus major*. Therefore, *Oligokyphus minor* is included in *Oligokyphus major* in the database. The newly described specimen of *Oligokyphus* sp. from the McCoy Brook Formation of Canada *Oligokyphus* sp. (Fedak et al., 2015) is not included, as the Kayenta specimens already represent a North American occurrence of the genus *Oligokyphus* and are much better preserved.

Tritylodontoideus maximus has been suggested to represent a junior synonym of *Tritylodon longaevus* (Hopson and Kitching, 1972; Sues and Jenkins, 2006), but Gaetano et al. (2017) (implicitly) treat it as a separate taxon. Following Battail (1991) *Tritylodontoideus maximus* is herein treated as another species of the genus *Tritylodon* (see also Hammer and Hickerson, 1994).

Savage and Waldman (1966) referred a specimen from the Holwell Quarry (Somerset, UK) to *Oligokyphus*. This material was later on regarded as a tritylodontid *incertae sedis* (Savage, 1971) with affinities to *Tritylodon fraasi* (Savage, 1971; Cuny, 2004). *Tritylodon fraasi* is not based on material that is diagnostic at genus level (Hopson and Kitching, 1972; Battail, 1991, p. 69). Whiteside et al. (2016) also report the material from Holwell as Tritylodontae *incertae sedis*. As the precise affinities of this material are unclear, it is excluded from further analyses.

A.24 Mammaliaformes

Phylogeny: The strict consensus tree of Pacheco et al. (2018, fig. 5), which provides the scaffold for non-mammaliaform Eucynodontia (section A.22), is also used to add *Adelobasileus cromptoni* and *Sinoconodon rigneyi*. Note, that given the topology of the supertree neither of these taxa belongs to Mammaliaformes, if the definition of Rowe (1988) is strictly applied. *Sinoconodon rigneyi* is included, if Mammaliaformes *sensu* Luo et al. (2002) is used.

Mammaliaformes *sensu* Rowe (1988) are added using the Bayesian consensus tree of Huttenlocker et al. (2018b, fig. 4), who employ an expanded data matrix of Luo et al. (2015b) and Luo et al. (2015a) (see Han et al. (2017, fig. 4) for a slightly different topology.

Kuehneotherium praecursoris, *Delsatia rhupotopi*, *Woutersia mirabilis*, *Gondtherium dattai*, and *Tikitherium copei* are added according to the single most parsimonious tree of Meng et al. (2015, fig. 4A) (see also Meng et al. (2015, Supplement: p. 39)), which is based on an updated dataset of Luo and Martin (2007), incorporating changes of Averianov et al. (2010). The resolution of the phylogenetic placement of this clade on the scaffold tree is improved using the Bayesian consensus tree of Luo et al. (2017, Supplementary Information: Part O, p. 147), which is based on an expanded data matrix of Luo et al. (2015b).

Henosferus molus is added according to the strict consensus tree of Luo et al. (2015b, Supporting Information: p. 65).

Erythrotherium parringtoni, *Argentoconodon fariasorum*, and *Dinnetherium nezorum* are added according to the single most parsimonious tree of Martin et al. (2015, Extended Data fig. 3a), which is itself based on an update of several data sets (Rougier et al., 2007; Gao et al., 2010a; Kusuhashi et al., 2009; Gaetano and Rougier, 2011).

Bocaconodon tamaulipensis, *Victoriaconodon inaequalis*, and *Condorodon spanios* are added according to the single most parsimonious tree of Gaetano and Rougier (2012, fig. 3), which is based on a modified character matrix of Gaetano and Rougier (2011), which is itself based on Rougier et al. (2001) and Rougier et al. (2007).

Huasteconodon wiblei is added according to the strict consensus tree of Montellano et al. (2008, fig. 2), which is based on an updated data matrix of Rougier et al. (2007).

Trishulotherium kotaensis has been reported as a member of Kuehneotheriidae (Yadagiri, 1985; Datta et al., 2000; Datta and Das, 2001), a member of Tinodontidae (Prasad and Manhas, 1997, 2001, 2002), an “archaic” “symmetrodontan” (family *incertae sedis*; Kielan-Jaworowska et al., 2004, p. 28, 358), as Mammalia *incertae sedis* (Prasad and Manhas, 2007; Bandyopadhyay et al., 2010), and as a therian (Bandyopadhyay et al., 2010). Prasad and Manhas (1997) report *Trishulotherium* as being similar to *Kuehneotherium* but exhibiting a couple of features, that appear to be more derived. Note, that Fox (1985) includes *Kuehneotherium* in Tinodontidae and this interpretation is followed by Prasad and Manhas (1997). *Trishulotherium kotaensis* is herein assumed to be kuehneotheriid and added as the sister taxon of *Kuehneotherium*. Note, however, that this assignment can only be considered very tentative.

Debuysschere (2017) includes *Kuehneotherium*, *Fluctuodon necmergor*, and *Kotatherium haldanei* in Kuehneotheriidae. *Fluctuodon necmergor* and *Kotatherium haldanei* are added accordingly, creating a polytomy consisting of *Kuehneotherium*, *Fluctuodon necmergor*, *Kotatherium haldanei*, and *Trishulotherium kotaensis*.

The species *Kuehneotherium praecursoris*, *Kuehneotherium stanislavi*, ‘*Kuehneotherium* B’, and ‘*Kuehneotherium* C’ (see Debuysschere, 2017) are assumed to be closely related. *Kuehneotherium praecursoris* is more similar to ‘*Kuehneotherium* C’, while *Kuehneotherium stanislavi* bears a closer resemblance to ‘*Kuehneotherium* B’ (Debuysschere, 2017). The clades *Kuehneotherium praecursoris* + *Kuehneotherium* C and *Kuehneotherium stanislavi* + *Kuehneotherium* B are created. These clades are assumed to be sister taxa.

The two species of *Woutersia* are assumed to be sister taxa.

Multituberculata, represented by the eobaatarid *Indobaatar zofiae* (Parmar et al., 2013), are added according to the Bayesian consensus tree of Luo et al. (2017, Supplementary Information: Part O, p. 147), which also provides the scaffold for Mammaliaformes.

Mojo usuratus might be a multituberculate and member of Paulchoffatiidae (Kielan-Jaworowska et al., 2004, p. 310, 311), but this assignment has been considered uncertain (Kielan-Jaworowska et al., 2004, p. 263, 305). Indeed, Butler and Hooker (2005) considered it a potential member of Haramiyida. Bi et al. (2014, Supplementary Information) suggested that the taxon might represent a member of Euharamiyida. *Mojo usuratus* is herein treated as a member of Euharamiyida and is added according to the position of the clade in Luo et al. (2017, Supplementary Information: Part O, p. 147).

Theroteinidae, represented by *Theroteinus*, is added as the sister taxon of Haramiyidae according to the phylogenetic hypotheses proposed in Luo et al. (2015b, fig. 4A, B) and the comments in Luo et al. (2017, Supplementary Information: Part B, p. 9) and Debuysschere (2016). The two species of *Theroteinus* are assumed to be sister taxa and are treated accordingly.

The species of *Thomasia* are assumed to be sister taxa and are placed in a corresponding polytomy.

Kielan-Jaworowska et al. (2004, p. 359) regarded the referral of *Nakunodon paikasiensis* to Amphidontidae as “highly tentative” and indeed Averianov (2002) considered it as Holotheria *incertae sedis*. Herein, *Nakunodon paikasiensis* is treated as a potential amphidontid and added as the sister taxon of *Condorodon spanios*, according to the phylogenetic position of *Amphidon* in the strict consensus tree of Gaetano and Rougier (2012, fig. 2). It is accepted, however, that this assignment is only tentative.

Kielan-Jaworowska et al. (2004, p. 240) tentatively assign *Paikasigudodon yadagirii* to “Amphilestidae”. Butler and Sigogneau-Russell (2016) agree that this interpretation is uncertain, but an alternative assignment is not attempted. *Paikasigudodon yadagirii* is therefore added as the sister taxon of the clade *Condorodon spanios* + *Nakunodon paikasiensis*, according to the phylogenetic position of Amphilestidae in the strict consensus tree of Gaetano and Rougier (2012, fig. 2).

Kielan-Jaworowska et al. (2004, p. 234, 235) assign *Dyskritodon* tentatively to Eutriconodonta but leave the family *incertae sedis*. They regard the taxon as “clearly advanced with respect to morganucodontids” (Kielan-Jaworowska et al., 2004, p. 235). Among triconodonts with derived character states *Dyskritodon indicus* is most similar to *Argentoconodon fariasorum*, *Priacodon lulli*, and *Trioracodon ferox* according to Gaetano (2013, p. 181). A few differences, however, are noted as well and Gaetano (2013, p. 178, 183) therefore refers *Dyskritodon* to Mammaliaformes *incertae sedis*. Herein, *Dyskritodon indicus* is treated as the sister taxon of *Argentoconodon fariasorum* (*Priacodon lulli* and *Trioracodon ferox* are both Late Jurassic taxa and are therefore not part of the database).

Alpha taxonomy: The occurrence of *Kuehneotherium* sp. from the Triassic Emborough fissure (Fraser et al., 1985) is retained in the database as a separate entry due to its importance for the stratigraphic range of the taxon. It is herein assigned to ‘*Kuehneotherium* B’ following Debuysschere (2017), which is also reported for the Lower Jurassic Pant and Pontalun sites (Debuysschere, 2017). Similarly, the Triassic occurrence of *Kuehneotherium* sp. from Greenland

(Jenkins et al., 1994; Clemmensen et al., 2016) is retained in the database as '*Kuehneotherium* C', which is also known from the Pant and Potalun sites (Debuysschere, 2017).

Most of the Triassic occurrences of the *Kuehneotherium* sp. from France (Godefroit and Sigogneau-Russell, 1999) and the one from Luxembourg (Godefroit et al., 1998) are now assigned to *Kuehneotherium stanislavi* (Debuysschere, 2017) and are treated accordingly.

The stratigraphic and palaeobiogegraphic range of the genus *Thomasia* is updated according to Clemens and Martin (2014) and Kielan-Jaworowska et al. (2004, p. 257, 258). Due to the stratigraphic importance the specimens described as *Thomasia cf. moorei* from South Wales (Clemens, 2007) are retained in the database and treated as an occurrence of *Thomasia moorei*.

As mentioned in subsection A.38.3, the lower section of the Cañadón Asfalto Formation (Chubut Province, Argentina) is now considered to be of middle to late Toarcian age (Cúneo et al., 2013; but see Hauser et al., 2017). Thus, *Asfaltomylos patagonicus*, *Henosferus molus*, and *Argentoconodon fariasorum*, which were reported for this part of the formation (Cúneo et al., 2013) are included in the database.

Condorodon spanios is also reported for the lower member of the Cañadón Asfalto Formation (Gaetano and Rougier, 2012) and is thus also included.

The specimen reported as *Paikasigudodon cf. yadagirii* from Saint-Nicolas-de-Port in France (Debuysschere et al., 2015) is not included in the database due to the observed differences compared to the holotype of *Paikasigudodon yadagirii* (Debuysschere et al., 2015), awaiting further confirmation of the assignment.

Debuysschere (2017) considers *Kuehneon duchyense* a *nomen dubium*, following thereby Kielan-Jaworowska et al. (2004, p. 363). The taxon is treated accordingly in the database.

A.24.1 Morganucodonta

Phylogeny: *Paceyodon davidi* is considered as family *incertae sedis* within Morganucodonta (Clemens, 2011). A trichotomy consisting of *Paceyodon davidi*, Morganucodontidae, and Megazostrodontidae is therefore created.

Rosierodon anceps is a morganucodont that "does not resemble any of the known genera of Morganucodonta" (Debuysschere et al., 2015, p. 845). It is therefore added to the existing polytomy of *Paceyodon davidi*, Morganucodontidae and Megazostrodontidae.

The Chinese species *Morganucodon oehleri* and *Morganucodon heikuopengensis* are more similar to each other than to *Morganucodon watsoni* (Kielan-Jaworowska et al., 2004, p. 174, 175). *Morganucodon heikuopengensis* is therefore added as the sister taxon of *Morganucodon oehleri*. All species of *Morganucodon* are assumed to be closely related. Therefore, a polytomy consisting of *Morganucodon watsoni*, *Morganucodon peyeri*, and the clade *Morganucodon heikuopengensis* + *Morganucodon oehleri* is created.

The morganucodontid *Eozostrodon parvus* is very similar to *Morganucodon watsoni* (Kielan-Jaworowska et al., 2004, p. 24; O'Meara and Asher, 2016) and it has been suggested that

Morganucodon watsoni is a junior synonym of *Eozostrodon* (Kielan-Jaworowska et al., 2004, p. 169; Kemp, 2005, p. 142; Clemens, 2011). *Eozostrodon parvus* is therefore added as the sister taxon of *Morganucodon*.

Hallautherium is similar to *Morganucodon*, *Megazostrodon*, and *Erythrotherium* (Clemens, 1980, p. 86). *Hallautherium* is a morganucodontan (Clemens, 2011; Clemens and Martin, 2014) and possibly a morganucodontid (Świło et al., 2014). *Hallautherium schalchi* is therefore added as an early diverging member of Morganucodontidae in a polytomy with *Erythrotherium parringtoni* and the clade *Eozostrodon parvus* + *Morganucodon*.

Gondwanadon is potentially a morganucodontid (Kielan-Jaworowska et al., 2004, p. 177, 178; Datta et al., 2004; Clemens, 2011) and is more similar to *Indotherium* than to other morganucodonts (Clemens, 2011). *Gondwanadon tapani* and *Indotherium pranhitae* are therefore treated as sister taxa and this clade is added to Morganucodontidae in a polytomy with *Hallautherium schalchi*, and the clade *Erythrotherium parringtoni* + *Morganucodon*.

Brachyzostrodon is a megazostrodontid that is more closely related to *Megazostrodon* than to *Morganucodon* (Kielan-Jaworowska et al., 2004, p. 179). *Brachyzostrodon* is therefore added as the sister taxon of *Megazostrodon*. The species of *Brachyzostrodon* (including the *cf. Brachyzostrodon* sp. occurrence from Greenland; Jenkins et al., 1994) are assumed to be sister taxa and placed in a corresponding polytomy. Note, however, that Debuysschere et al. (2015) considered *Brachyzostrodon* (and other morganucodonts) family *incertae sedis* and a phylogenetic analysis of all morganucodonts is deemed necessary (Debuysschere et al., 2015).

Kielan-Jaworowska et al. (2004, p. 174, 177) referred *Helvetiodon* to Morganucodontidae but noted a few similarities with *Brachyzostrodon*. Butler and Sigogneau-Russell (2016) suggest a closer relationship with Megazostrodontidae and *Wareolestes*, which also shares some similarities with *Brachyzostrodon*. *Helvetiodon schutzi* is therefore added to Megazostrodontidae as the sister taxon of *Brachyzostrodon*.

Clemens (2011) leaves the moganucodontan *Bridetherium dorisae* as family *incertae sedis* but reports it as most similar to *Megazostrodon*. Clemens (2011) compared *Bridetherium dorisae* also with *Brachyzostrodon coupatezi* and found them to be less similar. *Bridetherium dorisae* is therefore added as the sister taxon of *Megazostrodon*.

The two species of *Megazostrodon* are assumed to be sister taxa and are added accordingly.

Alpha taxonomy: Clemens (2011), Sullivan et al. (2013), Kümmell and Frey (2014), and Debuysschere et al. (2015) treat *Erythrotherium parringtoni* as a valid taxon. It is added to the database.

Due to its palaeobiogeographic and stratigraphic importance, the *Hallautherium* sp. occurrence from Poland (Świło et al., 2014) is added to the occurrences of *Hallautherium schalchi*.

Following Clemens (1979), Kielan-Jaworowska et al. (2004, p. 24, 169) restrict *Eozostrodon parvus* to the specimens known from the Holwell Quarry in England and regard the specimens from Wales as belonging to *Morganucodon watsoni*. This view is followed herein.

Debuysschere et al. (2015) accept *Morganucodon heikuopengensis* as a valid taxon and it is therefore included in the database. The specimen described as *Morganucodon* sp. from the Kayenta Formation (USA; Jenkins et al., 1983; Debuysschere et al., 2015) is not included, awaiting the formal erection of a new species.

The new specimen of *Megazostrodon* from South Africa described by Gow (1986) is slightly different from the holotype. These differences, however, are too minor to warrant the erection of a new species (Gow, 1986). Therefore, herein the specimen is considered to represent another occurrence of *Megazostrodon rudnerae*.

Due to its stratigraphic and palaeobiogeographic importance, the *cf. Brachyzostrodon* sp. occurrence from Greenland (Jenkins et al., 1994) is retained in the database as a separate taxon.

Kunminia minima is most similar to *Morganucodon* (Zhang, 1984) and it is potentially a junior synonym of *Morganucodon oehleri* (Hopson and Kitching, 1972). Li and Sun (2008) refer the taxon to Cynodontia *incertae sedis* and consider it as "systematically indeterminable at present" (Li and Sun, 2008, p. 416). Due to the uncertain status of the species, it is excluded from further analyses.

A.25 Parareptilia

Phylogeny: This portion of the supertree uses the strict consensus tree of MacDougall et al. (2017, fig. 5) as scaffold, which is based on an updated and expanded character matrix of MacDougall et al. (2016). The latter one is based on the character matrices of Modesto et al. (2015) (which is itself based on the data matrix of Reisz et al., 2014) and MacDougall and Reisz (2014). The alternative parareptile topology recovered by Laurin and Piñeiro (2017, fig. 5) has been criticised (MacDougall et al., 2018) and is not further considered herein.

Stereosternum tumidum and *Brazilosaurus sanpauloensis* are added according to the single most parsimonious tree of Rossmann and Maisch (1999). Rossmann and Maisch (1999) do not show the tree, but the results and the associated character matrix are reported on p. 81 of Rossmann and Maisch (1999). Karl et al. (2007, Appendix 2: Outtree by PARS) recovered the same relationships for the three mesosaurid taxa (see also Tsuji and Müller, 2009, fig. 3).

The millerettid taxa *Broomia perplexa*, *Millerosaurus nuffieldi*, *Millerosaurus ornatus*, and *Milleropsis pricei* are added according to the single most parsimonious tree of Cisneros et al. (2008, fig. 4A).

The clade Bolosauridae is added to the Parareptilia scaffold tree according to the strict consensus tree of Falconnet (2012, fig. 4), which is itself based on an updated dataset of Müller et al. (2008).

Permotriturus herrei appears indistinguishable from *Belebey vegrandis* and *Belebey maximi* and might be the senior synonym of *Belebey* (Falconnet, 2012). *Permotriturus herrei* is therefore added to a polytomy including *Belebey vegrandis*, *Belebey maximi*, and *Belebey chengi*.

Recently erected taxa like *Feeserpeton oklahomensis* and *Delorhynchus cifellii* have changed the lanthanosuchian part of the parareptilian phylogeny and *Acleistorhinus pteroticus* and *Colobomycter pholeter* no longer form a sister taxon relationship as in the informal supertree of Tsuji and Müller (2009, fig. 3). In Tsuji and Müller (2009, fig. 3) the taxa *Lanthaniscus* and *Chalcosaurus* form a polytomy with *Lanthanosuchus* and the clade *Acleistorhinus* + *Colobomycter*. Following the parareptile phylogeny of Tsuji and Müller (2009, fig. 3) the taxa *Lanthaniscus* and *Chalcosaurus* would thus be placed as early diverging lanthanosuchians, in a polytomy with *Feeserpeton oklahomensis* and the clade consisting of all other later diverging lanthanosuchians. *Feeserpeton oklahomensis* has been recovered as a lanthanosuchoid but is not a member of Lanthanosuchidae (MacDougall and Reisz, 2012; Reisz et al., 2014 recovered it as an acleistorhinid, but Modesto et al., 2015 - see fig. 4 of the supplement - found the same placement as MacDougall and Reisz, 2012). Similarly, *Colobomycter pholeter* also belongs to Lanthanosuchoidea, but is not a lanthanosuchid (MacDougall et al., 2017). The current defintion of Lanthanosuchidae *sensu* deBraga and Rieppel, 1997 (= the most recent common ancestor of *Lanthanosuchus* and *Lanthaniscus*) includes *Lanthaniscus* as a lanthanosuchid. Ivakhnenko (2008b, p. 70) assigns the taxon to the new family Lanthaniscidae, without carrying out a quantitative phylogenetic analysis. Reisz et al. (2014) treat *Lanthanosuchus* and *Lanthaniscus* as members of a single clade and MacDougall et al. (2016) still treat them as lanthanosuchids. *Acleistorhinus pteroticus* is considered to belong to a different clade, Acleistorhinidae (deBraga and Rieppel, 1997). Indeed, deBraga and Reisz (1996, fig. 3) recover Lanthanosuchidae (represented by *Lanthanosuchus* and *Lanthaniscus*) as sister taxon to *Acleistorhinus*. *Lanthaniscus efremovi* is therefore added as the sister taxon of *Lanthanosuchus watsoni* (but see Tsuji and Müller, 2009, fig. 3).

Chalcosaurus is a lanthanosuchid (Tverdokhlebov et al., 2005; Ivakhnenko, 2008b, p. 72–74; Schoch and Milner, 2014, p. 115). It is therefore added to a polytomy including *Lanthaniscus* and *Lanthanosuchus*. *Chalcosaurus lukjanovae* is assumed to be closely related to *Chalcosaurus rossicus* and is therefore added as its sister taxon.

The current definitions of Lanthanosuchidae and Lanthanosuchoidea *sensu* deBraga and Rieppel, 1997 require revision or quantitative phylogenetic analyses of *Lanthaniscus efremovi* as a separate OTU, as the above-mentioned placement of *Lanthaniscus efremovi* on the supertree excludes several taxa (*Delorhynchus*, *Colobomycter*) from Lanthanosuchoidea *sensu* deBraga and Rieppel, 1997, which previously have been considered lanthanosuchoids (MacDougall et al., 2017).

Delorhynchus priscus is assumed to be closely related to *Delorhynchus cifellii* and is added as its sister taxon.

The two species of *Nyctiphruretus* are assumed to be sister taxa and are treated accordingly.

Alpha taxonomy: *Milleretta rubidgei* is also known from the *Tropidostoma* AZ (Viglietti et al., 2016) and the lower and upper *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1) and is treated accordingly. *Millerosaurus nuffieldi* is restricted to the lower *Daptocephalus*

AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1) and is treated accordingly. Viglietti et al. (2016) mention *Millerosaurus nuffieldi* also for the *Tropidostoma* AZ, but in (Viglietti et al., 2016, fig. 2) the range of the taxon is restricted to the lower *Daptocephalus* AZ, with no occurrence in the *Cistecephalus* AZ. Therefore, the (possible?) occurrence of the taxon in the *Tropidostoma* AZ is not incorporated into the database.

Falconnet (2012) considered seven bolosaurid species to be valid and suggested *Bolosaurus major* to be synonymous with *Bolosaurus striatus*. This interpretation is followed herein. Broom (1913) discriminated between *Bolosaurus major* and *Bolosaurus striatus* only based on their different size and the different size of their teeth. Indeed, although Watson (1954) cited Broom (1913) in his account on *Bolosaurus*, he does not mention *Bolosaurus major*. Reisz et al. (2002) erected the new species *Bolosaurus grandis* but also did not mention *Bolosaurus major*. Müller et al. (2008) only mention *Bolosaurus grandis* and *Bolosaurus striatus* as recognized species of *Bolosaurus* (*Bolosaurus traati* Tatarinov, 1974 is not mentioned).

Delorhynchus priscus is not regarded a *nomen dubium* by, e.g., Modesto (1999) or Reisz et al. (2014), and is treated accordingly in the database.

Mesosaurus pleurogaster is a *nomen dubium* according to Rossmann (2000). It is thus not included in this analysis.

Broom (1909) considered *Heleophilus acutus* a close relative of *Heleosaurus scholtzi* (a varanopid; Berman et al., 2014) and assigned it to Mesosauria. Romer (1956a, p. 522) mentioned it as a younginid and Kuhn (1969b, p. 42) referred the taxon to Eosuchia *incertae sedis*. Carroll (1988, Appendix: p. 615) and Laurin and Reisz (1995, p. 204) treat it as a possible millerettid. Due to the uncertain relationships and the fragmentary nature of the holotype (Broom, 1909), *Heleophilus acutus* is excluded from further analyses.

Kuhn (1969a, p. 87) considered *Millerinoides* an indeterminate genus. Specimens assigned to *Millerinoides acutirostris* belong to *Millerosaurus* and the *Millerosaurus*-*Milleropsis* group according to Gow (1972). *Millerinoides acutirostris* is therefore not included in this analysis as a separate taxon.

Nanomilleretta kitchingi is excluded from further analyses because its holotype is devoid of diagnostic features according to Gow (1972). Indeed, Kuhn (1969a, p. 87) considered the genus indeterminate.

Bolosaurus traati is a tetrapod of uncertain relationship (Falconnet, 2012) and is therefore excluded from this study. *Davletkulia gigantea* is considered a *nomen dubium* by Reisz et al. (2002), might be a dinocephalian (Reisz et al., 2002; Falconnet, 2012). Due to its uncertain phylogenetic position *Davletkulia gigantea* is also excluded from further analyses.

The 'Red Tank Belebeyinae' (Falconnet, 2012), which was described by Harris et al. (2004) and is only represented by tooth material, probably belongs to a new bolosaurid taxon (Harris et al., 2004; Falconnet et al., 2012). It is not included (as a possible sister taxon of the genus *Belebey*), awaiting further study of the material and the formal erection of a new genus and species name.

Falconnet (2012) regarded *Gnorhimosuchus satpaevi* as either a parareptile or a captorhinid of indeterminate position. Golubev (2000) reports the taxon as a member of Bolosauridae. Due to its uncertain phylogenetic position and because it is only represented by dorsal vertebrae it is not included in further analyses. The same applies to *Timanosaurus ivachnenkoi* (Falconnet, 2012).

The taxon *Lanthanosuchus qualeni* is a *nomen nudum* (Ivakhnenko, 2008b; M. F. Ivakhnenko, pers. comm., 2015) and is therefore excluded from further analyses.

The genus *Bolterpeton*, previously considered a gymnarthridid (Anderson and Reisz, 2003), is a junior synonym of *Delorhynchus* and *Bolterpeton carrolli* is now considered a *nomen dubium* (Haridy et al., 2018). The taxon is treated accordingly.

A.25.1 Pareiasauromorpha

Phylogeny: The 50% majority rule consensus tree of Benton (2016, fig. 19A; corrected version from 4 March 2016) is used as basis for non-pareiasaur Pareiasauromorpha and integrated into the scaffold tree of Parareptilia. This tree is also used to add the taxa *Sanchuansaurus pygmaeus* and *Obirkovia gladiator*. Benton (2016) used an updated data matrix of Turner et al. (2015), which itself is based on an updated data matrix of Tsuji et al. (2013b) with updates taken from Xu et al. (2015).

The clade Pareiasauria is added according to the majority rule consensus tree of Liu and Bever (2018, fig. 5B), which is also based on a revised character matrix of Turner et al. (2015).

Macroleter agilis Olson, 1980 (Reisz and Laurin, 2001) is assumed to be a sister taxon of *Macroleter poezicus* (see also Tsuji et al., 2012) and is added accordingly.

Alpha taxonomy: Ivakhnenko (1997b) assigned *Nycteroleter bashkyricus* to the genus *Bashkyroleter* (see also Tsuji et al., 2012). The taxon is treated accordingly.

Tokosaurus perforatus is a junior synonym of the pareiasauromorph *Macroleter poezicus* according to Tsuji et al. (2012). It is thus not included in this analysis as a separate taxon.

Material that previously had been referred to *Bradysaurus bombidens* (Owen, 1876) (new genus *Bradysaurus* created by Watson, 1914b) can be assigned to *Bradysaurus seeleyi*, *Bradysaurus baini*, and *Pareiasaurus bombidens* according to Lee (1994, p. 68–72). *Pareiasaurus bombidens* is considered a *nomen vanum* (Lee, 1994, p. 121, 122). The taxa are treated accordingly.

Lee (1997a) recognized *Embrithosaurus schwarzi* as the only valid species of the genus. He considered *Embrithosaurus strubeni* (Broom (1924) originally described it as *Pareiasaurus strubeni*) a *nomen vanum* and *Embrithosaurus angusta* (Haughton and Boonstra (1929) originally described it as *Dolichopareia angusta*) as belonging to *Nochelesaurus alexanderi*. The taxa are treated accordingly.

Deltavjatia vjatkensis is a synonym of *Deltavjatia rossicus*, which is the only currently valid species of the genus *Deltavjatia* according to Tsuji (2013). The taxa are treated accordingly.

Xu et al. (2015) resurrect *Honania complicidentata* and show *Tsiyuania simplicidentata* and *Taihangshania imperfecta* (misspelled as *Taihangshania imperfacta*) to be its junior synonyms. The taxon is treated accordingly.

Anthodon gregoryi and *Anthodon nesemanni* are both synonyms of *Pareiasaurus serridens* (Findlay, 1970; Lee, 1994, p. 92–98; Table 6). The taxa are treated accordingly.

Pareiasaurus is found in both *Tropidostoma* AZ (Day et al., 2015a, fig. 1) and the lower and upper *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2). As *Pareiasaurus serridens* is the only valid species of the taxon (Lee, 1997a), it is treated accordingly. Furthermore, *Pareiasaurus serridens* is also known from the Usili Formation of Tanzania (Sidor et al., 2010, Table 1; Sidor et al., 2013, Table S1) and this occurrence is added to the database.

Propappus omocratus and *Propappus rogersi* are junior synonyms of *Pareiasaurus serridens* according to Lee (1994, p. 92; 96; Table 6). The taxa are treated accordingly.

Sanchuansaurus pygmaeus Gao, 1989 is a valid taxon according to Benton (2016) (contra Li and Liu, 2013). Benton (2016) also considers *Huanghesaurus liulinensis* and *Shansisaurus xuecunensis* to be junior synonyms of *Shihtienfenia permica*. The taxa are treated accordingly.

Obirkovia gladiator is included in recent phylogenetic analyses (e.g., Tsuji et al., 2013b; Tsuji, 2013; Xu et al., 2015) and is therefore added to the database, despite being known only from a single quadratojugal (Tsuji, 2013).

Anthodon serrarius is also known from the Usili Formation of Tanzania (Sidor et al., 2010, Table 1; Sidor et al., 2013, Table S1) and this occurrence is added to the database. Furthermore, its stratigraphic range also includes the lower *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1) and it is treated accordingly.

The stratigraphic range of *Anthodon* and are not updated according to Viglietti et al. (2016, fig. 2) as the actual specimens are referred to *Anthodon gregoryi* (misspelled as *Anthodon gregori* in Viglietti et al., 2016, Supplementary data: mmc1; reported as *Anthodon* sp. in Viglietti et al., 2016, Supplementary data: mmc2 and Viglietti et al., 2016) and *Nanoparia pricei* respectively (Viglietti et al., 2016, Supplementary data: mmc1), which are currently not considered to be valid taxa Lee (1997a). The upper bound of the stratigraphic range of *Pareiasuchus* is also not updated as no information on the specimens and species assignment is given in the supplementary data of Viglietti et al. (2016, Supplementary data: mmc1). *Pareiasuchus peringueyi* and *Pareiasuchus nasicornis* are already known from the *Tropidostoma* AZ (Viglietti et al., 2016) and are treated accordingly.

Anthodon minusculus is a *nomen dubium* (Lee, 1994, p. 119, 120; Table 6) and is therefore excluded from further analyses.

Pareiasaurus pinnatus is a *nomen dubium* and *Pareiasaurus russouwi* is a *nomen vanum* according to Lee (1994, p. 98, 99; 125, 126). The material referred to *Pareiasaurus henneni* White, 1917 (briefly described by Case, 1917) has been incorrectly identified as pareiasaurian and is probably not even organic (Romer, 1952, p. 88; Kuhn, 1969a, p. 84; Lee, 1994, p. 127). None of these taxa is therefore included in the database for further analyses.

A.25.2 Procolophonoidea

Phylogeny: Owenettidae and the taxon *Ruhuhuaria* are added according to the strict consensus tree of Tsuji et al. (2013a, fig. 4), which is based on an expanded character matrix of Modesto et al. (2003) with updates from Cisneros et al. (2004).

The Procolophonidae portion of the Parareptilia tree is augmented with the 50% majority rule consensus tree of Zaher et al. (2019, fig. 13B), which is based on an expanded character matrix of Cisneros (2008b) with updates from MacDougall et al. (2013).

Lasasaurus beltanae and *Mandaphon nadra* are added according to the strict consensus tree of Tsuji (2018, fig. 5), which is based on an expanded character matrix of Cisneros (2008b) with updates from Cisneros (2008a), Modesto et al. (2010), MacDougall and Modesto (2011), MacDougall et al. (2013), and Falconnet et al. (2012).

Koiloskiosaurus coburgensis is added according to the strict consensus tree of Modesto and Damiani (2007, fig. 7A), which is based on an expanded character matrix of deBraga (2003). Note, however, that *Koiloskiosaurus coburgensis* is in need of redescription (Modesto and Damiani, 2007; Sues and Reisz, 2008; Säilä, 2010).

Anomoiodon liliensterni is added according to the strict consensus tree of Säilä (2008, fig. 4), considering also the comments in Säilä (2008) and the placement of the taxon on the informal supertree of Tsuji and Müller (2009, fig. 3).

Suchonosaurus minimus is an early diverging member of Procolophonidae that is most similar to *Contritosaurus*, *Phaanthosaurus*, *Coletta*, and *Pintosaurus* (Säilä, 2009). It is therefore added to a polytomy consisting of *Coletta seca* and the clade including *Sauropareion anoplus* and later diverging procolophonids, as *Coletta seca* represents the earliest diverging procolophonid recovered in recent phylogenetic analyses (Falconnet et al., 2012; Tsuji, 2018; Zaher et al., 2019) among these taxa and resembles *Suchonosaurus minimus* most closely in regards to the shape of the maxillary bone and the tooth number (Säilä, 2009).

Santaisaurus yuani is probably a procolophonid (Wang and Evans, 2006; Li, 2008, p. 31, 32; Liu and Abdala, 2017b). It is therefore added to a polytomy consisting of other early diverging members of Procolophonidae.

Contritosaurus is part of the strict consensus tree of Säilä (2008, fig. 8), which, however, does not contain *Phaanthosaurus* as a separate OTU. The strict consensus tree of Cisneros (2008b, fig. 4) and analyses derived from the respective dataset (e.g., Cisneros, 2008a; Modesto et al., 2010; MacDougall and Modesto, 2011; MacDougall et al., 2013), on the other hand, treat *Contritosaurus* as a junior synonym of *Phaanthosaurus* (see also Spencer and Benton, 2000, p. 163) and do not code the two taxa separately. Säilä (2009) and Verrière et al. (2016) still treat *Contritosaurus* as a separate taxon and it is retained as such in the database, but the potential synonymy with *Contritosaurus* (Spencer and Benton, 2000, p. 163) indicates their close relationship. *Contritosaurus* is therefore added as the sister taxon of *Phaanthosaurus* (see also the informal supertrees of Tsuji and Müller (2009, fig. 3) and of Ruta et al. (2011, text-fig. 1)). The two species of *Contritosaurus* are assumed to be sister taxa and are treated accordingly.

Gomphiosauridion baileyae has been considered a procolophonid of uncertain affinities (Sues and Olsen, 1993; Cisneros, 2008b), sharing a diagnostic feature (fluted enamel) with *Thelegnathus* (Sues and Olsen, 1993). *Thelegnathus* is now considered a *nomen dubium* and material that had previously been assigned to the taxon is now referred to four different genera of procolophonids, namely *Thelerpeton*, *Theledectes*, *Thelephon*, and *Teratophon* (Modesto and Damiani, 2003). *Gomphiosauridion baileyae* is therefore added to a polytomy including Theledectinae and the clade consisting of later diverging procolophonids. Note, that this placement can only be considered tentative as fluted enamel is also known from *Colognathus obscurus* (Heckert, 2004), which is currently only questionably assigned to Amniota (Sues and Schoch, 2013b). Indeed, *Gomphiosauridion baileyae* has been considered to be most similar to *Colognathus obscurus*, differing from it only in its characteristic procolophonid features (Heckert et al., 2012b).

The two species of *Tichvinskia* are assumed to be sister taxa and *Tichvinskia jugensis* is added accordingly.

Myocephalus crassidens is a procolophonid (Laurin and Reisz, 1995; deBraga and Rieppel, 1997; Sues and Schoch, 2013b) that appears to be similar to *Procolophon* (von Huene, 1956, p. 179; Kuhn, 1969a, p. 55). Indeed, the phylogenetic hypothesis of Colbert (1946, fig. 18) places it as the sister taxon of *Procolophon* and Ivakhnenko (1979, p. 20) includes it within Procolophoninae. According to Modesto and Damiani (2003), however, the maxillary morphology of *Myocephalus crassidens* is very similar to that of leptopleuronine procolophonids. *Myocephalus crassidens* is therefore added to a polytomy including Procolophoninae and Leptopleuroninae.

Acadiella psalidodon and *Haligonia bolodon* are procolophonids (Sues and Baird, 1998; Sues and Olsen, 2015) and *Haligonia bolodon* appears to "superficially" resemble *Myocephalus crassidens* (Sues and Baird, 1998, p. 528). Both *Acadiella psalidodon* and *Haligonia bolodon* generally resemble *Thelephon contritus* (Modesto and Damiani, 2003). Säilä (2008) notes similarities between the dental pattern of *Acadiella psalidodon* and *Anomoiodon*. The teeth of *Haligonia bolodon* appear to be similar to those of *Thelephon contritus* and *Kapes amaenus* (Cisneros, 2008b; Schoch, 2011a). Given these interpretations, *Acadiella psalidodon* and *Haligonia bolodon* are added to a polytomy consisting of *Thelephon contritus* and the clade including *Anomoiodon* and later diverging procolophonids. Note, however, that the phylogenetic position of these taxa is still uncertain (Sues and Olsen, 2015).

Anomoiodon krejcii is assumed to be a sister taxon of *Anomoiodon liliensterni* and is added accordingly.

The four species of *Kapes* are assumed to be sister taxa and are added to a corresponding polytomy.

Procolina is considered a 'kapoid', close to *Kapes* (Borsuk-Białynicka and Lubka, 2009).

Lestanshoria massiva, *Orenburgia bruma*, and *Samaria concinna* are reported to be similar to each other and to *Kapes* (Spencer and Benton, 2000; Spencer and Storrs, 2002). *Insulophon* is also very similar to *Orenburgia bruma* (Spencer and Benton, 2000). *Procolina*, *Lestanshoria massiva*, *Orenburgia bruma*, *Samaria concinna*, and *Insulophon morachovskayae* are therefore added as sister clade to *Kapes* (see also the hypothesized phylogenetic relationships in Borsuk-Białynicka and Lubka, 2009, fig. 20).

The two species of *Orenburgia* are assumed to be sister taxa and are treated accordingly.

The probable procolophonians *Tricuspisaurus* and *Xenodiphyodon* resemble each other closely (Sues and Olsen, 1993). *Tricuspisaurus thomasi* and *Xenodiphyodon petraios* are therefore treated as sister taxa and added accordingly. *Tricuspisaurus* has even been suggested to represent a procolophonid (Sues and Olsen, 1993; Heckert et al., 2001; Spielmann et al., 2007) and, indeed, *Xenodiphyodon* might actually represent a leptopleuronine procolophinid, comparable to *Scoloparia* (Cisneros, 2008b). Sues and Baird (1998) report osteoderms from south Wales, that might be referable to *Tricuspisaurus* and are similar to osteoderms seen in *Sclerosaurus* and *Scoloparia*. The clade *Tricuspisaurus thomasi* + *Xenodiphyodon petraios* is therefore added to a polytomy including the clade *Scoloparia glyphanodon* + *Sclerosaurus armatus* and the clade consisting of *Leptopleuron lacertinum* and later diverging leptopleuronines.

The leptopleuronine *Libognathus* is closely related to *Hypsognathus* (Small, 1997; see also Spencer, 2000) and is therefore added as its sister taxon.

Alpha taxonomy: Evans (2001) assigned *Colubrifer campi* to *Owenetta* sp. (see also Reisz and Scott, 2002). As *Colubrifer campi* probably stems from the *Lystrosaurus* AZ, Damiani et al. (2003) considered it likely to represent another specimen of *Owenetta kitchingorum*. *Owenetta rubidgei*, however, is also known from the *Lystrosaurus* AZ (Viglietti et al., 2016, Supplementary data: mmc1, mmc2) (some of these specimens have previously been described as *Owenetta kitchingorum*). The specimen previously assigned to *Colubrifer campi* is therefore herein retained for *Owenetta rubidgei*, considering also that *Owenetta kitchingorum* might actually belong to a different genus (Modesto et al., 2003; Cisneros et al., 2004; Tsuji et al., 2013a).

According to Spencer and Benton (2000, p. 167) *Tichvinskia vjatkensis* probably includes the genus *Burtensia*. *Burtensia burtensis* is treated accordingly in the database. It should be noted, however, that Borsuk-Białynicka and Lubka (2009) provisionally considered the genus valid for comparative purposes.

The species *Procolophonoides baini* is not considered valid any more (Cisneros, 2008b) and *Procolophonoides baini* is listed in Cisneros (2008c) as belonging to *Procolophon trigoniceps*. The taxon is treated accordingly.

Myognathus is mentioned by von Huene (1956, p. 180), who attributes the author citation to Broom. von Huene (1956, fig. 225) supposedly shows the skull of *Myognathus*, but, as already noted by Ivakhnenko (1979, p. 8), the skull aspects shown in the figure are identical to those of Broom (1936b, fig. 2C, D), which represent *Myocephalus*. This mistake was recognized by von

Huene (1959, p. 7, 8) and the name *Myognathus* was abandoned. Indeed, according to Kuhn (1969a, p. 55) *Myognathus* von Huene, 1956 actually represents *Myognathus* Broom, 1936b. The taxon is treated accordingly.

Macrophon is a junior synonym of *Kapes* according to Spencer and Benton (2000, p. 169, 170) and Spencer and Storrs (2002). The taxon is treated accordingly in the database.

Kapes serotinus is synonymous with *Kapes majmesculae* according to Spencer and Storrs (2002). The fourth valid *Kapes* species is *Kapes komiensis* (Spencer and Benton, 2000; Spencer and Storrs, 2002; see also Ruta et al., 2011, text-fig. 1). The taxa are treated accordingly.

N. C. Fraser in Benton (1994a) reports *Leptopleuron* from the Late Triassic fissure and cave fills of South Wales and the Bristol region. According to Säilä (2010), however, *Leptopleuron lacertinum* is restricted to the Lossiemouth Sandstone Formation of Scotland. According to Whiteside et al. (2016) procolophonids are, indeed, known from the 'sauropsid type fissures' of South Wales and Bristol (see also Edwards and Evans, 2006) but a more precise taxonomic assignment beyond the family level still needs to be carried out. The *Leptopleuron* sp. record from the Bristol fissures is therefore removed from the database and the stratigraphic range of *Leptopleuron lacertinum* is treated accordingly.

Libognathus sheddi is known from the Dockum Group of Texas and the Chinle Formation of Colorado (Small, 1997; Heckert and Lucas, 2006; Martz, 2008, p. 173–175; Small and Martz, 2013; Pardo et al., 2017b, Supporting Information: Appendix – Materials, Methods, Discussion), but not from the Owl Rock Formation/Member of Utah. The leptopleuronine procolophonid specimen from the Owl Rock Formation/Member of Utah could not be compared with *Libognathus sheddi* at the time of description, as no overlapping material was known (Fraser et al., 2005). Note, however, that skull material is now also available for *Libognathus sheddi* (Lehman and Chatterjee, 2005). The data entry of *Libognathus sheddi* is updated accordingly.

The specimen of *Hypsognathus fenneri* reported from the Fundy Basin of Canada (Sues et al., 2000) is retained in the database due to its stratigraphic and palaeobiogeographic importance. Note, however, that Whiteside et al. (2011, Supporting Information: Table S2) and Sues and Olsen (2015) report the specimen as *Hypsognathus cf. fenneri*.

Spondylolestes rubidgei is restricted to the upper *Daptocephalus* AZ (Viglietti et al., 2016, fig. 2; Supplementary data: mmc1). Cisneros (2008b) considered *Spondylolestes rubidgei* to be a valid taxon but it is widely regarded a *nomen dubium* (Spencer, 2000; Spencer and Benton, 2000; Modesto et al., 2002). Spencer and Benton (2000, p. 162) and Spencer (2000) considered even its status as amniote uncertain. Even if the taxon is valid, the phylogenetic relationships (Cisneros, 2008b) and the age (Säilä, 2009) of this potential procolophonid are uncertain (but see Viglietti et al., 2016). *Spondylolestes rubidgei* is therefore excluded from further analyses.

The potential procolophonid from the Anisian of the Catalonian Basin (Fortuny et al., 2014) is not included, awaiting the description of additional specimens and the formal erection of a new taxon.

Basileosaurus freyi is not included in this analysis, as its holotype and only specimen was lost, preventing further analysis of its relationships (von Huene, 1932b; Sues and Reisz, 2008).

Estheriophagus chatangensis is mentioned in Olson (1957, p. 207; 221) (a summary, mainly based on Efremov and V'yushkov, 1955) and Carroll (1988, Appendix: p. 615) as a (potential) member of Procolophonidae, while von Huene (1956, p. 697) reports it as a nyctiphruretid. A question mark is preceding the genus name in Carroll (1988, Appendix: p. 615), which indicates that Carroll (1988) was uncertain about the validity of the taxon. Indeed, this taxon is only based on the fragment of a lower jaw (Kuhn, 1969a, p. 55) and some dubious skull fragments (Novozhilov, 1948, fig. 1). *Estheriophagus chatangensis* is therefore not included in the database.

Bartholomai (1979) describes *Kudnu mackinlayi* as a squamate and member of the family Paliguanidae. Evans (2003) reports *Kudnu mackinlayi* as possibly representing a juvenile prolacertiform. Evans and Jones (2010) consider the taxon to be too poorly preserved for a safe interpretation but regard it a possible procolophonian. Due to the uncertainty of the assignment *Kudnu mackinlayi* is excluded from the database.

Even though Sues and Schoch (2013b) recently described new material of *Colognathus*, its phylogenetic relationships are still unclear (?Amniota). It is thus excluded from this analysis.

Kinelia broomi is considered Tetrapoda *incertae sedis* by Säilä (2009) and is therefore excluded.

A.26 'Basal' Eureptilia

Phylogeny: The 50% majority rule consensus tree of Müller and Reisz (2006, fig. 2) is used as the scaffold tree for early diverging Eureptilia and 'protorothyridid' taxa are placed according to this tree.

The two species of *Protorothyris* are assumed to be sister taxa.

The unnamed protorothyridid from Fort Sill (Oklahoma, USA) described by Reisz (1980) is the youngest 'protorothyridid' survivor. *Protorothyris* is the second youngest 'protorothyridid' in the database and Reisz (1980) also reports similarities between the two taxa (where a comparison is possible). The unnamed protorothyridid is therefore added as the sister taxon of *Protorothyris*.

Alpha taxonomy: The unnamed protorothyridid described by Reisz (1980) is retained in the database due to its stratigraphic importance as the latest 'protorothyridid' survivor.

A.26.1 Captorhinidae

Phylogeny: The strict consensus tree of Modesto et al. (2018, fig. 7), based on an expanded dataset of Reisz et al. (2015), is used as the scaffold tree for *Thuringothyris mahlendorffae* + Captorhinidae.

Specimens of *Captorhinikos parvus* have initially been assigned to *Captorhinikos chozaensis* (Olson, 1970, p. 419), which is now considered to belong to a different genus (Modesto et al., 2014).

According to Olson (1970, p. 419, 420) *Captorhinikos parvus* is more similar to *Captorhinikos valensis* than to *Captorhinikos chozaensis*, but Modesto et al. (2014, p. 299) report it as being "not a close relative of *C. valensis*". *Captorhinikos parvus* is added according to the strict consensus tree of Jung (2018, fig. 23), which is based on an expanded character matrix of Reisz et al. (2015). As implied by Modesto et al. (2014), *C. parvus* is not recovered as the sister taxon of *C. valensis* in the analysis of Jung (2018).

Limnostygis relictus has initially been described as a limnoscelid captorhinomorph (Carroll, 1967), but Wideman and Sumida (2004) considered the taxon to consist of ophiacodont and captorhinid material, thereby representing the oldest occurrence of Captorhinidae. This view was also followed by Wideman et al. (2005) and is mentioned by Kennedy (2010), whereas according to Müller and Reisz (2005) additional evidence is needed, as *Limnostygis relictus* might have affinities with other 'cotylosaurs'. Recent phylogenetic analyses recover *Thuringothyris mahlendorffae* as the sister taxon of Captorhinidae (e.g., Müller et al., 2006; Reisz et al., 2011a Modesto et al., 2014; LeBlanc et al., 2015; Reisz2015) but the taxon is not treated as a member of Captorhinidae (see, e.g., Müller et al., 2006; LeBlanc et al., 2015, fig. 8; Reisz et al., 2015). Considering the previous alphataxonomic opinions on *L. relictus*, *Limnostygis relictus* is added to a polytomy including *Thuringothyris mahlendorffae* and Captorhinidae.

Riabininus uralensis is a captorhinid (Ivakhnenko, 1990; Lozovsky, 2005; Brocklehurst et al., 2017). According to Modesto and Rybczynski (2000, p. 19, 20) material from the Inta locality of Russia has been referred to *Riabininus uralensis* but is indistinguishable from basal captorhinid material from North America and Africa. Modesto and Rybczynski (2000) considered this material therefore as Captorhinidae *incertae sedis*. *Riabininus uralensis* is therefore added as an early diverging captorhinid to a polytomy consisting of *Euconcordia cunninghami* and the rest of Captorhinidae.

The phylogenetic position of *Acrodenta irerhi* (Dutuit (1976) used the genus name *Acrodenta*, while Jalil and Dutuit (1996) use *Acrodonta*) within Captorhinidae is considered uncertain (Jalil and Dutuit, 1996), but material that previously had been assigned to the taxon was later on referred to Moradisaurinae (Jalil and Dutuit, 1996). The tooth morphology of *Acrodenta irerhi* is considered to be "more primitive than *Labidosaurus*, *Captorhinus* and all other multiple tooth-rowed captorhinids" (Jalil and Dutuit, 1996, p. 914). It is therefore added in a polytomy *Saurorictus australis* and the rest of Captorhinidae with more derived character states.

The tooth morphology of *Baeotherates fortsillensis* is similar to that of *Captorhinus aguti* (Brocklehurst, 2016). It is therefore added as the sister taxon of *Captorhinus*.

Labidosaurikos barkeri is potentially a junior synonym of *Labidosaurikos meachami* (Dodick and Modesto, 1995) and is therefore added as its sister taxon.

Gecatogomphius kavejevi and *Kahneria seltina* are moradisaurine captorhinids (Modesto et al., 2014), which form a clade with *Labidosaurikos*, *Moradisaurus*, *Rothianiscus*, and *Captorhinikos* (Dodick and Modesto, 1995). Kuhn (1969a, p. 38) reports *Gecatogomphius kavejevi* as being close to *Kahneria*. *Moradisaurus grandis* has previously been considered most closely related to *Gecatogomphius* and *Kahneria* (Richards et al., 2007). *Gecatogomphius kavejevi* and *Kahneria seltina* are therefore added to a polytomy including *Moradisaurus grandis*.

The two species of *Rothianiscus* are assumed to be sister taxa.

Alpha taxonomy: The genus name of *Concordia cunninghami* is replaced with *Euconcordia* following Reisz et al. (2016).

Protocaptorhinus pricei is also known from the Wellington Formation of Oklahoma (Modesto, 1996) and its data row is updated accordingly.

Captorhinus laticeps is also known from the Petrolia Formation and the Waggoner Ranch Formation of Texas (Heaton, 1979, Appendix; Modesto, 1998; Kissel, 2010, p. 134). The palaeobiogeographic and stratigraphic range of the taxon is updated accordingly. *Captorhinus aguti* is also known from the Richards Spur locality, the Waggoner Ranch Formation (Kissel et al., 2002; Kissel, 2010, p. 129, 134; MacDougall and Reisz, 2012, Table 1) and the Bally Mountain locality (LeBlanc et al., 2015) and is treated accordingly. The occurrence of the taxon from the lower Pedra de Fogo Formation (Cisneros et al., 2015a) is also added.

Rothianiscus multidonta is also known from the Flowerpot Formation (Kuhn, 1969a, p. 36–38; Lucas, 2006) and is treated accordingly.

Gaffney and McKenna (1979) described *Protocaptorhinus* sp. from the Middle Madumabisa Mudstones, but Modesto (1996) considered the specimens to be Captorhinidae *incertae sedis* and Modesto and Smith (2001) mentioned similarities between the specimens and *Saurorictus*. The specimens are therefore excluded from the database.

A.27 'Basal' Diapsida

Phylogeny: This branch of the early tetrapod supertree is based on the strict consensus tree of Scheyer et al. (2017, Supplementary Information: Supplementary fig. S6) who use an expanded version of the dataset of Chen et al. (2014). The latter dataset is an expanded version of the one presented by Reisz et al. (2011b) (see Reisz et al., 2011b, fig. 4 for a comparison). The recovered topology is very similar to that of Motani et al. (2015a, fig. 4b; Extended Data fig. 2), which is also based on an expanded character matrix of Chen et al. (2014). The position of Choristodera is modified according to the the strict consensus trees of Motani et al. (2015a, fig. 4a; Extended Data fig. 1) and the majority rule consensus tree of Schoch and Sues (2015, fig. 4), who both recover the clade as sister taxon of Archosauromorpha. *Pachystropheus rhaeticus* represents the only member of Choristodera (its phylogenetic position is still debated; see, e.g., Storrs et al., 1996; Renesto, 2005; Matsumoto and Evans, 2010; Allard et al., 2015) in the dataset. *Pachystropheus rhaeticus* is therefore used to replace Choristodera in the scaffold tree of early diverging diapsids.

The Adams consensus tree of Bickelmann et al. (2009, fig. 4B) is used to add four additional taxa. *Kenyasaurus mariakaniensis* is placed in a polytomy with *Lanthanolania ivakhnenkoi* and the rest of Neodiapsida. *Palaeagama vielhaueri* and *Saurosternon bainii* form a clade that is added as sister taxon of Sauria.

The taxon *Elachistosuchus huenei* is added according to strict consensus tree of Sobral et al. (2015, fig. 9), forming a polytomy with Choristodera and Archosauromorpha (the underlying dataset is also based on Chen et al., 2014).

Carroll (1987, p. 664) describes *Heleosuchus griesbachi* as a “primitive lepidosauromorph” and compares it with *Galesphyrus* and *Hovasaurus*. Carroll (1987) considers *Galesphyrus* to be closer to early diverging lepidosauromorphs than to early diverging archosauromorphs. Similarly, Evans (1988a, p. 243, 244) tentatively assigns *Heleosuchus griesbachi* to Lepidosauromorpha and considers it a possible sister taxon of Younginiformes. Recent analyses do not recover the younginiform taxa of Evans (1988a, fig. 6.2) as a clade, but as a paraphyletic set of early diverging non-saurian neodiapsids (Bickelmann et al., 2009; Ezcurra et al., 2014; Motani et al., 2015a). *Heleosuchus griesbachi* is therefore added according to the cladogram of Evans (1988a, fig. 6.2) to a polytomy consisting of *Lanthanolania ivakhnenkoi*, *Kenyasaurus mariakaniensis*, and the clade consisting of later diverging neodiapsids.

Hovasaurus ranohirensis is assumed to be closely related to *Hovasaurus boulei* and is therefore added as its sister taxon.

The type specimen of *Niphosaurus kermacki* was previously assigned to *Saurosternon bainii* (Evans, 1985) and is thus placed as its sister taxon.

Alpha taxonomy: *Acanthotoposaurus bremneri* is a subjective junior synonym of *Youngina capensis* according to Reisz et al. (2000) and this view appears to be followed by Ezcurra et al. (2014). The taxon is treated accordingly in the database. The stratigraphic range of *Youngina capensis* is updated according to Viglietti et al. (2016, fig. 2; Table 1; Supplementary data: mmc1).

Fossil remains of *Hovasaurus boulei* are also reported from the Middle Sakamena Formation of Madagascar (Ketchum and Barrett, 2004). The stratigraphic range of the taxon is updated accordingly. Note, however, that these specimens are quite fragmentary and their provenance is uncertain (Maganuco et al., 2009, p. 48; see also discussion in Ketchum and Barrett, 2004).

The stratigraphic range of *Saurosternon bainii* is updated according to Viglietti et al. (2016, fig. 2; Supplement data: mmc1).

Dolerosaurus trauthi, a possible phytosaur, is excluded as it is regarded Diapsida *incertae sedis* (Butler, 2013). *Palacrodon browni* is also considered Diapsida *incertae sedis* (Gow, 1999; see also Kligman et al., 2018) and is therefore excluded.

Carroll and Thompson (1982) noted a few similarities between *Lacertulus bipes* and the ‘paliguanids’ *Paliguana*, *Saurosternon*, and *Palaeagama*. Indeed, Sennikov (2008, p. 263) includes *Lacertulus bipes* in Paliguanidae. Paliguanidae, however, does not represent a monophyletic taxon (Evans, 1988a, p. 241; Ezcurra et al., 2014) and while *Paliguana* is still recovered as a lepidosauromorph in recent phylogenetic analyses, both *Saurosternon* and *Palaeagama* are recovered as non-saurian neodiapsids (Bickelmann et al., 2009; Ezcurra et al., 2014). *Lacertulus* *bipes* is now considered to represent a non-squamate diapsid but further determination of its relationships is currently not possible due to the poor preservation status of the holotype (Ezcurra et al., 2014). Due to its uncertain phylogenetic relationships *Lacertulus bipes* is excluded from further analyses.

A.27.1 Araeoscelidia

Phylogeny: Araeoscelidia is added according to the single most parsimonious tree of Sobral et al. (2015, fig. 11), which is based on an extended character matrix of Ezcurra et al. (2014).

Spinoaequalis schultzei is placed according to the single most parsimonious tree of deBraga and Reisz (1995, fig. 6) as a member of Araeoscelidia.

The phylogenetic position of *Aphelosaurus lutevensis* is based on the cladogram of Evans (1988a, fig. 6.1).

Zarcasaurus tandyderus is an araeoscelid, that is more closely related to *Araeoscelis* than to *Petrolacosaurus* (Brinkman et al., 1984) and is thus placed as sister taxon to *Araeoscelis*.

Araeoscelis gracilis and *Araeoscelis casei* are assumed to be closely related and are therefore treated as sister taxa.

Alpha taxonomy: Falconnet and Steyer (2007), Gand et al. (2012) and Falconnet (2014) treat *Aphelosaurus lutevensis* as a valid taxon. It is therefore included in the database.

Olson (1970) erected the taxon *Dictybolos tener* and assigned it to Araeosceloidea. Evans (1988a) finds no support for the inclusion of the species in Araeoscelidia but does not provide an alternative assignment. Sander (2000, fig. 7.5A) treats the taxon (misspelled as *Dictyobolus*) as a captorhinomorph. Due to the uncertain relationships of *Dictybolos tener* it is excluded from further analyses.

Kadaliosaurus priscus, which is only known from fragments (Reisz et al., 1984; Werneburg and Schneider, 2006), is treated as a valid taxon by Werneburg and Schneider (2006), Schneider and Werneburg (2012), Spindler (2013) and Schoch (2014a, p. 90) but its phylogenetic position is uncertain (Reisz et al., 1984; Müller and Danto, 2012). It is therefore not further considered in the analyses.

A.27.2 Thalattosauria

Phylogeny: This branch of the supertree is based on the strict consensus tree of Li et al. (2016b, fig. 4), which relies on an expanded dataset of Liu et al. (2013a).

Neosinasaurus hoangi is a thalattosaurian according to Wu et al. (2009) and is thus added to a polytomy including Askeptosauroidea and Thalattosaroidea.

Alpha taxonomy: There have been different interpretations of the validity and potential synonymy of *Xinpusaurus kohi* and *Xinpusaurus bamaolinensis* (Rieppel and Jun, 2006; Liu, 2013a; Maisch, 2014b; Li et al., 2016b). Herein the interpretations of Maisch (2014b) and Li et al. (2016b) are followed, who consider *Xinpusaurus kohi* to be a valid species that is distinct from *Xinpusaurus bamaolinensis*. Maisch (2014b) and Li et al. (2016b) consider *Xinpusaurus bamaolinensis* a *species inquirenda* and this taxon is also retained in the database, awaiting further scrutiny of its holotype.

Anshunsaurus huangnihensis has been treated as a valid species by Cheng et al. (2011), Maisch (2015) and Li et al. (2016b). It is therefore included in the database.

New material of *Blezingeria ichthyospondyla* (initially described as by Fraas, 1896) is reported by Diedrich (2015) for the Upper Muschelkalk of Lamerden (Germany). The enigmatic taxon has previously been considered an ichthyosaur and was later considered to represent a thalattosaur McGowan and Motani (2003, p. 140). Diedrich (2015) considers it to be a nanchangosaur. The taxon is mainly based on vertebrae and a few referred additional postcranial bones and the determination of its affinities has been considered equivocal (Müller, 2005a; Schoch, 2015b). Therefore, *Blezingeria ichthyospondyla* is not included in the database.

A.27.3 Drepanosauromorpha

Phylogeny: The phylogenetic of Drepanosauromorpha/Drepanosauridae *sensu lato* (see Renesto et al., 2010, p. 51; Pritchard et al., 2016) in recent analyses is unstable (see also the discussion in Pritchard and Nesbitt, 2017, Appendix A). The single most parsimonious tree of Gottmann-Quesada and Sander (2009, fig. 28A) recovered the clade (represented by *Megalancosaurus*) as the sister taxon of *Protorosaurus*. An early diverging position among archosauromorphs was also found by, e.g., the 50% majority rule consensus supermatrix tree of Hone and Benton (2008b, fig. 4) and the most parsimonious tree of Renesto et al. (2010, fig. 42C). Sookias et al. (2012b) placed the clade again as the sister taxon of *Protorosaurus* when constructing their informal supertree of Archosauromorpha (see also Sookias et al., 2012b, Supplementary Methodology, Figures, Tables and References: fig. S1). The formal supertree of Brocklehurst et al. (2015, Supplementary information: Supplementary Data 4) also recovers the clade among early diverging archosauromorphs.

On the other hand, the 50% majority rule consensus tree of Evans (2009, fig. 24) recovers Drepanosauridae as sister taxon of the clade *Pamelina polonica* + Kuehneosauridae and thus nested within the Lepidosauromorpha (see also Evans and Borsuk-Białynicka, 2009, fig. 12B).

The single most-parsimonious tree of Senter (2004, fig. 1) indicates a closer relationship with the clade consisting of *Coelurosauravus* and *Longisquama*. A sister taxon relationship to Pterosauria (see Renesto and Binelli, 2006, fig. 9B; Renesto et al., 2010, fig. 40B) has also been proposed.

Recently, Pritchard et al. (2016, fig. 3) recovered Drepanosauromorpha in a polytomy with Sauria and the early diverging neodiapsids *Hovasaurus boulei*, *Thadeosaurus colcanapi* and *Claudiosaurus germaini*. The most recent analyses of drepanosauromorph relationships (Pritchard and Nesbitt, 2017, fig. 8; Pritchard et al., 2018, Supplementary Information: Supplementary fig. 14), which are based on a modified composite data matrix of Pritchard et al. (2016) and Nesbitt et al. (2015), recover them as an early diverging clade of non-saurian neodiapsids. These new results could explain previous contradicting topologies which found drepanosauromorphs nested among Archosauromorpha or Lepidosauromorpha. Drepanosauromorpha is herein added to a polytomy consisting of the neodiapsids *Lanthanolania ivakhnenkoi*, *Kenyasaurus mariakaniensis*, *Heleosuchus griesbachi*, and the clade consisting of later diverging neodiapsids, following the strict consensus tree of Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14).

Kyrgyzsaurus bukhanchenkoi is probably the earliest diverging representative of the clade (Alifanov and Kurochkin, 2011) and is added according to the phylogenetic hypothesis of Alifanov and Kurochkin (2011, fig. 2).

Vallesaurus zorzinensis (Renesto et al., 2010) is assumed to be the sister taxon of *Vallesaurus cenensis* and is added accordingly.

Alpha taxonomy: Simões et al. (2018, Supplementary Information: p. 26, 27) consider *Megalancosaurus endennae* a junior synonym of *Megalancosaurus preonensis*. The species is treated accordingly.

Protoavis texensis Chatterjee, 1991 is not included in this analysis, as its phylogenetic position remains controversial (e.g., Witmer, 2002; Nesbitt et al., 2007). There were suggestions that at least parts of the referred specimens belong to a *Megalancosaurus*-like animal and other parts to a non-tetanuran theropod (Renesto, 2000; Nesbitt et al., 2007).

A.27.4 Saurosphargidae

Phylogeny: The inner relationships of Saurosphargidae are based on the strict consensus tree of Li et al. (2014, fig. 7a), which uses a modified character matrix of Li et al. (2011a).

Hemilopas might be conspecific with *Saurosphargis* (Surmik, 2016), which is now considered a *nomen dubium* (Scheyer et al., 2017). *Hemilopas* is therefore added according to the proposed relationships in Surmik (2016, fig. 10), replacing the position of *Saurosphargis*.

Alpha taxonomy: *Hemilopas mentzeli* is a valid taxon (Surmik, 2016) and is therefore added to the database.

Saurosphargis volzi is considered a *nomen dubium* (Scheyer et al., 2017) and is therefore excluded from further analyses.

Surmik (2016) treats *Proneusticosaurus silesiacus* as a valid taxon, but the respective specimen probably belongs to *Cymatosaurus* sp. (Sues, 1987; Rieppel, 1997a; Rieppel and Hagdorn, 1997; Rieppel, 2000, p. 41) and this interpretation is also mentioned by Voeten et al. (2015), Sander et al. (2014) and Maisch (2014a). *Proneusticosaurus silesiacus* is therefore not added to the database. Note, however, that the proposed synonymy of *Proneusticosaurus* with *Cymatosaurus* is largely based on stratigraphic reasons (Maisch, 2014a).

A.28 Lepidosauromorpha

Phylogeny: This branch of the supertree is mainly based on the aforementioned trees for early diverging diapsids and a few additional trees for lepidosauromorph clades (see below).

Longisquama insignis is the sister taxon of *Coelurosauravus elivensis* in the sole cladogram of Renesto and Binelli (2006, fig. 9B), which is based on an updated character set of Senter (2004) (see also Renesto et al., 2010, fig. 39, 40). *Longisquama insignis* is not considered a weigeltisaurid/coelurosauravid (Renesto and Binelli, 2006, p. 88; Bulanov and Sennikov, 2015a; Pritchard and Nesbitt, 2017, fig. 5; see also Bulanov and Sennikov, 2010). *Longisquama insignis* is therefore added according to the sole cladogram of Renesto and Binelli (2006, fig. 9B) as the sister taxon of Weigeltisauridae.

The strict consensus tree of Schoch and Sues (2018a, fig. 8B), which is based on a modified and expanded character matrix of Ezcurra et al. (2014), is used to add the taxon *Paliguana whitei*, in accordance with previous analyses (Evans and Borsuk-Białynicka, 2009, fig. 12A; Jones et al., 2013, fig. 3; see also Schoch and Sues, 2018a, fig. 8A, C). Note, that Sobral et al. (2015, fig. 11) recover *Paliguana whitei* as sister taxon to all other squamates. Such a placement was not found in other recent analyses (e.g., Evans and Borsuk-Białynicka, 2009, fig. 12A; Jones et al., 2013, fig. 3; Ezcurra et al., 2014, fig. 1; Schoch and Sues, 2018a, fig. 8A-C) and is therefore not further considered herein. The strict consensus tree of Schoch and Sues (2018a, fig. 8B) is also used to add the taxon *Fraxinisaura rozynekae*.

Cargninia enigmatica is a lepidosaur according to Bonaparte et al. (2010) and is added accordingly to a polytomy including Rhynchocephalia and Squamata.

Alpha taxonomy: Benton (2011, p. 25) mentions “*Coartaredens isaaci* and other unidentified small reptiles”. Spencer and Storrs (2002) considered it to be a lepidosauromorph, but Evans and Jones (2010) refer it to Procolophonia. The differing opinions exemplify the uncertainty surrounding this taxon and thus it is excluded from the database.

A.28.1 Weigeltisauridae

Phylogeny: The clade *Rautiania alexandri* + *Weigeltisaurus jaekeli* is added as the sister taxon of *Coelurosauravus elivensis* following the strict consensus tree of Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14), which has also been used to add Drepanosauromorpha (see subsection A.27.3). Note, however, that Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14) do not recover Weigeltisauridae as lepidosauromophs, different from previous analyses (e.g., Sobral et al., 2015, fig. 10; Motani et al., 2015a, fig. 4b; Scheyer et al., 2017, fig. S6)

Rautiania minichi is assumed to be closely related to *Rautiania alexandri* and is added as its sister taxa.

The holotype of *Glaurung schneideri* has previously been referred to *Coelurosauravus* sp. (Schaumberg et al., 2007; Bulanov and Sennikov, 2015a). Schaumberg et al. (2007) treated *Coelurosauravus jaekeli* (= herein *Weigeltisaurus jaekeli*) as a valid taxon. *Glaurung schneideri* is therefore added to a polytomy consisting of *Coelurosauravus elivensis* and the clade *Weigeltisaurus jaekeli* + *Rautiania*. *Wapitisaurus problematicus* is a weigeltisaurid (Brinkman, 1988) like *Weigeltisaurus jaekeli* and is therefore added to this polytomy.

Alpha taxonomy: Evans and Haubold (1987) considered *Weigeltisaurus jaekeli* to be congeneric with *Coelurosauravus*. Bulanov and Sennikov (2010) and Bulanov and Sennikov (2015b) questioned this assignment and considered the genus *Weigeltisaurus* a valid taxon. Simões et al. (2018, Supplementary Information: p. 23) follow the assignment of Evans and Haubold (1987), but the topology of Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14) suggests that *Weigeltisaurus jaekeli* does not belong to the genus *Coelurosauravus*. Therefore, *Weigeltisaurus* is retained in the database as a separate genus.

A.28.2 Kuehneosauridae

Phylogeny: *Pamelina polonica* represents the sister taxon of the clade consisting of all other members of Kuehneosauridae (Evans, 2009). These other kuehneosaurid taxa are *Kuehneosaurus latus*, *Kuehneosuchus latissimus*, and *Icarosaurus siefkeri*.

Icarosaurus siefkeri is added as the sister taxon of *Kuehneosaurus latus* according to the strict consensus tree of Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14), which has also been used to add Drepanosauromorpha (see subsection A.27.3). Note, however, that Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14) do not recover Kuehneosauridae as lepidosauromophs, different from previous analyses (e.g., Sobral et al., 2015, fig. 10; Motani et al., 2015a, fig. 4b; Schoch and Sues, 2015, fig. 4; Scheyer et al., 2017, fig. S6).

Kuehneosuchus latissimus and *Kuehneosaurus latus* are assumed to be sister taxa, as they were initially described as congeneric and recently it was speculated that they possibly represent the male and female morph of the same species (Stein et al., 2008). Note, that Sues and Fraser (2010, p. 118, 119) do not consider *Kuehneosaurus latus*, *Kuehneosuchus latissimus*, and *Icarosaurus siefkeri* to be distinct enough to warrant generic separation.

A.28.3 Rhynchocephalia

Phylogeny: The phylogeny of Rhynchocephalia is based on the 50% majority rule consensus tree of Herrera-Flores et al. (2018, fig. 3: 1), which is based on an expanded and revised character matrix of Hsiou et al. (2015).

The polytomy consisting of *Rebbanasaurus*, *Pelecymala robustus*, *Godavarisaurus* + *Sphenocondor gracilis*, and the crown-sphenodontians *sensu* Apesteguía and Carballido (2014) is partially resolved using the reduced strict consensus tree of Apesteguía and Carballido (2014, fig. 7).

Whitakersaurus bermani is added according to the 50% majority rule consensus tree of Jones et al. (2013, fig. 3).

Th resolution within the genus *Clevosaurus* is increased using the tree of Hsiou et al. (2015, fig. 5B), which was obtained applying the iterPCR protocol. Unstable taxa are added according to their earliest diverging position within the tree. The data matrix of Hsiou et al. (2015, fig. 5B) is based on an expanded version of the one used by Apesteguía et al. (2014).

Bharatagama rebbanensis has long been considered the earliest diverging squamate (Benton et al., 2015; Evans et al., 2002) but this hypothesis has only recently been tested using a formal phylogenetic analysis (Conrad, 2018). Conrad (2018) recovers the taxon as a rhynchocephalian and sister taxon of *Pleurosaurus*. *Bharatagama rebbanensis* is added accordingly.

The two species of *Gephyrosaurus* are assumed to closely related and *Gephyrosaurus evansae* is therefore added as the sister taxon of *Gephyrosaurus bridensis*. *Penegephyrosaurus*, another member of Gephyrosauridae, is added as the sister taxon of the resulting clade, following the relationships proposed in Whiteside and Duffin (2017, fig. 9).

Deltadectes elvetica is a gephyrosaurid (Whiteside et al., 2017) and is therefore added to a polytomy including *Penegephyrosaurus* and *Gephyrosaurus*.

Langobardisaurus rossii was initially considered a protorosaur but later on shown to be a lepidosauromorph (Renesto and Dalla Vecchia, 2007). It is probably a rhynchocephalian (Renesto and Dalla Vecchia, 2007; Saller et al., 2013) and thus placed as an early diverging member of Rhynchocephalia.

Sigmala sigmala is a sphenodontian that has never been included in a phylogenetic analysis and which has tentatively been regarded as most similar to *Sphenodon* and *Opisthias* (Fraser, 1986). *Sigmala sigmala* is probably an early diverging member of Opisthodontia (J. A. Herrera-Flores, pers. comm., 2018) and is added accordingly to the supertree.

Paleollanosaurus fraseri is a sphenodontian that is similar to *Diphydontosaurus* and *Planocephalosaurus* (Heckert, 2004, p. 50–52) and is therefore added to the polytomy including *Diphydontosaurus* and other early diverging sphenodontians.

Planocephalosaurus lucasi is assumed to be closely related to *Planocephalosaurus robinsonae* and is therefore added as its sister taxon.

Clevosaurus minor is very similar to *Clevosaurus hudsoni* (Fraser, 1988), the main differences being size and their occurrences at different localities (Säilä, 2005). *Clevosaurus minor* might be the sister taxon of *Clevosaurus hudsoni* (J. A. Herrera-Flores, pers. comm., 2017) and it is added accordingly.

The tooth morphology of *Clevosaurus cambricus* (= *C. cambrica*) resembles that of *Clevosaurus hudsoni*, *Clevosaurus sectumsemper*, and *Clevosaurus convallis* (Keeble et al., 2018). The taxon is therefore added to a polytomy consisting of *Clevosaurus sectumsemper*, the clade *Clevosaurus minor* + *Clevosaurus hudsoni*, and the clade consisting of later diverging species of *Clevosaurus*.

Alpha taxonomy: *Gephyrosaurus* has been described from the Pant 4 fissure of South Wales (Gill et al., 2006; Whiteside et al., 2016). This material is usually assumed to represent *Gephyrosaurus bridensis*, but note, that the assignment at species level is not completely certain (P. G. Gill, pers. comm., 2018). Herein, the material is assumed to represent *Gephyrosaurus bridensis* and the stratigraphic range of the taxon is treated accordingly.

So far, *Langobardisaurus rossii* has not been referred to a new genus (Saller et al., 2013) and thus the genus name is retained for the species in the database (see subsection A.32.1).

The taxa *Paleollanosaurus fraseri* and *Planocephalosaurus lucasi*, described by Heckert (2004), are mentioned by Apesteguía et al. (2012) and Whiteside and Duffin (2017). Whiteside et al. (2017) report a new specimen of *Paleollanosaurus* sp. from Switzerland and implicitly also mention *Planocephalosaurus lucasi* (Whiteside et al., 2017, p. 66). The two taxa are therefore added to the database. Note, however, that both *Paleollanosaurus fraseri* and *Planocephalosaurus lucasi* are based on very fragmentary specimens (Heckert et al., 2008).

The age of *Sphenocondor gracilis* was initially reported to be probably Middle Jurassic (Apesteguía et al., 2012). New geochronologic results show that the lower part of the Cañadón Asfalto Formation (Chubut Province, Argentina), in which the species was found, can be assigned a middle to upper Toarcian age (Cúneo et al., 2013; but see Hauser et al., 2017). The taxon is thus included in the database.

Jones (2006) considered the Chinese taxa *Clevosaurus petilus* (including "*Clevosaurus wangi*") and *Clevosaurus mcgilli nomina dubia* and referred them to *Clevosaurus*. The cladistic analysis of Hsiou et al. (2015) suggests that *Clevosaurus petilus*, *Clevosaurus wangi*, and *Clevosaurus mcgilli* might represent valid taxa. The species are therefore retained in the database.

Jones (2006) also suspected the poorly known taxon *Clevosaurus latidens* not to belong to the genus *Clevosaurus*. This taxon has been included in recent phylogenetic analyses (Martínez et al., 2013; Hsiou et al., 2015) and thus is herein regarded a valid taxon. The phylogenetic analyses confirm the suspicion of Jones (2006) as *Clevosaurus latidens* is not recovered among the other *Clevosaurus* species but among the Opisthodontia. Thus it probably represents a different genus.

The specimen SAM K7890 could not be assigned to a species but only to the genus *Clevosaurus* sp. (Sues and Reisz, 1995). It is, however, included in the phylogenetic analysis of Hsiou et al. (2015, fig. 5B) and is retained in the database due to its palaeobiogeographic importance.

Other specimens reported as *aff. Clevosaurus* (Reynoso and Cruz, 2014) are not included. Similarly, the specimen MCSNB 4862 assigned to *Diphydontosaurus* sp. (Renesto, 1995) is also excluded. This also applies to the specimen described by Duffin (1995) as *cf. Diphydontosaurus* sp. Material considered to represent Lower Jurassic *aff. Opisthias* (Reynoso and Cruz, 2014) is not included.

The assignment of *Scharschengia enigmatica* to Rhynchocephalia is uncertain (Fraser, 1988). The taxon has been considered “problematic” (Shishkin and Novikov, 2017, p. 615) and its status within Diapsida is unclear (Benton et al., 2015). The taxon is therefore excluded from further analyses.

A.28.4 Squamata

Phylogeny: *Megachirella wachtleri* is added as the earliest diverging member of Squamata following the majority rule consensus tree of the Bayesian inference analysis of Simões et al. (2018, fig. 2). *Tamaulipasaurus morenoi* is placed as sister taxon to Squamata following the strict consensus tree of Reynoso (1996, p. 240).

Alpha taxonomy: *Tikiguania estesi* was considered the oldest record of Squamata (Datta and Ray, 2006) but Hutchinson et al. (2012) have shown that the specimen probably represents a Quarternary or Late Tertiary agamid, that was incorporated into the Triassic Tiki Formation due to erosion and/or fissuring. Therefore this taxon is not included in the database.

A.29 Sauropterygia

Phylogeny: The scaffold tree for Sauropterygia is provided by the strict consensus tree of Liu et al. (2015b, fig. 5), focusing on the ingroup relationships of Eusauropterygia. The character matrix of Liu et al. (2015b) is based on an updated dataset of Ma et al. (2015).

Wumengosaurus delicatomandibularis is excluded from Eosauropterygia (contra Ma et al., 2015, fig. 4; Neenan et al., 2015, fig. 7), as it is probably the sister taxon of the clade consisting of Hupehsuchia and Ichthyosauriformes (= Ichthyosauromorpha; Chen et al., 2014; Motani et al., 2015a, fig. 4a; Extended Data fig. 1; see also section A.27).

Atopodentatus unicus is added according to the strict consensus tree of Cheng et al. (2014, Supplement: fig. S5) in a polytomy with Eusauropterygia and Placodontiformes.

Odoiporosaurus teruzzi, *Neusticosaurus peyeri*, and *Neusticosaurus edwardsii* are added according to the best tree of Renesto et al. (2014, fig. 9C).

Neusticosaurus toeplitschi is added as sister taxon of *Neusticosaurus edwardsii*, following the single most parsimonious tree of Rieppel and Kebang (1995, fig. 24).

Dianmeisaurus gracilis and *Dawazisaurus brevis* are added according to the strict consensus tree of Shang et al. (2017, fig. 7), which is based on an updated character matrix of Shang and Li (2015). Note, however, that the clade of Chinese pachypleurosaur-like taxa found by Shang et al. (2017, fig. 7) is recovered as a grade in the analyses of Liu et al. (2015b, fig. 5) and Ma et al. (2015, fig. 4) and is therefore also treated as a grade on the scaffold tree.

Neusticosaurus staubi is assumed to be the sister taxon of the other species of the genus and is placed accordingly in a polytomy with *N. pusillus* and the clade consisting of *N. peyeri* and *N. edwardsii* + *N. toeplitschi*.

Anarosaurus heterodontus is assumed to be the sister taxon of *Anarosaurus pumilio* (see also Klein and Albers, 2009). *Keichousaurus yuananensis* is assumed to be the sister taxon of *Keichousaurus hui*. The taxa are added accordingly.

Alpha taxonomy: Rieppel and Kebang (1995) and Rieppel (2000, p. 55, 56) assign *Psilotrachelosaurus toeplitschi* to the genus *Neusticosaurus* and the taxon is treated as such by Klein (2012), Motani et al. (2015b, Supplementary Information: Supplementary Table S2), and Jiang et al. (2016, Supplementary Information: Supplementary Table S3). The taxon is treated accordingly.

Horaffia kugleri is only represented by five humeri and interpreted as a marine diapsid (Klein and Hagdorn, 2014). An assignment to a certain group within Diapsida is not possible (Klein and Hagdorn, 2014) and the taxon is thus excluded from further analysis.

Serpianosaurus germanicus, erected by Diedrich (2013), is not included, as it is based on fragmentary remains, which are probably not diagnostic (Renesto et al., 2014). Diedrich (2013) also mentioned *Serpianosaurus zinae*, which is not included, as it is a *nomen nudum* (Renesto et al., 2014).

A.29.1 Placodontiformes

Phylogeny: The ingroup relationships of Placodontiformes are based on the strict consensus tree of de Miguel Chaves et al. (2018a, fig. 2), which is based on the second (modified and expanded) character matrix of Neenan et al. (2015).

Pararcus diepenbroeki is added according to the strict consensus tree of Neenan et al. (2015, fig. 7) as sister taxon to the genus *Placodus*.

The phylogenetic position of *Psephosauriscus* within Cyamodontoidea is unclear (Rieppel, 2002). It is therefore added as an early diverging member of Cyamodontoidea. The three species of *Psephosauriscus* are assumed to be sister taxa and are placed accordingly.

Cyamodus muensteri was included in some of the phylogenetic analyses of Rieppel (2001), but the respective trees were not shown. It was, however, reported (Rieppel, 2001, p. 70, 71), that an inclusion of the taxon led to an unresolved polytomy consisting of the analysed three species of *Cyamodus* (*C. rostratus*, *C. kuhnschnyderi*, *C. muensteri*). *Cyamodus muensteri* is placed accordingly and *Cyamodus tarnowitzensis* is added to this polytomy, assuming a sister taxon relationship with the other species of *Cyamodus*.

Psephosaurus suevicus is a cyamodontoid placodont (Rieppel, 2002) and is difficult to distinguish from *Psephoderma* (Rieppel and Hagdorn, 1998). Thus it is placed as sister taxon to the genus *Psephoderma*.

Psephoderma sculptata is assumed to be closely related to *Psephoderma alpinum* and is therefore added as its sister taxon.

Alpha taxonomy: *Psephosauriscus* was included in the palaeobiogeographic analysis of Bardet et al. (2014) and thus the three species *Psephosauriscus mosis*, *Psephosauriscus ramonensis*, and *Psephosauriscus sinaiticus* are also included in this database (Rieppel, 2002). It should be noted, however, that *Psephosauriscus* is only represented by dermal armor fragments (Rieppel, 2002).

Rieppel (2000, p. 38) and Rieppel (2002, p. 14) mention *Psephoderma anglicum* as a junior synonym of *Psephoderma alpinum* and Nordén et al. (2015) accept this synonymy. According to Nordén et al. (2015) all British placodont material should be assigned to the single species *Psephoderma alpinum*. Thus *Psephoderma anglicum* is included within *Psephoderma alpinum* in the database. Rieppel (2002) erected the new taxon *Psephoderma sculptata* based on fragmentary remains. The taxon is also used for comparative purposes by de Miguel Chaves et al. (2015) and is thus included in the database.

The cranial and postcranial remains from Germany (Lower and Upper Muschelkalk), Poland (Upper Muschelkalk), Romania (lowermost Anisian of Romanian Southern Carpathian Mountains), and the Netherlands (Lower Muschelkalk of Winterswijk), assigned to *Paraplacodus cf. broilii* by Diedrich and Gradinaru (2013) are not included due to their fragmentary nature (see also Sander et al., 2014 for the specimens from the Netherlands).

Smilarly, the vertebrate remains from the Triassic (Ladinian) Villány locality of Hungary assigned to *cf. Cyamodus* sp. (Ősi et al., 2013; Makádi et al., 2014) are also not included due to their fragmentary nature.

A.29.2 Nothosauroidea

Phylogeny: The taxa *Chinchenia sungi*, *Kwangsisaurus orientalis*, and *Sanchiaosaurus dengi* are added according to the 50% majority rule consensus tree of Sato et al. (2014a, fig. 10B). *Chinchenia sungi* and *Kwangsisaurus orientalis* form a clade that acts as sister taxon of *Corosaurus alcoveensis* and *Sanchiaosaurus dengi* is the sister taxon of the genus *Cymatosaurus*. It should be noted, however, that the strict consensus tree of Sato et al. (2014b, fig. 4a) reports *Chinchenia sungi*, *Kwangsisaurus orientalis*, and *Sanchiaosaurus dengi* as sister clade to *Diandongosaurus acutidentatus* and thus the clade would form a polytomy with this taxon and *Majiashanosaurus discocoracoidis*.

The ingroup relationships of the genus *Cymatosaurus* are resolved according to the single most parsimonious tree of Maisch (2014a, fig. 5).

Paludidraco multidentatus is added according to the strict consensus tree of de Miguel Chaves et al. (2018b, fig. 1b), which is based on a modified and expanded character matrix of Cheng et al. (2016).

The Nothosauria branch of Sauropterygia is expanded with the strict consensus tree of Lin et al. (2017, fig. 5B), which is based on a revised data matrix of Liu et al. (2014a). *Hispaniasaurus cranioelongatus* is added according to the cladogram of Marquez-Aliaga et al. (2019, fig. 6), which is based on a modified character matrix of Neenan et al. (2013). *Lariosaurus vosseveldensis* is added according to the strict consensus tree of Klein et al. (2016b, fig. 4), which is based on an updated data matrix of Liu et al. (2014a). *Lariosaurus stensioei* is added as sister taxon of *Lariosaurus buzzii* following the strict consensus tree of Rieppel et al. (1999, fig. 42A). This creates a polytomy consisting of *Lariosaurus buzzii*, *Lariosaurus stensioei* and *Lariosaurus winkelhorsti*.

Ceresiosaurus lanzi is added as the sister taxon of *Lariosaurus calcagnii* according to the strict consensus tree of Hänni (2004, fig. 68).

Sennikov (2001) and Sennikov (2015) assigned *Tanaisosaurus kalandadzei* to Cymatosauridae and it is thus placed as an early diverging member of Cymatosauridae (Cymatosauridae *sensu* Rieppel, 2000 is a monophyletic taxon that includes the genera *Corosaurus* and *Cymatosaurus*).

Cymatosaurus multidentatus is assumed to be the sister taxon of the other species of the genus *Cymatosaurus* and is placed accordingly in a polytomy with *Cymatosaurus gracilis* and the clade consisting of the other species of *Cymatosaurus*.

Nothosaurus cymatosauroides is assumed to be a sister taxon of the other species of the genus *Nothosaurus*, which has been shown to be paraphyletic (Liu et al., 2014a), and is therefore placed as an early diverging member of Nothosauria in a polytomy. It should be noted, however, that Klein et al. (2015) do not mention *Nothosaurus cymatosauroides* among the valid taxa of the genus *Nothosaurus*.

Alpha taxonomy: Based on specimen BGR 9218 the species *Cymatosaurus gracilis* was resurrected by Maisch (2014a) and is thus included in this study.

Tanaisosaurus kalandadzei is based on very fragmentary remains (Sennikov, 2001). However, it is still mentioned in recent literature (Sennikov, 2011, 2015) and it is retained here as a valid taxon.

According to Yin et al. (2014) *Nothosaurus rostellatus* is a junior synonym of *Nothosaurus yangjuanensis*. Albers (2011) considers *Nothosaurus winterswijkensis* a junior synonym of *Nothosaurus marchicus*. Both taxa are treated accordingly. Note, however, that Klein et al. (2015) mention *Nothosaurus rostellatus* as a separate species.

According to Rieppel and Wild (1996) *Opeosaurus suevicus* is synonymous with *Nothosaurus aduncidens*, which is itself a junior synonym of *Nothosaurus giganteus*. *Paranothosaurus amsleri* is also synonymous with *Nothosaurus giganteus* (Rieppel and Wild, 1996). Both *Opeosaurus* and *Paranothosaurus* are synonymous with the genus *Nothosaurus* (Rieppel and Wild, 1996). The taxa are treated accordingly. Due to their stratigraphic and palaeobiogeographic importance the specimens from Fusea (northeastern Italy) described as *Nothosaurus cf. giganteus* (Rieppel and Dalla Vecchia, 2001; Dalla Vecchia and Avanzini, 2002) are retained in the database for *Nothosaurus giganteus*.

Instead of the misspelled species name "*Nothosaurus tchernovi*" (Rieppel et al. (1999, p. 27), Rieppel (2000, p. 85); as Rieppel (1999) and Rieppel et al. (2000) clearly did not intend to erect a new species, the name must be misspelled), *Nothosaurus tchernowi* is retained with the original spelling of Haas (1980).

Liu et al. (2014a) claim that all currently recognized species of Nothosauria are included in their data matrix, except for the taxa *Micronothosaurus stensioei* (misspelled as "*Micronothosaurus stensioi*"; Liu et al., 2014a), *Nothosaurus cymatosauroides*, and *Ceresiosaurus lanzi*. Thus, all these taxa are included in the database.

Micronothosaurus stensioei has been assigned to the genus *Lariosaurus* (Rieppel et al., 1999) and *Lariosaurus stensioei* is treated as a valid taxon by Klein et al. (2016b) and Lin et al. (2017). The species is treated accordingly.

Ceresiosaurus is considered a synonym of *Lariosaurus* (Rieppel, 1998), but *Ceresiosaurus lanzi* is still (implicitly) treated as a valid taxon by Liu et al. (2014a) and Klein et al. (2016a). It is treated accordingly in the database.

Nothosaurus juvenilis, *Nothosaurus youngi*, and *Nothosaurus winkelhorsti* have been reassigned to the genus *Lariosaurus* (Lin et al., 2017) and are treated accordingly.

Fragments found near Berlin in the upper Buntsandstein described as *Cymatosaurus* sp. (formerly known as *Cymatosaurus erythreus*; see Rieppel, 1997b) are not included. The postcranial remains from the Lower Muschelkalk (early Anisian) of Winterswijk assigned to *cf. Cymatosaurus* or a closely related taxon (Sander et al., 2014) are also not included as *Cymatosaurus* is not known from any postcranial remains. Thus the assignment, although being likely, is not completely certain.

Germanosaurus latissimus was considered a *nomen dubium* (Rieppel, 1997b, 2000) due to the loss of the holotype and only known specimen and is thus not included.

Nothosaurus remains are mentioned for the Sadowa Góra quarry from the Middle Triassic (Upper Gogolin Formation) of Poland (Surmik et al., 2014), but they are not assigned to any species and thus not included.

The vertebrate remains from the Triassic (Ladinian) Villány locality of Hungary assigned to *Nothosaurus* sp. (Ősi et al., 2013; Makádi et al., 2014) are not included due to their fragmentary nature.

Klein et al. (2016b, p. e1163712-7) consider the assignment of *Lariosaurus teutonicus* (Diedrich, 2014) as "speculative" and note a few mistakes in Diedrich (2014) regarding the stratigraphic range of the taxon. This taxon is herein excluded from further analyses.

Rieppel and Werneburg (1998) considered *Lariosaurus lavizzarii*, which is based on a juvenile specimen, a *nomen dubium*. Therefore it is not included in this analysis.

A.29.3 Plesiosauria

Phylogeny: Plesiosauria is added according to the strict consensus tree of Fischer et al. (2017, Supplemental Information: fig. S2), which is based on an expanded character matrix of Benson and Druckenmiller (2014) with modifications of Fischer et al. (2015).

The tree of Vincent et al. (2013, fig. 11) recovers *Cryonectes neustriacus* as an early diverging pliosaurid, that is less closely related to *Hauffiosaurus longirostris* and *Thalassiodracon hawkinsii* than to the clade consisting of *Pliosaurus brachyspondylus* and later diverging pliosaurids. Following Vincent et al. (2013, fig. 11), *Cryonectes neustriacus* is therefore added as the sister taxon of *Attenborosaurus conybeari*.

Arminisaurus schuberti is added as the sister taxon of *Cryonectes neustriacus* according to the strict consensus tree of Sachs and Kear (2018, fig. 8). *Rhaeticosaurus mertensi* is then added according to the strict consensus tree of Wintrich et al. (2017a, fig. 3A), creating a polytomy consisting of *Cryonectes neustriacus*, *Arminisaurus schuberti*, and *Rhaeticosaurus mertensi*.

The strict reduced consensus tree of Ketchum and Benson (2010, fig. 6) recovers *Plesiosaurus macrocephalus* (based on specimen NHMUK OR1336) as sister taxon of the clade consisting of *Attenborosaurus conybeari* and Neoplesiosauria. The strict consensus tree of Benson et al. (2011b, fig. 16), which is based on a modified matrix of Ketchum and Benson (2010), recovers *Plesiosaurus macrocephalus* as sister taxon to the genus *Hauffiosaurus*. The strict reduced consensus tree of Druckenmiller and Knutsen (2012, fig. 2), which is based on an expanded character matrix of Benson et al. (2011b), recovers *Plesiosaurus macrocephalus* as sister taxon to the clade Pliosauridae + Leptocleidida. In Druckenmiller and Knutsen (2012, fig. 2) a clade consisting of the genus *Hauffiosaurus* and the two species *Archaeonectrus rostratus* and *Macroplata tenuiceps* is found as sister taxon to the clade consisting of *Plesiosaurus macrocephalus* and Pliosauridae + Leptocleidida. *Plesiosaurus macrocephalus* is placed in a polytomy with the genus *Hauffiosaurus* and the clade consisting of *Attenborosaurus conybeari*, *Cryonectes neustriacus*, and *Arminisaurus schuberti*, following the analyses of Benson et al. (2011b) and Druckenmiller and Knutsen (2012). Considering the different relationships recovered for *Plesiosaurus macrocephalus* in recent phylogenetic analyses, this placement can only be deemed tentative.

Sthenarosaurus dawkinsi is added according to the strict consensus tree of Smith and Dyke (2008, fig. 3a).

Thaumatodracon wiedenrothi is added according to the (pruned) strict consensus tree of Smith and Araújo (2017, text-fig. 13A), which is based on an expanded character matrix of Benson and Druckenmiller (2014).

Microcleidus melusinae is added according to the strict consensus tree of Vincent et al. (2019), which is based on a modified and expanded character matrix of Benson et al. (2012, fig. 10).

Lusonectes sauvagei is added as sister taxon to the genus *Microcleidus* following the strict consensus tree of Smith et al. (2012a, fig. 4).

The Rhaetian material referred to Plesiosauria *incertae sedis* by Storrs (1994) had initially been assigned to various species of the genus *Plesiosaurus*, which was treated as a 'wastebasket' taxon at the time (Storrs, 1997). This material is not diagnostic at specific or generic level but probably belongs to a single genus (Storrs, 1994). It is therefore added as an early diverging member of Plesiosauria.

Thaumatosaurus aff. megacephalo (retained in the database as *Thaumatosaurus megacephalo*), described by Brandes (1914), is probably more closely related to *Meyerasaurus victor* than to *Atychodracon megacephalus* (Großmann, 2007) and might be even synonymous (however, a final identification was not made; see also Smith and Araújo, 2017). It is therefore placed as sister taxon to *Meyerasaurus victor*.

Microcleidus macropterus is reported to be very similar to *Microcleidus homalospondylus* (Watson, 1911), but its status is currently unclear (Sachs et al., 2016). *Microcleidus macropterus* is therefore added to a polytomy including *Microcleidus melusinae* and the clade consisting of all other species of the genus *Microcleidus*.

Alpha taxonomy: The type species of *Plesiosaurus dolichodeirus* is treated as a valid taxon by e.g., Storrs (1997), Großmann (2007), Ketchum and Benson (2010), Benson and Druckenmiller (2014), and Fischer et al. (2017). The taxon is therefore added to the database.

The Rhaetian material referred to Plesiosauria *incertae sedis* by Storrs (1994) is retained in the database (as *Plesiosaurus* sp.), due to its significance for the stratigraphic range of Plesiosauria.

Plesiosaurus macrocephalus is assumed to be represented by the type specimen NHMUK OR1336 (Ketchum and Benson, 2010, Appendix 2; see also Vincent and Benson, 2012). The specimen NHMUK 49202, which has previously been referred to this species, is now the type specimen of *Anningasaura lymense* (Vincent and Benson, 2012). The taxa are treated accordingly.

Smith (2015) erected the new genus *Atychodracon* for material previously assigned to *Plesiosaurus megacephalus* and *Rhomaleosaurus megacephalus*. *Rhomaleosaurus victor* is not referable to the genus *Rhomaleosaurus* according to Smith and Vincent (2010), who erected the taxon *Meyerasaurus victor* for the respective material. The taxa are treated accordingly.

Großmann (2007) considered *Plesiopterys wildi* to be a junior synonym of *Seeleyosaurus guilelmiimperatoris*, but Benson et al. (2012) coded the two taxa separately in their phylogeny of Lower Jurassic plesiosaurians (to test whether they are conspecific) and observed "numerous differences" between them according to Vincent and Benson (2012, p. 1051). It should be noted, however, that these differences were not mentioned explicitly in the text of Benson et al. (2012). Nevertheless, the two taxa are herein also considered to be separate, as is also done in the phylogeny of Benson and Druckenmiller (2014, fig. 2). Note, however, that Sachs et al. (2016) agree with Großmann (2007) in considering *Plesiopterys wildi* a junior synonym of *Seeleyosaurus guilelmiimperatoris*.

A few specimens that were previously assigned to *Thalassiosaurus hawkinski* have been assigned to *Stratesaurus taylori* by Benson et al. (2012). Furthermore, *Hydrorion brachypterygius* was recombined to *Microcleidus brachypterygius* by Benson et al. (2012). The taxa are treated accordingly.

Occitanosaurus tournemirensis (not '*O. tournemiensis*', a spelling mistake on p. 7 of Benson et al., 2012) is referred to *Microcleidus tournemirensis* by Benson et al. (2012) and is treated as such in this analysis.

Evans (2012) erected a new genus with two new species in his dissertation: *Raptocleidus blakei* and *Raptocleidus bondi*. So far, these taxa have not been included in a phylogeny that was published in a peer-reviewed journal (e.g., Benson et al., 2012; Benson and Druckenmiller, 2014). Thus, the two taxa are currently not further considered in this analysis.

'*Plesiosaurus*' *cliduchus* is probably a valid taxon (Benson et al., 2011a, 2012, 2015 contra Storrs and Taylor, 1996) but is not included in this analysis, awaiting a formal resurrection of the taxon or creation of a new genus.

The species *Pliosaurus macromerus* is excluded because it falls outside the observed timeframe (Kimmeridgian: e.g., Phillips, 1871, p. 354, Lydekker, 1889, p. 132, Knutsen, 2012; see also comment of Benson et al., 2013).

A.30 Ichthyosauromorpha

Phylogeny: The ichthyosauromorph part of the supertree (including Hupehsuchia) is based on the strict consensus tree of Jiang et al. (2016, Supplementary Information: Extended Data fig. 1b) (see also Jiang et al., 2016, fig. 4), which is mainly based on the data matrix of Ji et al. (2016) and augmented with the data matrix of Motani et al. (2015a). The resolution of this scaffold tree is slightly improved using the strict consensus trees of Ji et al. (2016, fig. 1, 2), whose characters are mainly based on Motani (1999) and Fischer et al. (2013) (see Ji et al., 2016, Supplementary Information. The strict consensus tree of Ji et al. (2016, fig. 1) is used to improve the resolution for the taxa *Parvinatator wapitiensis*, *Utatsusaurus hataii*, *Callawayia wolonggangensis*, and the clade Mixosauridae. The strict consensus tree of Ji et al. (2016, fig. 2) is used to improve the resolution of Cymbospondylidae.

The strict consensus tree of Motani et al. (2015a, fig. 4c) (see also Motani et al., 2015a, Extended Data fig. 3) is used to improve the resolution of the tree for the genus *Chaohusaurus*. The tree is based on an earlier version of the data matrix of Ji et al. (2016).

Note, however, that several ichthyosaurian clades might be less well supported than previously accepted (Moon, 2019).

Mikadocephalus gracilirostris is added according to the strict consensus tree of Fischer et al. (2013, Electronic Supplementary Material: fig. S10), which is based on an expanded data matrix of Caine and Benton (2011), which is itself based on that of Maisch and Matzke (2000). *Mikadocephalus gracilirostris* is also included in the analyses of Fischer et al. (2013, fig. 2a) and Fischer et al. (2016, fig. 1a), but as an outgroup. Therefore, these (more recent) analyses are not considered in the placement of the taxon. Fischer et al. (2013, Electronic Supplementary Material: fig. S10) is also used to add *Wimanius odontopalatus*, *Phantomosaurus neubigi*, and *Thaisaurus chonglakmanii*.

Quasianosteosaurus vikinghoegdai and *Pessopteryx nisseri* (the latter one represented by *Merriamosaurus hulkei*) are added according to the strict consensus tree of Maisch and Matzke (2003b, fig. 3), which is based on an expanded data matrix of Maisch and Matzke (2003a), which is itself based on Maisch and Matzke (2000). Note, however, that the codings for *Pessopteryx nisseri* are also based on “freely assigned” material (Maxwell and Kear, 2013, p. 89), which might not belong to the taxon.

Cymbospondylus petrinus is added according to the strict consensus tree of Ji et al. (2013, fig. 6), which is based on a modified data matrix of Motani (1999) with additions of Sander et al. (2011).

The holotype of *Isfjordosaurus minor* is very similar to *Utatsusaurus hataii* (Motani, 1999). It is therefore added as its sister taxon. Note, however, that McGowan and Motani (2003, p. 126) treat the taxon “tentatively” as *species inquirenda*. Similarly, Maxwell and Kear (2013) also consider the taxon a *species inquirenda*.

The systematic affinities of *Omphalosaurus* are uncertain. According to Motani (2000) it does not belong to Ichthyopterygia, while Sander and Faber (1998) and Sander and Faber (2003) argue for ichthyosaurian affinities. McGowan and Motani (2003, p. 139) follow the interpretation of Motani (2000) and regard the taxon as non-ichthyosaurian. This view is implicitly followed by Kelley et al. (2014). On the other hand, Maisch (2010, p. 159, 160), Botha-Brink and Smith (2011), Houssaye (2013), Fröbisch et al. (2013), Scheyer et al. (2014b, Table 1), and Diedrich (2015, Table 3) explicitly or implicitly treat the genus as a member of Ichthyosauria. This view is accepted herein and a polytomy within early diverging Ichthyosauria is created, consisting of Cymbospondylidae, Hueneosauria and *Omphalosaurus*. Better specimens of the genus and quantitative phylogenetic analyses are deemed necessary to resolve the conflicting interpretations.

Omphalosaurus wolfi was reassigned to *Omphalosaurus cf. O. nevadanus* by Sander and Faber (2003), but Maisch (2010) did not follow this interpretation and retained the species. Sander and Faber’s (2003) account shows the close relationship between the two species *O. wolfi* and *O. nevadanus* and they are therefore treated as sister taxa. All species of *Omphalosaurus* are assumed to be closely related and *Omphalosaurus nettarhynchus* is therefore added as the sister taxon of the clade *Omphalosaurus wolfi* + *Omphalosaurus nevadanus*.

The Russian *Cymbospondylus* sp. OTU (Storrs et al., 2000, p. 199; Sennikov, 2001) is assumed to be closely related to the other species of *Cymbospondylus* and is therefore placed in a polytomy consisting of *Cymbospondylus piscosus*, *Cymbospondylus petrinus*, and the clade *Cymbospondylus buchseri* + *Cymbospondylus nichollsi*.

According to Maisch (2010, p. 160) *Xinminosaurus* might be a junior synonym of *Tholodus*.

Tholodus schmidi is therefore added as the sister taxon of *Xinminosaurus catactes*.

The two species of *Toretocnemus* are assumed to be sister taxa and indeed they might be even conspecific (McGowan and Motani, 2003, p. 72).

Alpha taxonomy: Benjamin C. Moon kindly provided a list of currently valid (23rd July 2016) ichthyosauromorph taxa. This list has been used together with the available literature to make the reported alphataxonomical decisions.

Chaohusaurus chaoxianensis is a valid taxon according to Motani et al. (2015c) and is treated accordingly.

Due to its palaeobiogeographic and stratigraphic importance the specimen described as *Utatsusaurus* sp. by Cuthbertson et al. (2014) is retained in the database within the entry for *Utatsusaurus hataii*.

Massare and Callaway (1994) referred fragmentary specimens from the latest Early Triassic Thaynes Formation to *Cymbospondylus* sp. This would represent the oldest occurrence of the genus (Balini and C. Renesto, 2012). According to McGowan and Motani (2003, p. 66) this assignment is probably based on an undiagnostic character, but Maisch and Matzke (2000) and Fröbisch et al. (2006) retain the feature as diagnostic and this interpretation is also followed by Balini and C. Renesto (2012). Scheyer et al. (2014b) and Renesto and Dalla Vecchia (2018) (implicitly) follow the interpretation of McGowan and Motani (2003, p. 66). Here I follow the interpretation of McGowan and Motani (2003, p. 66) and do not include the specimens reported by Massare and Callaway (1994).

Due to its palaeobiogeographic and stratigraphic importance, the specimen reported as *Cymbospondylus* sp. from the Olomon Massif (Storrs et al., 2000, p. 199; Sennikov, 2001) is retained in the database as a separate entry.

Tholodus schmidi is also known from the Lower Muschelkalk of Poland (Sander and Mazin, 1993; McGowan and Motani, 2003, p. 69) and this occurrence is added to the database.

Xinminosaurus catactes is treated as a valid taxon by Benton et al. (2014b) and Ji et al. (2016). It is therefore included in the database.

Pessopteryx nisseri is a valid taxon that is restricted to the Vendomdalen Member ("Lower Saurian Niveau") of the Vikinghøgda Formation (Maxwell and Kear, 2013) and is treated accordingly. Maxwell and Kear (2013) implicitly accept that *Merriamosaurus hulkei* is a junior synonym of *Pessopteryx nisseri* as proposed by McGowan and Motani (2003, p. 136, 137). Maisch (2010) considers *Merriamosaurus hulkei* to be a subjective junior synonym of *Pessopteryx nisseri*. The taxon is treated accordingly.

Cymbospondylus nevadanus is considered a *species inquirenda* by McGowan and Motani (2003, p. 125) and Fröbisch et al. (2006). It is not part of the list of currently valid ichthyosauromorph taxa (B. C. Moon, pers. comm., 2016). The taxon is therefore excluded from the database.

Wintrich et al. (2017b) refer the holotype of *Omphalosaurus peyeri* to *Placodus cf. gigas*. *Omphalosaurus peyeri* is therefore excluded from further analyses.

Pessopteryx nisseri is based on ichthyosaurian and omphalosaurid material from Svalbard (Wiman, 1916; Motani, 1999). McGowan and Motani (2003, p. 139) mention *Omphalosaurus nisseri* for the omphalosaurid material, but also report that Sander and Faber (1998) considered the species *O. nisseri* a *nomen dubium*. Note that Maisch and Matzke (2000, p. 65–67) considered *Pessopteryx nisseri* an omphalosaur and erected the new taxon *Rotundopteryx hulkei* (later amended to *Merriamosaurus hulkei* by Maisch and Matzke, 2002) for the ichthyosaurian material of *Pessopteryx nisseri*. McGowan and Motani (2003, p. 136, 137), on the other hand, treated *Pessopteryx nisseri* as an ichthyosaurian and considered *Rotundopteryx hulkei* to be a junior synonym of it. Maisch (2010) finally erected *Omphalosaurus merriami* for the omphalosaurid material, following McGowan and Motani's (2003) suggestions in regarding *Pessopteryx nisseri* an ichthyosaurian. According to Maxwell and Kear (2013) the material assigned to *Omphalosaurus merriami* is not diagnostic at species level and is regarded a *nomen dubium*. It is therefore excluded from the database.

A.30.1 Mixosauria

Phylogeny: The Swiss *Phalarodon* sp. OTU (Brinkmann, 1997, 1998) is assumed to be a sister taxon of the other species of *Phalarodon* and is therefore added in a polytomy with *Phalarodon atavus* and the clade consisting of *Phalarodon fraasi* + *Phalarodon callawayi*.

Alpha taxonomy: Liu et al. (2013b) assigned all specimens listed by Schmitz et al. (2004) as *Mixosaurus nordenskioeldii* to *Phalarodon fraasi* and this interpretation is followed herein. Note, however, that the specimens known from the Sulphur Mountain Formation cannot be assigned confidently to any of its members (Nicholls et al., 1999; see also McGowan and Motani, 2003, p. 58; Kelley et al., 2014, Supplementary data). These specimens are therefore not used to modify the lower boundary of the stratigraphic range of the taxon (see also Kelley et al., 2014, Supplementary data; Motani et al., 2015b, Supplementary Information: Supplementary Table S2; Motani et al., 2017, Supporting Information: Table S1). Furthermore note, that the holotype of *Phalarodon fraasi* is probably known from the Fossil Hill Member of the Prida Formation, not the "lower member" (Nichols and Silberling, 1977) of the Prida Formation (McGowan and Motani, 2003, p. 58; see also Sander et al., 1994; Sander and Faber, 1998; Kelley et al., 2016).

Schmitz et al. (2004) also report several specimens of *Mixosaurus nordenskioeldii* for *Mixosaurus callawayi* (now *Phalarodon callawayi*; Maisch and Matzke, 2005) and the database is updated accordingly. Note again, that the specimens from the Sulphur Mountain Formation are not used to modify the lower boundary of the stratigraphic range of the taxon for the reasons reported above. Maxwell and Kear (2013) consider the Svalbard specimens reported by Schmitz et al. (2004) as *Phalarodon cf. fraasi* and *Phalarodon cf. callawayi* as valid. Due to their stratigraphic and palaeobiogegraphic importance, these specimens are retained in the database for *Phalarodon fraasi* and *Phalarodon callawayi*, respectively.

The specimen PIMUZ T1311 described as *Phalarodon* sp. for the Grenzbitumenzone of Switzerland (Brinkmann, 1997, 1998) is retained in the database due to its palaeobiogeographic importance. Brinkmann (1998, p. 170) refers to it both as *aff. Sangiorgiosaurus* (= *Mixosaurus kuhnschnyderi*; Brinkmann, 1998) and *Phalarodon* sp. Cleary et al. (2015a, Appendix 1: 1 Species info) treat it as a specimen of *Mixosaurus kuhnschnyderi*. Herein the specimen is retained in a separate entry as *Phalarodon* sp., following Brinkmann (1997) and Brinkmann (1998).

Contecto atavus is treated as *Mixosaurus atavus* by McGowan and Motani (2003, p. 67), but more recent studies report it as *Phalarodon atavus* (Jiang et al., 2006; Liu et al., 2013b; Ji et al., 2016). It is treated accordingly.

Mixosaurus natans is a *nomen dubium* (Liu et al., 2013b) and is treated accordingly.

Mixosaurus xindianensis is a *species inquirenda* (Liu et al., 2013b; Benton et al., 2014b) and is therefore not included in the database.

Mixosaurus nordenskioeldii is a *nomen dubium* (Schmitz, 2005; Hurum et al., 2014) and is therefore excluded from the database.

Mixosaurus major is a *nomen dubium* according to McGowan and Motani (2003, p. 135). The designation of a new lectotype by Maisch and Matzke (2001) who tried to re-establish the species as *Phalarodon major* is not valid according to McGowan and Motani (2003, p. 135). Indeed, both Liu et al. (2013b) and Ji et al. (2016) do not mention *Phalarodon major* among the valid species of *Phalarodon*. *Phalarodon major* is therefore excluded from the database.

A.30.2 Shastasauridae

Phylogeny: *Himalayasaurus tibetensis* is added according to the preferred of six most parsimonious trees of Dal Sasso and Pinna (1996, fig. 24) (see also Motani et al., 1999, fig. 1C), which is based on an expanded data matrix of Callaway (1989).

Alpha taxonomy: The '*Callawayia*' *wolonggangensis* (erected as *C. wolonggangense* by Chen et al., 2007) appears to be a valid species, but it does not belong to the genus *Callawayia* (Ji et al., 2016). Maisch (2010, p. 163, 164) assigned the taxon to the genus *Guizhouichthyosaurus*, but the phylogenetic analyses of Ji et al. (2016, fig. 2) do not support such an interpretation and indeed Ji et al. (2016) still refer to the taxon as '*Callawayia*' *wolonggangensis*. Another new genus designation has not been made so far and the taxon is recorded accordingly in the database.

Shastasaurus pacificus is the only valid species of *Shastasaurus* (Ji et al., 2016). *Shastasaurus osmonti* is a junior synonym of *Shastasaurus pacificus* (McGowan and Motani, 2003, p. 71). The taxon is treated accordingly. Therefore, *Guizhouichthyosaurus tangae* and *Guanlingsaurus liangae* are treated as not belonging to the genus *Shastasaurus* (see also Ji et al., 2013 and Ji et al., 2016).

The specimen described as *Shastasaurus cf. osmonti* (Orr, 1986) from the Martin Bridge Limestone of Oregon is retained within *Shastasaurus pacificus* due to its stratigraphic importance.

A specimen from the Wellenkalk (Lower Muschelkalk) of Bavaria reported by von Huene (1916, p. 42a) as *Shastasaurus* sp. has been considered Shastasauridae *incertae sedis* (Callaway, 1989, p. 11, 12). It is therefore excluded from the database. Note, that both Callaway (1989, p. 9, 10) and Diedrich (2012, p. 30) (see also von Huene, 1916, p. 38, 46) report *Shastasaurus* sp. for the Upper Muschelkalk of Germany. An assignment to a valid species of *Shastasaurus*, however, is not possible at the moment (Diedrich, 2012, p. 31) and these occurrence are therefore not further considered herein.

The specimens from the Antimonio Formation of Mexico referred to *Shastasaurus altispinus* (Callaway and Massare, 1989) have been reassigned to *Shonisaurus* sp. (Motani, 1999; McGowan and Motani, 2003, p. 52) and are therefore excluded from the database.

Callaway (1989, p. 9) reports fragmentary remains of ?*Shonisaurus* sp. from the Kössen Formation of Graubünden (Switzerland). These remains, however, have never been described or illustrated (Dalla Vecchia and Avanzini, 2002). A large vertebral centrum from the Kössen Formation of Vienna (Austria), with similarities to *Shonisaurus*, has preliminarily been described as *Leptopterygius* (?) sp. (Zapfe, 1976). Note, that *Leptopterygius* "has served as a catch-all genus for a wide variety of species that have little or nothing in common" (McGowan and Motani, 2003, p. 75). Another large vertebral centrum with affinities to *Shonisaurus* has recently been described for the lower Kössen Formation of Bavaria (Germany) and has been assigned to Ichthyosauria gen. et sp. indet. (Karl et al., 2014). As there is still no conclusive evidence for the appearance of *Shonisaurus* in the Kössen Formation (which would result in a major range extension of the genus) the respective occurrence is excluded from the database. The specimen described as *Shonisaurus aff. popularis* from the Dürrenstein Formation of Belluno (Italy; Dalla Vecchia and Avanzini, 2002) is also not included.

A.30.3 Parvipelvia

Phylogeny: The strict consensus tree of Ji et al. (2016, fig. 2) is also used to modify the topology of Parvipelvia, which agrees better with the trees of Motani et al. (2015a, Extended Data fig. 3), Fischer et al. (2016, fig. 1a), and Lomax (2017, fig. 8). Ji et al. (2016, fig. 2) therefore provides the topology for Parvipelvia and Jiang et al. (2016, Supplementary Information: Extended Data fig. 1b) is only used to improve the resolution of the resulting tree for *Hudsonelpidia brevirostris*, *Temnodontosaurus* + Leptonectidae, and *Suevoleviathan*.

Temnodontosaurus trigonodon, *Wahlisaurus massarae*, *Stenopterygius triscissus*, and *Stenopterygius uniter* are added according to the strict consensus tree of Lomax (2017, fig. 8), which is based on a modified data matrix of Maxwell et al. (2012).

The different species of *Ichthyosaurus* are added according to the single most parsimonious tree of Lomax and Massare (2017, fig. 8), which is based on a modified dataset of Massare and Lomax (2016).

Protoichthyosaurus prostaxalis and *Protoichthyosaurus applebyi* are added according to the strict consensus tree of Lomax et al. (2017, fig. 7), which is based on a modified character matrix of Fischer et al. (2013). *Protoichthyosaurus fortimanus* is assumed to be closely related to the other *Protoichthyosaurus* species and placed in a corresponding polytomy.

Dearcmhara shawcrossi is a basal (non-thunnosaurian) neoichthyosaurian that appears to be most similar to *Leptonectes* spp., *Temnodontosaurus trigonodon*, and *Temnodontosaurus azerguensis* (Brusatte et al., 2015b). The taxon is therefore added to a polytomy which also contains Leptonectidae and *Temnodontosaurus*.

According to Martin et al. (2012), the basicranium and postcranial anatomy of *Temnodontosaurus azerguensis* is most similar to *Temnodontosaurus trigonodon* and the two species are therefore treated as sister taxa. All species of *Temnodontosaurus* are assumed to be closely related. Therefore, a polytomy consisting of *Temnodontosaurus eurycephalus*, *Temnodontosaurus crassimanus*, *Temnodontosaurus acutirostris*, *Temnodontosaurus platyodon*, and the clade consisting of *Temnodontosaurus azerguensis* + *Temnodontosaurus trigonodon* is created.

Alpha taxonomy: *Temnodontosaurus burgundiae* is a junior synonym of *Temnodontosaurus trigonodon* (Maisch, 1998; McGowan and Motani, 2003, p. 85–87) and is indeed not mentioned among the referred species of *Temnodontosaurus* by Ji et al. (2016). It is treated accordingly.

Martin et al. (2012, fig. 6) report *Temnodontosaurus trigonodon* for the early and late Toarcian. The stratigraphic range is based on the information provided by Maisch and Matzke (2000) and McGowan and Motani (2003). Based on their personal observations of SMNS material Maisch and Matzke (2000, p. 72), indeed, report the species also from the Upper Toarcian of Aalen (Baden-Württemberg, Germany). No such material, however, appears to be in the collections of the SMNS (E. E. Maxwell, pers. comm., 2018). There is, however, a partial skull from the *Grammoceras thouarense* Zone of Bayreuth (Bavaria, Germany), that is consistent with *T. trigonodon* (E. E. Maxwell, pers. comm., 2018). The stratigraphic range of the taxon is updated accordingly.

Temnodontosaurus crassimanus is a valid taxon (McGowan and Motani, 2003, p. 87, 88; Maisch, 2010, p. 164; Ji et al., 2016) and is treated accordingly.

Temnodontosaurus acutirostris is provisionally recognized as a valid species by McGowan and Motani (2003, p. 88–90) and is also treated as a valid species by Vincent et al. (2014) and Ji et al. (2016) (but see Maisch, 2010, p. 165). Herein, *T. acutirostris* is treated as a valid species of the genus *Temnodontosaurus*.

Suevoleviathan disinteger is a junior synonym of *Suevoleviathan integer* (Maxwell, 2018) and is treated accordingly.

The following species of the genus *Stenopterygius* are considered to be valid (Maxwell, 2012; Dick and Maxwell, 2015; Ji et al., 2016): *Stenopterygius quadriscissus*, *Stenopterygius triscissus*, *Stenopterygius uniter*, *Stenopterygius aaleniensis*. The species are retained accordingly in the database. *Stenopterygius aaleniensis* is not included, as its first appearance is in the Middle Jurassic (Maxwell et al., 2012). *Stenopterygius* synonymy follows Maisch (2008).

Protoichthyosaurus fortimanus is a valid species (Lomax and Massare, 2018) and is therefore added to the database.

Ichthyosaurus communis is restricted to England (Massare and Lomax, 2018) and reports of the species from Switzerland (Maisch et al., 2008) and Belgium (Godefroit, 1996) are based on fragmentary specimens that do not allow a species assignment (Massare et al., 2015; Massare and Lomax, 2018). The species is treated accordingly.

Godefroit (1992) describes a specimen of *Leptonectes tenuirostris* from the Ethe Formation of Belgium, but Boulvain et al. (2000, Table 2) report it as *Leptonectes cf. tenuirostris* and, indeed, both McGowan and Motani (2003, p. 77) and Maisch and Reisdorf (2006) consider the specific assignment of the specimen doubtful. The respective occurrence is therefore not added to the database.

Stenopterygius hauffianus is a *nomen dubium* (Maisch, 2008) and is treated accordingly.

A.31 Pan-Testudines

Phylogeny: The 50% majority rule consensus tree of Szczygielski and Sulej (2016, fig. 11), based on an updated and modified data matrix of Gaffney et al. (2007) with modifications of Joyce et al. (2013), is used as the scaffold tree of Pan-Testudines.

Eunotosaurus africanus, *Pappochelys rosinae*, and *Eorhynchochelys sinensis* are added to the remaining Pan-Testudines according to the strict consensus tree of Li et al. (2018, Extended Data fig. 7), which is based on a modified data matrix of Schoch and Sues (2018b). This tree recovers Pan-Testudines in a large polytomy with sauropterygians, lepidosauromorphs, several archosauromorph taxa, and a few neodiapsid species (see also Schoch and Sues, 2018b; Schoch and Sues, 2015). Most analyses based on molecular data recover Testudines as the sister taxon of Archosauria (e.g., Shen et al., 2011, fig. 3; 4; Crawford et al., 2012, fig. 2a; Chiari et al., 2012, fig. 1; 3; Field et al., 2014, fig. 1; 2; Crawford et al., 2015, fig. 2). Such a topology (sometimes with Pan-Testudines + Sauropterygia as sister taxon to Archosauromorpha) has been recovered in a couple of the analyses of Lee (2013) and has been mentioned recently by Carroll (2013), Werneburg (2013) and Benton et al. (2015, p. 7). Bhullar and Bever (2009, fig. 2) also recover Pan-Testudines as sister taxon to Archosauromorpha, but also entertain the possibility of a Pan-Testudines + Archosauriformes clade. In their analyses of metabolic rates in archosaurs Legendre et al. (2016) also choose to treat Pan-Testudines as the sister taxon of Archosauromorpha (see also Legendre et al., 2016, fig. 2). Pan-Testudines is therefore added to a polytomy which also includes *Elachistosuchus huenei*, *Pachystropheus rhaeticus* (both of which might also be closely related to archosauromorphs; see Sobral et al., 2015, fig. 9) and Archosauromorpha.

Indochelys spatulata and *Condorchelys antiqua* are added according to the strict consensus tree of Pérez-García and Codrea (2018, fig. 7A), which is based on an expanded data matrix of Sterli et al. (2015).

Proganochelys tenertesta and *Proganochelys ruchae* are assumed to be sister taxa of *Proganochelys quenstedtii* and are added according to the phylogenetic hypothesis of Joyce (2017, fig. 3).

The unnamed turtle specimen from the Nishinakayama Formation in Japan appears to be similar to toxochelyid species (Hasegawa et al., 1998), which are part of the Eucryptodira (Joyce, 2007, p. 66). The taxon is therefore added according to the position of (Eu-)Cryptodira in the strict consensus tree of Pérez-García and Codrea (2018) (see also Perea et al., 2014, fig. 7A).

Alpha taxonomy: *Eunotosaurus africanus* is no longer considered a millerettid parareptile (Cisneros et al., 2008) but a stem turtle (Bever et al., 2015; Schoch and Sues, 2015; Joyce, 2015; Schoch and Sues, 2018b) and is treated accordingly in the database (but see MacDougall et al., 2016 and MacDougall et al., 2017).

Keuperotesta limendorsa is reassigned to the genus *Proterochersis* (Joyce, 2017) and the taxon is treated accordingly.

According to Szczygielski and Sulej (2016) the stratigraphic range of *Proterochersis robusta* is restricted to the lower Löwenstein Formation (Lower Stubensandstein) and the taxon is treated accordingly.

The specimen described as *cf. Proganochelys* from Antarctica (Jenkins et al., 1994) is retained in the database within *Proganochelys quenstedtii* due to its palaeobiogeographic importance. These remains are attributed to *Proganochelys* sp. by de la Fuente et al. (2014, p. 155).

Proganochelys ruchae is a valid species (Joyce, 2017) and is therefore added to the database.

Joyce (2017) reassigns *Chinlechelys tenertesta* to the genus *Proganochelys*. The taxon is treated accordingly.

Condorchelys antiqua is reported for the Queso Rallado locality (Chubut Province, Argentina) within the Cañadón Asfalto Formation (Sterli, 2008; Sterli and de La Fuente, 2010; Cerda et al., 2016). The specimens stem from the middle part of the lower section of the formation (Sterli and de La Fuente, 2010). This part of the formation is now assigned to the middle to late Toarcian (Cúneo et al., 2013; but see Hauser et al., 2017). The taxon is therefore included in the database.

Due to its stratigraphic and palaeobiogeographic importance, the unnamed turtle specimen from the Nishinakayama Formation in Japan (Hasegawa et al., 1998) is retained in the database as ‘unnamed_turtle’.

A.32 ‘Basal’ Archosauromorpha

Phylogeny: The strict consensus tree of Ezcurra et al. (2017, Supplementary Information: fig. 12, 13) is used as scaffold for Archosauromorpha. The character matrix of Ezcurra et al. (2017) is based on an expanded dataset of Ezcurra (2016) as modified by Nesbitt et al. (2017) and Stocker et al. (2017). The resolution of the archosauromorph scaffold tree is slightly improved for *Jesairosaurus lehmani*, Tanystropheidae and Allokotosauria using the strict reduced consensus tree of Ezcurra (2016, fig. 48). The relationships of *Prolacertoides jimusarensis* are modified according to the earliest diverging position in the first reduced strict consensus tree of Ezcurra (2016, fig. 60).

The taxon composition and inner relationships of Allokotosauria are modified according to the strict consensus tree of Sengupta et al. (2017, Supplementary Information: fig. S4), which is also based on an expanded dataset of Ezcurra (2016) as modified by Nesbitt et al. (2017). The same tree is also used to improve the resolution for *Noteosuchus colletti*.

The single most parsimonious tree of Nesbitt et al. (2015, fig. 72) is used to add *Langobardisaurus pandolfii* and *Tanytrachelos ahynis*. This analysis is based on an expanded and modified dataset of Pritchard et al. (2015).

Czatkowiella harae is added as the sister taxon of the clade *Adelosaurus* + *Protorosaurus* following the strict consensus tree of Borsuk-Białynicka and Evans (2009a, fig. 14A).

The single most parsimonious tree of Smith (2011, fig. 33) recovers the clade *Malerisaurus robinsonae* + *Marasuchus lilloensis* as sister taxon to *Jesairosaurus lehmani* (note, that the genus *Malerisaurus* is recovered as paraphyletic). Relatively recent phylogenetic analyses (e.g., Bittencourt et al., 2015, fig. 13; Butler et al. (2014a, Supporting data: Additional File 4); Ezcurra, 2016, fig. 50), however, all recover *Marasuchus lilloensis* among Dinosauriformes and thus in a much later diverging position. On the other hand, the strict consensus tree of the first analysis of Li et al. (2004, Supporting Online Material) recovers *Malerisaurus robinsonae* as sister taxon to *Tanystropheus meridensis* (which is a synonym of *Tanystropheus longobardicus*; Nosotti, 2007; Fraser and Rieppel, 2006). Indeed, the single most parsimonious tree of Smith (2011, fig. 34) recovers *Malerisaurus robinsonae* as sister taxon to a clade consisting of other tanystropheid taxa. In agreement with these older analyses, that find *Malerisaurus robinsonae* in an early diverging position, the taxon is added in a polytomy with *Jesairosaurus lehmani* and *Prolacertoides jimusarensis*, following the single most parsimonious tree of Smith (2011, fig. 33).

Cosesaurus aviceps is added according to the single most parsimonious tree of Smith (2011, fig. 33), which agrees relatively well with the placement of the taxon in the 50% majority rule consensus supermatrix tree of Hone and Benton (2008b, fig. 4).

Malutinisuchus gratus is added as an early diverging member of Archosauromorpha following the strict consensus tree of Jalil (1997, fig. 21), which recovered the taxon in a large polytomy among Prolacertiformes.

Sharovipteryx mirabilis was included in the phylogenetic analyses of Peters (2000). The methodological issues of these analyses (Hone and Benton, 2007) preclude them from being further considered. *Sharovipteryx mirabilis* is probably a prolacertiform according to Unwin et al. (2000). Recent analyses, however, do not recover Prolacertiformes as a monophyletic clade (Ezcurra et al., 2014; Gottmann-Quesada and Sander, 2009; Ezcurra, 2016). Therefore, *Sharovipteryx mirabilis* is placed as an early diverging member of Archosauromorpha, in a polytomy with other early diverging archosauromorphs and the clade consisting of the remaining Archosauromorpha. *Mecistotrachelos apeoros* is added to this polytomy, as it is a possible archosauromorph and is potentially most closely related to *Sharovipteryx mirabilis*, but might as well belong to a different clade of archosauromorphs (Fraser et al., 2007).

Ozimek volans is a member of Sharovipterygidae and appears to be similar to *Sharovipteryx mirabilis* (Dzik and Sulej, 2016). It is therefore added as the sister taxon of *Sharovipteryx mirabilis*.

Sennikov (2011) considers both *Microcnemus efremovi* and *Malutinisuchus gratus* to be prolacertids and Gower and Sennikov (2000, p. 142) treat *Microcnemus efremovi* as a prolacertiform. *Microcnemus efremovi* is therefore also added to the the above-mentioned polytomy of early diverging archosauromorphs.

Protorosaurus huxleyi was erected by Hancock and Howse (1870) and Watson (1914a) assigned it to the genus *Adelosaurus*. Evans (1988b) confirmed the generic distinction between the two taxa. Due to its previous assignment, *Adelosaurus* is placed as the sister taxon to the genus *Protorosaurus*.

Arctosaurus osborni is an archosauromorph and might be a member of Allokotosauria (Sues, 2017). It is added accordingly as an early diverging member of Allokotosauria.

Trilophosaurus dornorum was interpreted as being synonymous with *Trilophosaurus jacobsi* (Spielmann et al., 2007), but is recognized as a valid taxon by Martz et al. (2012). *Spinosuchus caseanus* is now considered to include the *Trilophosaurus jacobsi* material (Nesbitt et al., 2015). *Trilophosaurus dornorum* is therefore added as the sister of *Spinosuchus caseanus*.

Variodens inopinatus was considered to be closely related to *Trilophosaurus jacobsi* (Murry, 1987; Sues and Olsen, 1993), which is herein treated as a junior synonym of *Spinosuchus caseanus* (see Nesbitt et al., 2015). Mueller and Parker (2006), Heckert et al. (2006), and Spielmann et al. (2008, p. 8) note a couple of differences between *Variodens inopinatus* and different species of the genus *Trilophosaurus*. Following the interpretation of Sues and Olsen (1993), *Variodens inopinatus* is herein treated as the sister taxon of the clade *Spinosuchus caseanus* + *Trilophosaurus dornorum*.

Alpha taxonomy: Gottmann-Quesada and Sander (2009) did not further investigate the affiliations of the *Protorosaurus* material from England in their redescription of *Protorosaurus speneri*. The specimen from the Quarrington Quarry, near Durham (UK), was assigned to *Protorosaurus* (Evans and King, 1993; a species name was not given). It is retained in the ETD as another specimen of *Protorosaurus speneri*.

The genus *Azendohsaurus* is valid (Nesbitt et al., 2015) and thus both its species (*A. laaroussii*, *A. madagaskarensis*) are treated accordingly.

Trilophosaurus jacobsi is probably the junior synonym of *Spinosuchus caseanus* (Nesbitt et al., 2015) and is treated accordingly. Spielmann et al. (2007) considered *Trilophosaurus dornorum* to be synonymous with *Trilophosaurus jacobsi*, but it is a valid taxon according to Martz et al. (2012). It is included in the database.

Spielmann and Lucas (2012, p. 12) mention *Variodens inopinatus* and it is also treated as a valid taxon by Whiteside et al. (2016) and Whiteside and Duffin (2017). Robinson (1957) considered it to be related to *Trilophosaurus*. Conversely, Sues and Olsen (1993) argued for a possible procolophonian affinity of the taxon, which they considered to be similar to *Trilophosaurus jacobsi*. As mentioned above, Nesbitt et al. (2015, p. 89–92) proposed *Trilophosaurus jacobsi* as the junior synonym of *Spinosuchus caseanus*. Therefore, *Trilophosaurus jacobsi* (= *Spinosuchus caseanus*) is a trilophosaurid. The close affinity of *Variodens inopinatus* to this species (Sues and Olsen, 1993) could suggest, that the initial interpretation of Robinson (1957) was correct. Murry (1987) considered some referred teeth of *Trilophosaurus jacobsi* as being nearly identical to *Variodens inopinatus* while Mueller and Parker (2006), Heckert et al. (2006), and Spielmann et al. (2008, p. 8) note a couple of differences between *Variodens inopinatus* and *Trilophosaurus*. Whiteside and Duffin (2017) report new specimens of *Variodens inopinatus* and agree with Robinson (1957) in considering it a trilophosaur. *Variodens inopinatus* is therefore added to the database.

Vritramimosaurus is mentioned by Sennikov (2011) and Bernardi et al. (2015). Its type material consists of a single cervical vertebra and a few other vertebrae are referred to the taxon (Sennikov, 2005). As the species *Vritramimosaurus dzerzhinskii* is only represented by these poor remains, it is excluded from the database.

Sennikov (2012), Sennikov (2015), and Bernardi et al. (2015) mention *Coelodontognathus*. Spencer and Benton (2000) excluded *Coelodontognathus ricovi* and *Coelodontognathus donensis* from Procolophonoidea. Arkhangelsky and Sennikov (2008) referred them to Trilophosauridae (but see Spielmann et al. (2008, p. 8) for a different interpretation). This referral, however, was only based on tooth shape (Säilä, 2009), which was also used for the previous assignment to Procolophonoidea. Due to the weak support for the assignment to either of the groups, both *Coelodontognathus ricovi* and *Coelodontognathus donensis* are not included in the database. The same applies to *Vitalia grata*, which was also previously thought to belong to Procolophonoidea and later considered to be a trilophosaurid (Spencer and Benton, 2000; Arkhangelsky and Sennikov, 2008; Säilä, 2009). This taxon is also not included in the ETD.

Sennikov (2012) and Sennikov (2015) mentions *Doniceps lipovensis* and Arkhangelsky and Sennikov (2008) treat it as a member of Trilophosauridae. However, both Benton (1994b) and Spielmann et al. (2008, p. 8) question this assignment and as the taxon is only poorly represented in the fossil record (Murry, 1987; Spielmann et al., 2008), it is excluded from the database.

A.32.1 Tanystropheidae

Phylogeny: *Macrocnemus fuyuanensis* is added as sister taxon to *Macrocnemus bassanii* following the single most parsimonious tree of Pritchard et al. (2015, fig. 12). *Dinocephalosaurus orientalis* is added according to the single most parsimonious tree of Liu et al. (2017, fig. 4).

Fuyuansaurus acutirostris, *Pectodens zhenyuensis*, *Protanystropheus antiquus*, *Augustaburiania vatagini*, and *Macrocnemus obristi* are added according to the first strict reduced consensus tree of Ezcurra and Butler (2018, Data Supplement: Supplementary Information: Supplementary fig. 2), which is based on an expanded and modified character matrix of Ezcurra (2016), with updates from Ezcurra et al. (2017), Nesbitt et al. (2017), Sengupta et al. (2017), and Stocker et al. (2017). According to Ezcurra and Butler (2018, Data Supplement: Supplementary Information: p. 4) the underlying modified data matrix “was not built for the purpose of testing phylogenetic relationships, but instead to sample the morphological diversity of middle Permian‚àíearly Carnian archosauromorphs”. Ezcurra and Butler (2018, Data Supplement: Supplementary Information: p. 5) do not recommend to use the data matrix to test phylogenetic relationships. The first strict reduced consensus tree of Ezcurra and Butler (2018, Data Supplement: Supplementary Information: Supplementary fig. 2) is therefore only used to add tanystropheid taxa that have previously not been included in a phylogenetic analysis and whose phylogenetic position agrees with previous interpretations (e.g., Benton and Allen, 1997; Sennikov, 2011; Pritchard et al., 2015; Li et al., 2017).

Trachelosaurus fischeri is also added according to the first strict reduced consensus tree of Ezcurra and Butler (2018, Data Supplement: Supplementary Information: Supplementary fig. 2). Note, that the phylogenetic position of this taxon is quite uncertain, as both the 50% majority rule consensus supermatrix tree of Hone and Benton (2008b, fig. 4) and the single most parsimonious tree of Smith (2011, fig. 33) recover the taxon in positions that differ substantially from each other and from that of Ezcurra and Butler (2018, Data Supplement: Supplementary Information: Supplementary fig. 2).

Malerisaurus langstoni is added as the sister taxon of *Trachelosaurus fischeri* following the 50% majority rule consensus supermatrix tree of Hone and Benton, 2008b, fig. 4). Similar to *Trachelosaurus fischeri* the phylogenetic position of the taxon is uncertain (see, e.g., Smith, 2011, fig. 33).

Similar to *Protanystropheus antiquus*, *Tanystropheus fossai* was coded in Benton and Allen (1997, Table 3) but excluded from subsequent phylogenetic analyses. The different species of *Tanystropheus* are assumed to be sister taxa and placed in a corresponding polytomy.

Gwyneddosaurus might be congeneric with *Tanytrachelos* (Olsen and Flynn, 1989; Lucas, 2010; Smith, 2011) and is thus placed as its sister taxon.

Alpha taxonomy: *Malerisaurus langstoni* is retained in the ETD as a valid taxon. Note however, that Spielmann et al. (2006) considered the holotype of *Malerisaurus langstoni* to be a chimera, consisting of several individuals of other taxa.

Benton et al. (2013c) recorded the genus name of the taxon *T. antiquus* as “Unnamed” (Benton et al., 2013a). Some of the material originally referred to *Tanystropheus antiquus* was used by Fraser and Rieppel (2006) to erect the taxon *Amotosaurus rotfeldensis*. Fraser and Rieppel (2006) retained the taxon *Tanystropheus antiquus* but questioned its validity. Indeed, Sennikov (2011) created the new genus *Protanystropheus* for the taxon. Thus, *Tanystropheus antiquus* is retained in the ETD as *Protanystropheus antiquus*. Klein et al. (2016b) mention *Amotosaurus rotfeldensis* for the Lower Muschelkalk of the Winterswijk locality (The Netherlands), citing hereby Wild and Oosterink (1984), who initially described the specimen as belonging to *Tanystropheus antiquus* (here: *Protanystropheus antiquus*; see above). Fraser and Rieppel (2006), who also cite Wild and Oosterink (1984) in these regards, did not refer the respective material to *Amotosaurus rotfeldensis*. Therefore, this occurrence is herein retained for *Protanystropheus antiquus*.

Pritchard et al. (2015) mention *Tanystropheus biharicus* as an example for the occurrence of *Tanystropheus* during the Middle Triassic of Romania. Despite being only represented by a cervical vertebra (Jurcsák, 1975), this taxon is therefore herein considered to be valid and incorporated into the ETD.

Tanystropheus meridensis is mentioned by Rieppel et al. (2010), Krainer et al. (2011), and Stockar et al. (2012), but it is considered synonymous with *Tanystropheus longobardicus* (Nosotti, 2007; Fraser and Rieppel, 2006) and is also not mentioned in the recent work of Pritchard et al. (2015) on Tanystropheidae among the recognized species of *Tanystropheus*. Thus, *Tanystropheus meridensis* is herein treated as a synonym of *Tanystropheus longobardicus*.

The temporal and palaeobiogeographical range of *Tanystropheus longobardicus* is extended by retaining the specimen from southwestern China described in Rieppel et al. (2010), who referred it to *Tanystropheus cf. T. longobardicus*.

Langobardisaurus rossii was initially considered a protorosaur but later on shown to be a lepidosauromorph, possibly even a rhynchocephalian (Renesto and Dalla Vecchia, 2007; Saller et al., 2013). It is treated accordingly (see also subsection A.28.3). On the other hand, *Langobardisaurus pandolfii* is a valid species of the protorosaur *Langobardisaurus* (Saller et al., 2013) and retained accordingly in the databse.

A.32.2 Rhynchosauria

Phylogeny: Rhynchosauria is added according to the strict consensus tree of Langer et al. (2017a, fig. 10), which is based on a modified data matrix of Schultz et al. (2016). *Teyumbaita sulcognathus* and the different species of *Hyperodapedon* are added according to the strict consensus tree of Mukherjee and Ray (2014, fig. 20A).

Colobops noviportensis is added according to the strict consensus tree of Pritchard et al. (2018, Supplementary Information: Supplementary fig. 14), which is based on a modified character matrix of Pritchard and Nesbitt (2017) and has also been used to add Drepanosauromorpha (see subsection A.27.3).

Eifelosaurus triadicus was considered a rhynchosaur (von Huene, 1929, 1932b) and it is thus placed as an early diverging member of Rhynchosauria in a polytomy with other early diverging rhynchosaurs and the clade consisting of *Mesosuchus browni* + *Howesia browni* + *Eohyosaurus wolvaardti* + Rhynchosauridae. It should be noted, however, that Kuhn (1969a, p. 56) considered *Eifelosaurus* a genus *incertae sedis* and the material is, indeed, in need of restudy (Butler et al., 2015).

Alpha taxonomy: *Eifelosaurus triadicus* is known from the Upper Buntsandstein, not the Middle Buntsandstein (see Jaekel, 1904; von Huene, 1929, p. 49; Kuhn, 1969b, p. 56; Krebs, 1969; Mader, 1984; Ezcurra et al., 2016). (Rath, 2003, p. 105) reports the taxon specifically for the Kyllburg-Schichten. The database is updated accordingly.

As *Hyperodapedon sulcognathus* is not part of the seven valid species of *Hyperodapedon* mentioned by Mukherjee and Ray (2014), it is excluded from the database. Montefeltro et al. (2010) erected the new genus *Teyumbaita* for the taxon *Scaphonyx sulcognathus*. *Teyumbaita sulcognathus* is treated as a valid taxon in Mukherjee and Ray (2014) and thus it is retained in the database.

Hyperodapedon stockleyi is considered a valid taxon by Mukherjee and Ray (2014). *Supradapedon* is a junior synonym of *Hyperodapedon* according to Langer et al. (2000), but Langer et al. (2017a) treat the species *S. stockleyi* again as a member of the genus *Supradapedon*. Thus, *Supradapedon stockleyi* is retained as such in the database. Note, however, that it might still belong to the genus *Hyperodapedon* (Langer et al., 2017a). Such a generic assignment would agree with the result of Mukherjee and Ray (2014, fig. 20).

Due to its palaeobiogegraphic importance, the 'Nova Scotia rhynchosaur' (Hone and Benton, 2008a, see p. 106) from the Wolfville Formation in Canada is retained in the ETD as '*Hyperodapedon* sp. Wolfville'. This taxon corresponds to the taxon *Hyperodapedon* sp. (Wolfville) mentioned in Mukherjee and Ray (2014).

The Indian specimen *Hyperodapedon* sp. (GSI) from the Upper Triassic Maleri Formation, mentioned in Mukherjee and Ray (2014), might represent another *Hyperodapedon* species, but is not included in the database, awaiting the formal erection of a species name.

Otischalkia elderae is an invalid taxon according to Mukherjee and Ray (2014) and is thus excluded from the database.

A.33 'Basal' Archosauriformes

Phylogeny: *Archosaurus rossicus* and *Eorasaurus olsoni* are added according to the first strict reduced consensus tree of Ezcurra (2016, fig. 53).

Teyujagua paradoxa and *Osmolskina czatkowicensis* are added according to the strict consensus tree of Pinheiro et al. (2016, fig. 4). Pinheiro et al.'s (2016) results are based on a novel cladistic analysis, which adds the new taxon *Teyujagua paradoxa* to a data matrix that is mainly drawn from Ezcurra et al. (2010) and Ezcurra et al. (2014).

Halazhaisuchus qiaoensis is added to Euparkeriidae following the strict consensus tree of Sookias (2016, fig. 2), which is based on an updated dataset of Nesbitt (2011) and Sookias et al. (2014b).

Triopticus primus is added according to the strict consensus tree of Stocker et al. (2016, fig. 1A), which is based on an expanded dataset of Nesbitt et al. (2015).

Chasmatosuchus rossicus, *Chasmatosuchus magnus*, and *Chasmatosuchus vjushkovi* are added according to the first strict reduced consensus tree of Ezcurra (2016, fig. 60) at the earliest diverging position.

Vonhuenia friedrichi (misspelled as *Vonhuenia fredericki* in Ezcurra, 2016, fig. 54) is added according to the second strict reduced consensus tree of Ezcurra (2016, fig. 54). *Kalisuchus rewanensis* and *Shansisuchus kuyeheensis* are added according to the third strict reduced consensus tree of Ezcurra (2016, fig. 55). *Uralosaurus magnus* is added according to the strict consensus tree of Ezcurra (2016, fig. 52).

According to Schoch (2011d) *Zanclodon laevis* cannot be assigned to crown-group archosaurs and is to be classified as Archosauriformes *incertae sedis*. The taxon is added accordingly as an early diverging member of Archosauriformes.

Uatchitodon has been assigned to Archosauriformes *incertae sedis* (Heckert et al., 2012b). It is added as an early diverging member of Archosauriformes and the two species of the genus are assumed to be sister taxa.

Alpha taxonomy: Ezcurra et al. (2014) consider *Eorasaurus olsoni* a valid taxon and thus it is included in the database.

The type of *Chasmatosaurus vanhoepeni*, described by Haughton (1924b), is referred to *Proterosuchus fergusi* following Ezcurra and Butler (2015b).

Chasmatosaurus alexanderi is assigned to the genus *Proterosuchus* following Ezcurra and Butler (2015b).

Ezcurra et al. (2013, Table 1) report *Chasmatosuchus vjushkovi* as a *nomen dubium*, but Ezcurra (2016) considers it to be a valid species (albeit not belonging to the genus *Chasmatosuchus*). It is therefore retained in the database as *Chasmatosuchus vjushkovi*.

Gamosaurus lozovskii is listed in Ezcurra et al. (2013, Table 1) but Ezcurra (2016) considers it to be a subjective junior synonym of *Chasmatosuchus magnus* and thus it is treated accordingly. Ezcurra (2016) treats *Jaikosuchus magnus* as being identical to *Chasmatosuchus magnus* and this view is followed herein.

Zanclodon laevis is mentioned by Schoch and Sues (2014) and is shortly described by Schoch (2011d), who considers it Archosauriformes *incertae sedis*. The taxon is added to the database.

Heckert et al. (2012b) assign *Uatchitodon* to Archosauriformes *incertae sedis*. It is ‘a tooth taxon’, but as the referred tooth specimens bear a distinct morphology (Sues, 1991, 1996; Mitchell et al., 2010) and as the taxon possibly represents the oldest record of a venomous bite in diapsid reptiles (Mitchell et al., 2010; but see Folinsbee et al., 2007 for a general critique towards inferring venom in fossil taxa) it is herein treated as valid. Thus, both species *Uatchitodon kroehleri* and *Uatchitodon schneideri* are included in the database.

Vonhuenia friedrichi is listed in Ezcurra et al. (2013, Table 1) among the known proterosuchians, is also mentioned by Bernardi et al. (2015) and Ezcurra (2016). Thus, it is herein considered to be a valid species and is incorporated into the ETD.

Cuyosuchus huenei is mentioned by Ezcurra et al. (2013) as a taxon that no longer belongs to ‘Proterosuchia’ and by Nesbitt et al. (2013c) as a taxon that was formerly considered a rauisuchian. It is also mentioned in Desojo et al. (2011), Ezcurra (2014), Sookias et al. (2014b), and Ezcurra et al. (2014) and treated as an OTU in the phylogenetic analysis of Ezcurra (2016, fig. 48). Thus, it is herein considered a valid taxon.

Ezcurra et al. (2013, Table 1) list *Guchengosuchus shiguaiensis* as a possibly erythrosuchid and it is also mentioned by Nesbitt et al. (2013a), Gower et al. (2014), and Bernardi et al. (2015) and included in the phylogenetic analysis of Ezcurra (2016, fig. 48). Thus, it is herein considered a valid taxon and is included in the ETD.

Gower and Sennikov (2000) considered *Vjushkovia triplicostata* a junior synonym of *Garjainia prima*. This view was followed by Gower et al. (2014) and Sookias et al. (2014c) and is subsequently also followed herein.

Ezcurra et al. (2013, Table 1) report *Chalishevia cothurnata* among the valid known proterosuchians and the taxon is also mentioned by Nesbitt et al. (2013a), Ezcurra (2014), and Gower et al. (2014). It is treated as an OTU in the phylogenetic analysis of Ezcurra (2016, fig. 48). The taxon is therefore considered to be valid and included in the database.

Ezcurra et al. (2013, Table 1) report *Uralosaurus magnus* as a valid species and it is also mentioned in Gower et al. (2014), Sookias et al. (2014c), and Niedźwiedzki et al. (2016). Furthermore, it is used as an OTU in the phylogenetic analysis of Ezcurra (2016, fig. 52). Thus, this taxon is considered to be valid herein.

Shansisuchus heiyuekouensis is a *nomen dubium* according to Ezcurra et al. (2013) and a subjective junior synonym of *Shansisuchus shansisuchus* according to Gower et al. (2014). In the ETD this taxon is treated as a synonym of *Shansisuchus shansisuchus*. On the other hand, *Shansisuchus kuyeheensis* is considered a valid taxon by Ezcurra et al. (2013) and thus it is incorporated into the ETD. It should be noted however, that the holotype and only known specimen of *Shansisuchus kuyeheensis* has seemingly been lost (Ezcurra, 2015, p. 184). The same applies to the holotype and only known specimen of *Fugusuchus hejiapanensis* (Ezcurra, 2015, p. 184).

Dorosuchus neoetus is a valid taxon according to Sookias et al. (2014c) and is thus retained in the ETD.

Niedźwiedzki et al. (2016) consider *Dongusuchus efremovi* to be a valid taxon and thus it is included in the database.

Exilisuchus tubercularis is listed in Ezcurra et al. (2013, Table 1) as a known proterosuchian (although its validity can be doubted; see Ezcurra et al., 2013, p. 11), but is considered a *nomen dubium* in Ezcurra (2016, p. 52). Thus, it is excluded from the database.

Ankistrodon indicus is listed among the known proterosuchians by Ezcurra et al. (2013, Table 1) and is also mentioned in Bernardi et al. (2015). However, Ezcurra (2016) considers *Ankistrodon indicus* to be a *nomen dubium* and thus it is not included in the database.

Chasmatosaurus ultimus is a *nomen dubium* according to Liu et al. (2015a) and is thus not included in the database.

The specimen described as *Chasmatosaurus* sp. for the Indian Panchet Formation by Satsangi (1964) and mentioned recently by a few authors (e.g., Ezcurra et al., 2013, Table 1; Bernardi et al., 2015; Ezcurra, 2016) is not included, awaiting further studies of the fragmentary remains and the (possible) formal erection of a new species.

Blomosuchus georgii is mentioned by Ezcurra et al. (2013), Bernardi et al. (2015), and Ezcurra and Butler (2015b) but is considered a *nomen dubium* by Ezcurra (2016) and is thus excluded from the database.

Graoullyodon hacheti is based on very fragmentary remains and was assigned to ?Archosauriformes *incertae sedis* (Godefroit and Cuny, 1997). The evidence for venom conduction in the taxon appears to be less clear than in *Uatchitodon* (Mitchell et al., 2010). Due to the uncertain systematic assignment of *Graoullyodon hacheti*, it is excluded from the database.

Wangisuchus tzeyii and *Turfanosuchus shageduensis* are considered *nomina dubia* (Sookias et al., 2014b) and are thus not included in the database.

Niedźwiedzki et al. (2016) mention *Dongusia colorata* but it is generally regarded a *nomen dubium* (Ezcurra et al., 2013; Sookias et al., 2014c) and thus not included in the ETD.

Crosbysaurus harrisae is a ‘tooth taxon’ of uncertain taxonomic affinities (Butler et al., 2008; Gay and Aude, 2015), that has been variously assigned to either Ornithischia (Heckert, 2004), Archosauriformes *incertae sedis* (Irmis et al., 2007b; Heckert et al., 2012b) or non-archosauriform Archosauromorpha (Gay and Aude, 2015). Due to the incompleteness of its remains and the taxonomic instability this taxon is not included in the ETD. For similar reasons, the tooth taxa (Gay and Aude, 2015) *Krzyzanowskisaurus hunti* (see also Heckert and Miller-Camp, 2013), *Tecovasaurus murryi*, *Lucianosaurus wildi*, *Protecovasaurus lucasi* are excluded as well (for further discussion of these tooth taxa see Irmis et al., 2007b).

A.33.1 Proterochampsia

Phylogeny: *Litorosuchus somnii* is added according to the strict consensus tree of Li et al. (2016a, Supplemental information: fig. 3S).

Doswellia sixmilensis is assumed to be the sister taxon of *Doswellia kaltenbachi* and is placed accordingly.

Ankylosuchus chinlegroupensis is a member of Doswelliidae (Lucas et al., 2013a) and is therefore placed as an early diverging member of this family.

Alpha taxonomy: *Gualosuchus reigi* is also known from the lower part of the Chañares Formation (Trotteyn et al., 2013; Mancuso et al., 2014) and the corresponding occurrence is recorded in the database.

Rhadinosuchus gracilis is considered a valid species by Ezcurra et al. (2015) and is thus included in the database.

The specimens from the Colorado City Formation of Texas and the Monitor Butte Formation from Utah assigned to *Doswellia* sp. by Heckert et al. (2012a) are not included in the database, awaiting the formal description of a new species, if more complete material becomes available.

A.34 'Basal' Archosauria

Phylogeny: The archosaurian scaffold tree builds upon the archosauromorph scaffold tree, the latter being mainly based on the strict consensus tree of Ezcurra et al. (2017, Supplementary Information: fig. 12, 13).

Sikannisuchus huskyi is considered Archosauria *incertae sedis* (but does not belong to Ornithodira; Nicholls et al., 1998) and is placed accordingly.

Vjushkovisaurus berdjanensis is only known from fragmentary postcranial remains and its systematic position remains uncertain (Gower and Sennikov, 2000; Juul, 1994). Niedźwiedzki et al. (2016) consider it an archosauriform or basal archosaur, while Benton et al. (2015) mention it as a "rauisuchian". Herein, it is added as a an early diverging archosaur.

Collilongus rarus is an archosauriform with uncertain family affiliations, but appears to be similar to *Dongusuchus efremovi* and *Vytshegdosuchus zheshartensis* (Borsuk-Białynicka and Sennikov, 2009). It is added accordingly in a polytomy with other early diverging archosaurs.

Alpha taxonomy: *Vjushkovisaurus berdjanensis* is mentioned by Benton (2011), Parham et al. (2012), Niedźwiedzki et al. (2016), and Benton et al. (2015) and is thus included in the database.

Parker and Martz (2010) and Heckert et al. (2015) referred isolated osteoderms from the Pekin Formation to *Lucasuchus* and thus these specimens are incorporated into the database.

Hoplitosuchus raui is mentioned by Desojo et al. (2011) but is reported as a *nomen dubium* by Nesbitt et al. (2013c, Table 2) and is thus not included in the database.

A.35 Pseudosuchia

Phylogeny: *Pagosvenator candelariensis* is added according to the simplified version of the strict consensus trees of Lacerda et al. (2018, fig. 8), which is based on a modified and expanded character matrix of Nesbitt (2011), also including the modifications of Butler et al. (2011b), Nesbitt and Butler (2013), Butler et al. (2014a), and von Baczko et al. (2014).

Koilamasuchus gonzalezdiazi is added according to the strict reduced consensus tree of Sengupta et al. (2017, Supplementary Information: fig. S4), which is also used to add Allokotosauria (section A.32).

Sues (1992) refers *Euscolosuchus olseni* to Crurotarsi *incertae sedis* with the dorsal armour closely resembling early diverging members of Crocodyliformes. Scheyer and Sues (2017,

p. e1248768-5) treat it as an "unusual pseudosuchian". The taxon is herein placed as an early diverging member of Pseudosuchia.

Alpha taxonomy: *Dasygnathoides longidens* (and therefore also *Ornithosuchus longidens*) is a *nomen dubium* (von Baczko and Ezcurra, 2016). *Ornithosuchus woodwardi*, on the other hand, is a valid species (von Baczko and Ezcurra, 2016). These taxa are treated accordingly.

The *Erpetosuchus* sp. specimen from the New Haven Formation described by Olsen et al. (2000) is retained in the database (included in *Erpetosuchus granti*) due to its stratigraphic and palaeobiogeographic importance. Note, that Irmis et al. (2013a) report the specimen as belonging to *Erpetosuchus granti*.

Dyoplax arenaceus is considered a "problematic" taxon by Irmis et al. (2013a), but the revision of Maisch et al. (2013) reports it as a valid taxon, tentatively referring it to ?Erpetosuchidae (but see Nesbitt and Butler, 2013; Ezcurra et al., 2017, Supplementary Information: fig. 12, 13). It is treated accordingly in the database.

A.35.1 Phytosauria

Phylogeny: The phytosaurian part of the supertree is based on the strict consensus tree of Stocker et al. (2017, Supplementary Information: fig. S6), which is based on an expanded character matrix of Kammerer et al. (2016c). The shown relationships are incorrect for *Parasuchus bransoni*, *Smilosuchus adamanensis* and *Smilosuchus lithodendrorum* (M. R. Stocker, pers. comm., 2017). These relationships are reported to be identical (Stocker et al., 2017) to the ones seen in the strict consensus tree of Kammerer et al. (2016c, fig. 16) and are modified accordingly.

Mystriosuchus planirostris, *Machaeroprosopus bermani*, *Machaeroprosopus buceros*, *Machaeroprosopus gregorii*, and *Machaeroprosopus lottorum* are added according to the strict consensus tree of Hungerbühler et al. (2012, fig. 25B). The clade *Machaeroprosopus gregorii* + *Machaeroprosopus lottorum* is added as sister taxon of the clade *Machaeroprosopus jablonskiae* + *Mystriosuchus*.

Nicrosaurus kapffi and *Nicrosaurus meyeri*, which Hungerbühler et al. (2012) consider as the earliest diverging members of Pseudopalatinae (now Mystriosuchini; Kammerer et al., 2016c), are added according to the single most parsimonious tree of Parker and Irmis (2006, fig. 13) and the strict consensus tree of Hungerbühler et al. (2012, fig. 25B) (see also the strict reduced consensus tree of Ezcurra, 2016, fig. 50).

Zanclodon arenaceus is placed as sister taxon to Phytosauria, following the single most parsimonious tree of Hungerbühler (2001, fig. 5a).

Stocker and Butler (2013, Table 1) treat both *Belodon superciliosus* and *Coburgosuchus goeckeli* as belonging to Phytosauria *incertae sedis*. The taxa are placed accordingly among the early diverging members of Phytosauria (see also Kammerer et al. (2016c, Table 2) for the clade definition).

Parasuchus magnoculus could be a juvenile specimen of *Parasuchus hislopi* (but this needs further study; see Kammerer et al., 2016c) and is therefore added as the sister taxon of *Parasuchus hislopi*.

The different species of *Angistorhinus* are assumed to be sister taxa and are placed in a corresponding polytomy. Kammerer et al. (2016c) consider *Paleorhinus parvus* to be *Angistorhinus*-like. The species is therefore added as an early diverging member of Mystriosuchinae in a polytomy with *Angistorhinus*, *Paleorhinus sawini*, *Brachysuchus megalodon*, and the clade consisting of the other mystriosuchine taxa.

Machaeroprosopus andersoni is possibly a junior synonym of *Machaeroprosopus buceros* (Hungerbühler et al., 2012) and is therefore added as its sister taxon. *Machaeroprosopus validus* is herein assumed to be the sister taxon of the other species of *Machaeroprosopus* and is therefore added in a polytomy with the earliest diverging members of the genus.

Alpha taxonomy: Hungerbühler (2001) considered the inclusion of *Z. arenaceus* in the genus *Zanclodon* to be wrong but did not erect a new generic name for the species. The phylogenetic analysis of Hungerbühler (2001, fig. 5) found *Z. arenaceus* as the sister taxon of Phytosauria. Hungerbühler (2001) considered this result as not well supported and referred *Z. arenaceus* to Archosauria *incertae sedis*. Dzik and Sulej (2007) regarded *Z. arenaceus* to be very similar to a juvenile *Paleorhinus* from Krasiejów (Poland), which they considered to be clearly a phytosaur. Dzik and Sulej (2007) assigned the Krasiejów material to *Paleorhinus cf. arenaceus*. In their review of Phytosauria Stocker and Butler (2013) followed Hungerbühler (2001) and considered *Zanclodon arenaceus* (misspelled as *Zanclodon arenaceous*) not to be a phytosaur. They did not, however, cite Dzik and Sulej (2007) in their paper. The 2013 version of the ETD (Benton et al., 2013c,a) includes the taxon *Paleorhinus arenaceus*, but does not include the taxon *Zanclodon arenaceus*. Butler et al. (2014b) cite Dzik and Sulej (2007), but regard the Krasiejów phytosaur specimen to be more similar to *Paleorhinus angustifrons* than to *Zanclodon arenaceus*. This view is followed herein. As *Paleorhinus angustifrons* is now assigned to the genus *Parasuchus* (Kammerer et al., 2016c), the Krasiejów specimens are assumed to represent additional material of *Parasuchus angustifrons* and are retained as such in the ETD. The type specimen of *Zanclodon arenaceus*, described by Fraas (1896), is assigned to the genus *Zanclodon* in the database (awaiting the formal erection of a new genus for this taxon).

Camp (1930, p. 145) considered *Belodon superciliosus* as a taxon of "uncertain status" and reported the locality of the holotype as being close to that of the type specimens of *Episcoposaurus haplocerus*, which are known from the Tecovas Formation of Texas (Parker, 2008). Mehl (1915) doubted the validity of *Belodon superciliosus*. Spielmann and Lucas (2012) treat *Coburgosuchus goeckeli* as a valid taxon. Stocker and Butler (2013, Table 1) list both *Belodon superciliosus* (misspelled as *Belodon superciliosis*) and *Coburgosuchus goeckeli* as belonging to Phytosauria *incertae sedis*. They are therefore included in the database.

Stocker and Butler (2013) treat both *Paleorhinus parvus* and *Parasuchus hislopi* as valid phytosaurian taxa. They are therefore included in the database. Kammerer et al. (2016c) also include *P. angustifrons*, *P. bransoni*, and *P. magnoculus* in the genus *Parasuchus* and this view is followed herein.

Stocker and Butler (2013, Table 1) report *Brachysuchus megalodon* only for the Dockum Group (see also Stocker, 2010, Supplemental Information). The stratigraphic and palaeobiogeographic range of the taxon is updated accordingly.

Stocker and Butler (2013) report not only *Angistorhinus grandis* and *Angistorhinus talainti* as valid taxa, but also *Angistorhinus maximus*, *Angistorhinus alticephalus*, and *Angistorhinus aeolamnis*. Thus all these taxa are included in the ETD. Note however, that Lucas et al. (2002) treat *Angistorhinus* as monospecific.

Both *Leptosuchus studeri* and *Smilosuchus lithodendrorum* are valid taxa according to Stocker and Butler (2013) and are thus included in the database. Stocker and Butler (2013) consider *Leptosuchus imperfecta* a *nomen dubium*, but it is included in the phylogenetic analysis of Kammerer et al. (2016c, fig. 16) and is thus also included in the ETD. Stocker (2010) referred *Leptosuchus adamanensis* to *Smilosuchus adamanensis* and this view is followed by Stocker and Butler (2013). *Smilosuchus adamanensis* is treated accordingly in the ETD.

Both *Phytosaurus doughtyi* and *Machaeroprosopus zunii* are reported as belonging to Phytosauria *incertae sedis* (Stocker and Butler, 2013, Table 1) and are incorporated in the phylogenetic analysis of Kammerer et al. (2016c, fig. 16). Thus, they are included in the database. It should be mentioned, however, that the type species of the genus *Phytosaurus*, *P. cylindricodon*, is considered a *nomen dubium* (Kammerer et al., 2016c).

Both *Machaeroprosopus andersoni* and *Machaeroprosopus validus* are considered valid taxa by Stocker and Butler (2013, Table 1), belonging to Phytosauria *incertae sedis* (see also Parker et al., 2012). They are both included in the database. The type specimen of *Machaeroprosopus andersoni* possibly comes from the Bull Canyon Formation (Long and Murry, 1995, p. 230). The holotype of *Machaeroprosopus validus* was lost (Stocker and Butler, 2013; Parker et al., 2012) but it probably stems from the upper part of the Petrified Forest Member (Chinle Formation, Arizona; Long and Murry, 1995, p. 3). The same locality is described as belonging to the Painted Desert Member by Heckert et al. (2005). *Machaeroprosopus validus* was erected by Mehl (1916), not by Mehl (1922) as mentioned by Heckert et al. (2005).

Pseudopalatus and *Arribasuchus* are junior synonyms of *Machaeroprosopus* according to Parker et al. (2012) and are treated as such in the ETD. *Redondasaurus* is also considered a junior synonym of *Machaeroprosopus* (Hungerbühler et al., 2012) and is treated accordingly. *Machaeroprosopus buceros*, *Machaeroprosopus jablonskiae*, *Machaeroprosopus mccauleyi*, *Machaeroprosopus pristinus*, *Machaeroprosopus lottorum*, *Machaeroprosopus gregorii*, and *Machaeroprosopus bermani* are currently recognized as valid species (Stocker and Butler, 2013; Hungerbühler et al., 2012) and are thus included in the database. Stocker and Butler (2013) report occurrences of

Machaeroprosopus pristinus for the Chinle Formation of both Arizona and New Mexico (USA). Long and Murry (1995, p. 53) report *Machaeroprosopus pristinus* (as *Pseudopalatus pristinus*) for the upper Petrified Forest Member of the Chinle Formation of New Mexico. Thus, this occurrence is also included in the database. The occurrence from the ?Rock Point Member of the Chinle Formation of New Mexico is uncertain as indicated by the question mark (Long and Murry, 1995, p. 53). It is therefore not included in the database. The juvenile specimen from the Rock Point Formation of New Mexico described for *Redondasaurus gregorii* (Lucas et al., 2013b) is herein treated as belonging to *Machaeroprosopus gregorii*. The specimens described as *Redondasaurus gregorii* from the upper Bull Canyon Formation of Texas and the Petrified Forest Formation (Painted Desert M.) of New Mexico (Spielmann and Lucas, 2012) probably do not belong to the genus *Redondasaurus* (Martz and Parker, 2017, p. 103) and are therefore herein also not assigned to *Machaeroprosopus gregorii*. Similarly, the specimen described as *Redondasaurus gregorii* from the lower Wingate Sandstone Formation of Utah (Lucas et al., 1997) cannot be confidently assigned to any *Machaeroprosopus* species (Martz et al., 2014, 2017) and is therefore not included in the database.

Machaeroprosopus tenuis is not listed among the valid phytosaurian taxa as presented in Stocker and Butler (2013, Table 1) and Hungerbühler et al. (2012) treat it as a synonym of *Machaeroprosopus pristinus* following Long and Murry (1995). The taxon is treated accordingly in the ETD.

According to Long and Murry (1995, p. 3, 48) *Smilosuchus gregorii* is based on the holotype (UCMP 27200) of *Machaeroprosopus gregorii* Camp, 1930. Stocker and Butler (2013, Table 1) list both *Smilosuchus gregorii* (holotype: UCMP 27200; Chinle Formation, Arizona, USA) and *Redondasaurus gregorii* Hunt and Lucas, 1993 (holotype: YPM 3294; Redonda Formation, New Mexico, USA) as valid phytosaurian taxa. As mentioned before, *Redondasaurus* is considered a junior synonym of *Machaeroprosopus* by Hungerbühler et al. (2012), who treat *Machaeroprosopus gregorii* (based on YPM 3294) and *Smilosuchus gregorii* as separate valid taxa. Thus, both *Machaeroprosopus gregorii* and *Smilosuchus gregorii* are retained in the database.

The *Paleorhinus* sp. specimen mentioned in Long and Murry (1995, p. 226) is not included in the database, as it cannot be referred to any species of *Paleorhinus*.

The teeth from the Upper Triassic of Saint-Nicolas-de-Port referred to *Rutiodon ruetimeyeri* belong to the genus *Angistorhinopsis*, not to the genus *Rutiodon* (Godefroit et al., 1998). *Angistorhinopsis ruetimeyeri* is considered a *nomen dubium* (Stocker and Butler, 2013; Witzmann et al., 2014) and is thus excluded from the database.

Promystriosuchus ehlersi and *Mesorhinosuchus fraasi* are listed as Phytosauria *incertae sedis* by Stocker and Butler (2013, Table 1). Their taxonomy is considered ‘uncertain’ by Kammerer et al. (2016c, Table 1) and *Promystriosuchus ehlersi* is “in need of redescription” (Kammerer et al., 2016c, p. 18). These taxa are therefore not included in the database.

Stocker and Butler (2013, Table 1) consider *Francosuchus broilii* a *nomen dubium* and it is reported as "Phytosauria indet." by Kammerer et al. (2016c). Thus, it is excluded from the database. The same applies to *Francosuchus latus*, which is also excluded.

The indeterminate phytosaurian remains reported for the Late Triassic of Lithuania (Brusatte et al., 2013) are not included, awaiting the assignment to a (new?) species when more informative material is found.

A.35.2 Aetosauria

Phylogeny: The aetosaurian part of the tree is based on the 50% majority rule consensus tree of Parker (2016, fig. 6C), which is nearly identical to the reduced strict consensus tree of Parker (2016, fig. 7), but also includes the taxon *Aetobarbakinoides brasiliensis*. The underlying data matrix was scored from scratch (Parker, 2016).

Acaenasuchus geoffreyi is added according to the single most parsimonious tree of Schoch and Desojo (2016, fig. 8). The analysis uses an updated data matrix of Roberto-da-Silva et al. (2014), which is itself based on the original data matrix of Parker (2007) and includes modifications of Desojo et al. (2012). It should be noted, however, that *Acaenasuchus geoffreyi* might not be an aetosaur (Parker, 2016).

Redondasuchus reseri scores as taxonomic equivalent of *Redondasuchus rineharti* according to Parker (2016) and they are therefore herein treated as sister taxa.

Lucas et al. (1998) assigned *Stegomus arcuatus* to the genus *Aetosaurus*. *Stegomus arcuatus* is therefore placed as the sister taxon of *Aetosaurus ferratus*.

The two species of *Coahomasuchus* (Heckert et al., 2017) are assumed to be sister taxa (see also Hoffman et al., 2018).

Chilenosuchus forttae scores as taxonomic equivalent of *Typothorax coccinarum* according to Parker (2016) and is therefore added as its sister taxon. The strict consensus tree of Desojo et al. (2011, fig. 15A) recovered *Chilenosuchus forttae* as the sister taxon of *Stagonolepis* and the few known character states are identical to those of the genus *Stagonolepis* according to Schoch and Sues (2014). These studies, however, did not focus on the ingroup relationships of Aetosauria but on those of (basal) archosauriforms. They are therefore not further considered herein.

Alpha taxonomy: Irmis et al. (2007b) assigned both *Galtonia gibbidens* and *Pekinosaurus olseni* to *Revueltosaurus* sp. Heckert et al. (2012b) consider *Galtonia gibbidens* and their new combination *Revueltosaurus olseni* (= *Pekinosaurus olseni*) to be valid species. Herein, the view of Irmis et al. (2007b) is followed and the tooth taxon *Galtonia gibbidens* is considered to be a synonym of *Revueltosaurus* sp. The differences between the teeth of *Revueltosaurus callenderi* and the tooth taxon *Revueltosaurus olseni* are considered to be too subtle and could also be explained by different tooth positions within the tooth-bearing element. Irmis et al. (2007b) are followed herein in regarding *Pekinosaurus olseni* (and thus *Revueltosaurus olseni*) as *Revueltosaurus* sp.

As *Revueltosaurus* thus remains monospecific (*Revueltosaurus callenderi*), the specimen data of *Galtonia gibbidens* and *Revueltosaurus olseni* are assigned to *Revueltosaurus callenderi*.

Desojo et al. (2013) report *Desmatosuchus smalli* and *Desmatosuchus spurensis* as valid aetosaur species and they are also mentioned in, e.g., Scheyer et al. (2014a) and Parker (2016). Thus, these two species of *Desmatosuchus* are included in the database.

Aetosauroides subsulcatus (= *Aetosauroides inhamandensis*; see Desojo and Ezcurra, 2011) is a *nomen nudum* (Desojo et al., 2013, Table 2) and a junior synonym of *Aetosauroides scagliai* (Desojo and Ezcurra, 2011). It is treated accordingly in the ETD.

Lucas et al. (1998) referred *Stegomus arcuatus* to the genus *Aetosaurus*. According to Schoch (2007) the few visible features of the poorly preserved specimens are consistent with *Aetosaurus ferratus*, but the diagnostic regions were not preserved. In their review of Aetosauria Desojo et al. (2013, Table 1) recognize *Stegomus arcuatus* as a valid species and mention, that its taxonomic assignment (including the one by Lucas et al., 1998) needs further validation. Thus, *Stegomus arcuatus* is kept in the database as a species of the genus *Stegomus*. It should be mentioned, however, that this taxon probably represents a *nomen dubium* and that the referred material cannot be confidently assigned to the taxon (see Parker, 2014, p. 375; Parker, 2016; W. G. Parker, pers. comm., 2016). *Aetosaurus crassicauda* was considered a junior synonym of *Aetosaurus ferratus* by Schoch (2007) and this view was followed by Desojo et al. (2013, Table 2). Thus, the specimens previously assigned to *Aetosaurus crassicauda* are included within *Aetosaurus ferratus* in the database.

Typothorax coccinarum might be a *nomen dubium* (Parker, 2012, 2016) but is retained in the database, awaiting the possible creation of a neotype (otherwise the name *Episcoposaurus horridus* should be used for the relevant diagnostic material; see Parker, 2012). *Typothorax antiquum* is probably just a smaller individual and thus a junior synonym of *Typothorax coccinarum* (Parker, 2006; Parker and Martz, 2011; Parker, 2012; Martz et al., 2012; Parker, 2014) and is treated accordingly. *Episcoposaurus horridus* can be considered synonymous with *Typothorax coccinarum* (Parker, 2012) and is treated accordingly.

Desojo et al. (2013, Table 1) list both *Redondasuchus reseri* and *Redondasuchus rineharti* as valid taxa. Thus, both taxa are included in the ETD. *Redondasuchus reseri* might be a juvenile of *Typothorax coccinarum*, but further research is needed to confirm this interpretation (Parker, 2014, p. 240).

Stagonolepis robertsoni and *Stagonolepis olenkae* are retained in the database as separate taxa (Desojo et al., 2013, Table 1), but the Polish material might also pertain to *Stagonolepis robertsoni* (Antczak, 2016), thus making the genus *Stagonolepis* monospecific.

Murry and Long (1989) proposed the new combination *Stagonolepis wellesi* for *Calyptosuchus wellesi* and it is also mentioned by Heckert et al. (2012a) and Heckert et al. (2013). But most authors (e.g., Desojo et al., 2012; Parker and Nesbitt, 2013; Scheyer et al., 2014a; Roberto-da-Silva et al., 2014; Antczak, 2016) retain the name *Calyptosuchus wellesi* and Desojo et al. (2013,

Table 1) list it as a valid aetosaur species. Thus, the species is retained as *Calyptosuchus wellesi* in the database. Specimens of *Calyptosuchus wellesi* are reported from the Chinle Formation of Arizona (Long and Murry, 1995, p. 83; Desojo et al., 2013, Table 1) and from the Cooper Canyon Formation of Texas (Martz et al., 2012). Parker (2014, p. 71; p. 217), however, reports only specimens from the (upper) Blue Mesa Member of the Chinle Formation of Arizona and from the Tecovas Formation of Texas. Only the latter occurrence data are included in the ETD.

Adamanasuchus eisenhardtae is mentioned by Scheyer et al. (2014a) and is considered a valid aetosaur by Desojo et al. (2013, Table 1). Thus, it is included in the database.

Rioarribasuchus chamaensis, described by Lucas et al. (2006), is mentioned by Nesbitt et al. (2013b, Table 1), in the supporting information of Whiteside et al. (2015, Table S5) and in Parker (2016). *Rioarribasuchus chamaensis* was nearly simultaneously described as *Heliocanthus chamaensis* by Parker (2007). However, the paper by Lucas et al. (2006) was published earlier and thus *Heliocanthus chamaensis* is the junior synonym of *Rioarribasuchus chamaensis*. Indeed, *Rioarribasuchus chamaensis* is mentioned by Irmis et al. (2007a) (who act as "first reviser" according to Article 24.2 of the International Code of Zoological Nomenclature; International Commission on Zoological Nomenclature (ICZN), 1999) and Parker (2014, p. 243) accepts this assignment. Thus, it is treated accordingly in the database. For additional details on the controversial naming history of the taxon, the reader is referred to Dalton (2008), Fleck (2008a), Fleck (2008b), SVP (2008b) and SVP (2008a).

The American specimens of *Paratypothorax andressorum* can be regarded as belonging to a separate taxon and herein this material is treated as *Paratypothorax* sp., following Parker (2016). Parker (2016) examined one of the specimens from Greenland (Jenkins et al., 1994) assigned to *Paratypothorax andressorum* and considered it to be not distinct enough to warrant the assignment to the taxon. Instead, Parker (2016) referred it to Paratypothoracini. The other Greenland specimens, however, were not examined by Parker (2016) and the Greenland occurrence of *Paratypothorax andressorum* is therefore retained in the database.

Parker (2012) confirms the assignment of *Episcoposaurus haplocerus* to the genus *Desmatosuchus* and the species *Desmatosuchus haplocerus* is also mentioned by Nesbitt et al. (2013c). However, Parker (2012) considers the type material of *Desmatosuchus haplocerus* not to be diagnostic at species level and, indeed, Parker (2008), Parker (2014, p. 225), and Parker (2016) considers the taxon to be a *nomen dubium*. Thus, *Desmatosuchus haplocerus* is excluded from the ETD. Note, however, that Heckert et al. (2015, fig. 5) include the taxon in their phylogenetic analyses.

Hoplitosuchus raui is mentioned by Raugust (2014), but is listed as an invalid taxon belonging to Aetosauria *incertae sedis* by Desojo et al. (2013, Table 2) and as a *nomen dubium* by Nesbitt et al. (2013c) and is thus excluded from the database.

The Moroccan specimens (Argana Formation) assigned to *Longosuchus meadei* by Lucas (1998) probably belong to another taxon (Parker and Martz, 2010; Parker, 2014, p. 22) and, indeed, no occurences outside of the U.S. are reported for *Longosuchus meadei* in Desojo et al. (2013, Table 1). Thus, these specimens are excluded from the database.

Acompsosaurus wingatensis is mentioned by Heckert et al. (2012a) but can be regarded as invalid, as the holotype was lost (Desojo et al., 2013). Thus, it is not included in the database.

A.35.3 Paracrocodylomorpha

Phylogeny: The archosaurian scaffold tree is augmented by the strict consensus tree of Nesbitt et al. (2017, Extended Data fig. 3) for *Ticinosuchus ferox* + early diverging Paracrocodylomorpha. Nesbitt et al. (2017) used the updated and expanded data matrix of Nesbitt (2011).

Arganasuchus dutuiti, *Stagonosuchus nyassicus*, and *Tikisuchus romeri* are added according to the 50% majority rule consensus tree of Lautenschlager and Rauhut (2015, fig. 20B) (see also Butler et al., 2011b, fig. 14), which is based on an updated character matrix of Brusatte et al. (2010b). The resolution for *Tikisuchus romeri* is improved using the 50% majority rule consensus tree of Butler et al. (2011b, fig. 13: right) and the strict consensus tree of Mastrantonio et al. (2013, fig. 10).

Ctenosauriscus koeneni and *Hypselorhachis mirabilis* are added according to the 50% majority rule consensus tree of Lautenschlager and Rauhut (2015, fig. 19B).

Bromsgroveia walkeri is added according to the 50% majority rule consensus tree of Lautenschlager and Rauhut (2015, fig. 20B) in a polytomy with the other ctenosauriscid taxa.

Mandasuchus tanyauchen is added according to the strict consensus tree of Butler et al. (2018, fig. 28), which is based on an updated and expanded data matrix of Nesbitt (2011) including the modifications of Butler et al. (2014a) and additional data from Nesbitt et al. (2014).

Apatosuchus orbitoangulatus is added according to the strict consensus tree of Sues and Schoch (2013c, fig. 7).

Youngosuchus sinensis is added according to the strict consensus tree of Ezcurra et al. (2017, Supplementary Information: fig. 12, 13).

Luperosuchus fractus is added according to the strict consensus tree of Nesbitt and Desojo (2017, fig. 7: (1)), which is based on an updated character matrix of Nesbitt (2011) with modifications of Butler et al. (2014a). This tree is also used to modify the positions of *Prestosuchus chiniquensis* and *Saurosuchus galilei*.

Decuriasuchus quartacolonia is added as the sister taxon of *Luperosuchus fractus* according to the strict consensus tree of Ezcurra et al. (2017, Supplementary Information: fig. 12, 13) (see also de França et al., 2011, fig. 4). Note, however, that the phylogenetic position of the taxon is still controversial (de França et al., 2011; de França et al., 2011; de França et al., 2013; Ezcurra et al., 2017).

Teratosaurus suevicus and *Vivaron haydeni* are added according to the strict consensus tree of Lessner et al. (2016, fig. 10), which is based on a modified data set of Nesbitt (2011).

Bystrowisuchus flerovi is a ctenosauriscid according to Sennikov (2012) and is added accordingly.

Poposaurus langstoni is assumed to be the sister taxon of *Poposaurus gracilis* and is added accordingly.

Vytshegdosuchus zheshartensis is possibly a ctenosauriscid (Butler et al., 2011b; Ezcurra, 2016; Nesbitt (2011, p. 253) recovers it in a large polytomy with other paracrocodylomorph taxa) and is placed accordingly.

Dagasuchus santacruzensis is a 'rauisuchian' member of Loricata (Lacerda et al., 2015) and is added accordingly as an early diverging member of Loricata.

P. loricatus does not belong to the genus *Prestosuchus* (Desojo and Rauhut, 2008, 2009; Lautenschlager and Desojo, 2011). It is therefore not added as the sister taxon to *Prestosuchus chiniquensis* but in a polytomy with the clade consisting of *Prestosuchus chiniquensis*, *Saurosuchus galilei*, *Luperosuchus fractus* + *Decuriasuchus quartacolonia*, and the clade consisting of *Apatosuchus orbitoangulatus* and later diverging loricatans.

Heptasuchus clarki is probably the sister taxon of *Batrachotomus kupferzellensis* (Zawiskie et al., 2011; Nesbitt, 2011; Martz et al., 2012) and is added accordingly.

Alpha taxonomy: *Vytshegdosuchus zheshartensis* is considered a valid rauisuchian by Nesbitt et al. (2013c) and is also mentioned by Niedźwiedzki et al. (2016) and Bernardi et al. (2015). It is thus included in the database.

Ctenosauriscus koeneni is not known from the Upper Buntsandstein (unlike the "Waldshuter Rauisuchier"; (Ebel et al., 1998); (Butler et al., 2011b)) and the database is updated accordingly.

Lythrosuchus is considered a junior synonym of *Poposaurus* by Weinbaum and Hungerbühler (2007), who retain the species *Lythrosuchus langstoni* as *Poposaurus langstoni*. This view is followed by Nesbitt et al. (2013c, Table 1) and thus *Poposaurus langstoni* is treated accordingly herein.

Prestosuchus loricatus is listed as a valid rauisuchian taxon by Nesbitt et al. (2013c, Table 1) and is also mentioned by Lacerda et al. (2015) and Lautenschlager and Rauhut (2015). It is thus included in the database. Note, however, that Lacerda et al. (2016) consider only *Prestosuchus chiniquensis* as a valid species of the genus.

Procerosuchus celer is listed as a "Problematicum" by Nesbitt et al. (2013c, Table 1) and Desojo and Rauhut (2009) refer *Procerosuchus* to *Prestosuchus chiniquensis*. This interpretation is followed herein and the taxon is treated as a junior synonym of *Prestosuchus chiniquensis*. According to Mastrantonio et al. (2013) and Nesbitt et al. (2013c, Table 1) *Procerosuchus celer* is known from the *Dinodontosaurus* AZ and thus from the lower part of the Santa Maria Formation and not from the upper part as reported in the ETD 2013 (Benton et al., 2013a). The data entry is modified accordingly.

Youngosuchus sinensis (= *Vjushkovia sinensis*) is listed as a valid proterosuchian taxon by Ezcurra et al. (2013, Table 1) and is also mentioned by Nesbitt et al. (2013a), Gower et al. (2014), Liu and Abdala (2015), and Ezcurra (2016). Thus, the taxon is included in the database.

According to Nesbitt (2011, p. 29) the skull of *Heptasuchus* does not belong to *Poposaurus gracilis* and Nesbitt et al. (2013c, Table 1) thus list *Heptasuchus clarki* as a separate valid taxon. This view is followed herein and the species is treated accordingly.

Long and Murry (1995, Appendix II: p. 236) report *Postosuchus kirkpatricki* also from the "Pre-Tecovas Horizon" of Texas (see also Weinbaum, 2013, Appendix II; but see Stocker, 2013, p. 97, 98). Parker (2016) reports *Postosuchus kirkpatricki* only from the Post Quarry of Texas, situated in the Cooper Canyon Formation. Indeed, none of the material known from the "Pre-Tecovas Horizon", Los Esteros Member (Santa Rosa Formation), Placerias Quarry, and Owl Rock Formation reported by Long and Murry (1995, Appendix II: p. 236, 237) can be confidently assigned to the taxon until an apomorphy based comparison is carried out (W. G. Parker, pers. comm., 2018; S. J. Nesbitt, pers. comm., 2018). Currently, only the Post Quarry material should be assigned to *Postosuchus kirkpatricki* (W. G. Parker, pers. comm., 2018). The stratigraphic range of the taxon is updated accordingly.

Pallisteria angustimentum is mentioned by Nesbitt et al. (2013a). The taxon, named by A. J. Charig in Appleby et al. (1967), is a *nomen nudum* (Barrett et al., 2015) and is thus excluded from the database. Note, that some authors consider the material assigned to *Pallisteria* diagnostic (Sidor et al., 2013, Supporting Information: p. 3).

The ctenosauriscid 'Waldhaus taxon' from the German Röt Formation, described by Butler et al. (2011b) and listed by Nesbitt et al. (2013c, Table 1) as a valid rauisuchian taxon, is not included, pending recovery of more complete remains and the subsequent assignment to a (new?) taxon. The same applies to the 'Moenkopi Shuvosaurid', 'Otis Chalk taxon' and the specimen SAM 383 as listed by Nesbitt et al. (2013c, Table 1).

Fenhosuchus cristatus is mentioned among the "Problematica" in Nesbitt et al. (2013c, Table 1) and is based on undiagnostic material (Gower, 2000; Liu et al., 2015a). It is thus excluded from the database.

Scythosuchus basileus is listed among the "Problematica" by Nesbitt et al. (2013c, Table 1). Thus, it is excluded from the database. It should be noted, however, that Sennikov (2012) considers it to be valid and reports new material for the taxon from Donskaya Luka (it is also mentioned by Sennikov, 2015).

Tsylmosuchus is mentioned by Niedźwiedzki et al. (2016) and *Tsylmosuchus donensis* is mentioned by Sennikov (2012) and Sennikov (2015), but Nesbitt et al. (2013c, Table 1) consider all three species of the genus (see also Gower and Sennikov, 2000) to be "Problematica" and thus they are excluded from further analyses, except for *Tsylmosuchus samariensis* which is a synonym of *Chasmatosuchus rossicus* (Ezcurra, 2016) and treated accordingly. Similarly, *Jushatyria vjushkovi* is also mentioned by Sennikov (2012) but regarded a "Problematicum" (Nesbitt et al., 2013c, Table 1) and thus excluded from the database. Sennikov (2012) also mentions *Energosuchus* and *Energosuchus garjainovi* is listed by Raugust (2014, Quadro 1), but it is regarded a “Problematicum” (Nesbitt et al., 2013c, Table 1) and thus excluded from the database.

A.35.4 Crocodylomorpha

Phylogeny: The strict consensus tree of Lecuona et al. (2016, fig. 14) is used as scaffold for the crocodylomorph part of the tree (for a different topology of basal Crocodylomorpha see Leardi et al., 2017). The analysis of Lecuona et al. (2016) is based on an expanded and modified character matrix of Lecuona (2013) which is itself based on Nesbitt (2011). This dataset also includes the modifications proposed by Butler et al. (2014a), Zanno et al. (2015) and Drymala and Zanno (2016). *Redondavenator quayensis* and *Saltoposuchus connectens* are added according to the strict consensus tree of Leardi et al. (2017, fig. 16), which is based on an expanded dataset of Pol et al. (2013). Leardi et al. (2017, fig. 16) recover *Erpetosuchus* as an early diverging crocodylomorph, but this result is not further taken into account when adding *Redondavenator quayensis*. Leardi et al. (2017, p. 43) themselves describe this result as “preliminary”.

The clade Thalattosuchia is added according to the strict consensus tree of Ősi et al. (2018, fig. 11), which is based on a modified character matrix of Wilberg (2017).

Eopneumatosuchus colberti is added according to the strict consensus tree of Ristevski et al. (2018, fig. 28), which is based on the merged and modified data matrices of Young et al. (2017).

Calsoyasuchus valliceps is added according to the strict consensus tree of Wilberg (2015b, fig. 2), which is based on a modified character matrix of Wilberg (2015a).

Edentosuchus sp. from the Early Jurassic Kayenta Formation (Clark and Fastovsky, 1986; Sues et al., 1994) and *Hemiprotosuchus leali* are added according to the strict consensus tree of Dal Sasso et al. (2017, fig. 7), which is based on an expanded character matrix of Fiorelli et al. (2016).

The potential atoposaurid from the Early Jurassic of Japan (Manabe and Hasegawa, 1998) is placed according to the the strict consensus tree of Wilberg (2015b, fig. 2). Member of Atoposauridae are definitely known from the Middle Jurassic (Young et al., 2016b).

Pedeticosaurus leviseuri is a crocodylomorph and possibly an early member of Crocodyliformes (Irmis et al., 2013a). It is placed as sister taxon to *Terrestrisuchus gracilis* according to the cladogram of Sereno and Wild (1992, fig. 12B).

According to Whetstone and Whybrow (1983) *Stegomosuchus longipes* is probably a ‘protosuchian’ and Walker (1968) describes *Stegomosuchus longipes* as closely resembling *Protosuchus*. *Stegomosuchus longipes* is added accordingly, forming a polytomy with *Hemiprotosuchus leali* and the genus *Protosuchus*.

Phyllodontosuchus lufengensis is a crocodylomorph (Irmis et al., 2013a) and is placed accordingly as an early diverging member of Crocodylomorpha.

Notochampsa istedana is a protosuchian (Whetstone and Whybrow, 1983; Gand et al., 2012) (protosuchid according to Olshevsky, 1991, p. 52) and is therefore placed as an early diverging member of Protosuchia.

Platyognathus hsui is a protosuchian that has more derived character states than *Orthosuchus* and is more closely related to the clade Protosuchidae + *Shantungosuchus* (Wu and Sues, 1996; see also Wu et al., 1994, fig. 10). It is placed accordingly.

Protosuchus micmac differs slightly from the other *Protosuchus* species (Gow, 2000) and is therefore placed as the sister taxon to the clade *Protosuchus richardsoni* + *Protosuchus haughtoni*.

Dianchungosaurus lufengensis is a mesoeucrocodylian (Barrett and Xu, 2005) and is added accordingly.

Alpha taxonomy: *Redondavenator quayensis* is mentioned by Zanno et al. (2015) and listed among the currently valid crocodylomorph taxa by Irmis et al. (2013a, Table 1). It is thus included in the database.

Parrishia mccreai is similar to *Hesperosuchus agilis* (Clark et al., 2001) but is generally considered a *nomen dubium* (Clark et al., 2001; Irmis, 2005b; Irmis et al., 2013a). Long and Murry (1995, Appendix II: p. 237) report *Hesperosuchus agilis* also from the Tecovas Formation of Texas but *Hesperosuchus agilis* is currently considered to be restricted to the Cameron Member of the Chinle Formation of Arizona (Nesbitt, 2011, p. 38, 39; Irmis et al., 2013a). The stratigraphic and palaeobiogeographic range of *Hesperosuchus agilis* is updated accordingly.

The specimens assigned to ?*Edentosuchus* from the Early Jurassic Kayenta Formation (Clark and Fastovsky, 1986; Sues et al., 1994) are retained in the ETD as *Edentosuchus* sp. due to their stratigraphic importance. In Ősi (2014) these specimens are reported as belonging to the 'Kayenta form', which is assigned to Protosuchia indet.

Desojo et al. (2013, Table 2) and von Baczko and Ezcurra (2013, Table 2) list *Stegomosuchus longipes* as a crocodylomorph or member of 'Protosuchia', respectively, even though it is not mentioned by Irmis et al. (2013a, Table 1) among the currently recognized valid early crocodylomorph taxa. Nesbitt et al. (2012) and Collette et al. (2011) mention it as a crocodyliform or crocodylomorph, respectively. It is thus included in the database.

Clark (1986, p. 112) synonymised *Lesothosuchus* with *Protosuchus* and this view is also followed by Benton and Clark (1988), Sues et al. (1996), and Knoll (2005). Indeed, Gow (2000) considers *Lesothosuchus charigi* and *Baroqueosuchus haughtoni* to be synonyms of *Protosuchus haughtoni*. The synonymy of *Baroqueosuchus haughtoni* with *Protosuchus haughtoni* is also mentioned by Nesbitt (2011, p. 42). However, *Lesothosuchus charigi* was erected in 1983 (Whetstone and Whybrow, 1983) while *Baroqueosuchus haughtoni* was erected in 1984 (Busbey and Gow, 1984). Thus - if the synonymy is accepted -, following Article 23 ("Principle of Priority") of the International Code of Zoological Nomenclature the species name should be *Protosuchus charigi* (see also Article 23.3; International Commission on Zoological Nomenclature (ICZN), 1999). Herein, *Lesothosuchus charigi* and *Baroqueosuchus haughtoni* are treated as synonyms of *Protosuchus haughtoni*, but the species name is not changed to *P. charigi* as recent analyses (Lecuona et al., 2016; Leardi et al., 2017) are also still using the species name *P. haughtoni*.

The potential atoposaurid from the Early Jurassic of Japan, described by Manabe and Hasegawa (1998), is retained in the database as “Atoposaurid” due to its stratigraphic importance.

Ristevski et al. (2018) treat *Eopneumatosuchus colberti* as a valid taxon. It is therefore added to the database.

Benton and Taylor (1984) mention that a few specimens of *Pelagosaurus brongniarti* were assigned to *Steneosaurus gracilirostris* by Westphal (1961). They also mention that Steel (1973) synonymised all the specimens of *Pelagosaurus brongniarti* from Whitby (UK) with *Steneosaurus bollensis*. However, Benton and Taylor (1984) still retain *Steneosaurus gracilirostris* as a valid species with the Whitby-Saltwick (UK) specimens BMNH 11589, BMNH R4, and SMC J35177 directly mentioned for this taxon (Benton and Taylor, 1984, p. 427). Indeed, Duffin (1979) reports that Westphal (1961, 1962) regarded *Pelagosaurus brongniarti* as a junior synonym of *Steneosaurus bollensis* [sic!], but also thinks that this might not apply to the specimens BMNH 11589 and BMNH R4. Mueller-Töwe (2006) mentions a specimen of *Pelagosaurus brongniarti* from La Caine (France) that is referred to *Steneosaurus gracilirostris* “with reservations” (Mueller-Töwe, 2006, p. 82). Benton and Spencer (1995, p. 119) also mention *Pelagosaurus brongniarti* as a valid species that is found both in the UK and Germany with approximately eight specimens (Benton and Spencer, 1995, p. 116) known from the British Early Jurassic of the Whitby area.

On the other hand, Pierce and Benton (2006) describe *Pelagosaurus* as a monotypic genus, with the only valid species being *Pelagosaurus typus*. The data portal of the Natural History Museum of London reports the specimens PV OR 11589 (= BMNH 11589) and PV R 4 (= BMNH R4) as belonging to *Steneosaurus gracilirostris* (Natural History Museum, 2014a,b). Thus, *Pelagosaurus typus* is assumed to be the only valid species of *Pelagosaurus* and *Pelagosaurus brongniarti* is included within *Steneosaurus gracilirostris*.

Dollman et al. (2019) provisionally treat *Notochampsa longipes* as a valid taxon, but Kitching and Raath (1984, Table 4) considered it of questionable validity and Clark (1986, p. 182, 183) considered it a *nomen dubium*. The taxon is therefore excluded from further analyses.

Steneosaurus pictaviensis, described by Vignaud (1998), is deleted from the database as its first occurrence is in the middle Callovian.

A.36 ‘Basal’ Avemetatarsalia

Phylogeny: The strict consensus tree of Ezcurra et al. (2017, Supplementary Information: fig. 12, 13), that is used as scaffold for the archosauromorph and archosaurian part of the supertree, also provides the scaffold for the early diverging part of Avemetatarsalia. The position of *Scleromochlus taylori* is modified according to the strict consensus consensus tree of Pinheiro et al. (2016, fig. 4).

Alpha taxonomy: *Spondylosoma absconditum* is treated as a valid taxon by Nesbitt et al. (2017). It is therefore retained in the database.

Perner (2018) described a new avemetatarsalian from the Ladinian of Northern Italy. This taxon is not included, awaiting further description in a peer-reviewed publication and a formal phylogenetic analysis of its relationships.

A.37 Pterosauria

Phylogeny: The time-calibrated tree of Longrich et al. (2018, fig. 16), which is based on an expanded character matrix of Andres et al. (2014), is used as scaffold for Pterosauria. The strict consensus tree of Vidovic and Martill (2018, fig. 4) recovers a slightly different topology, but treats *Raeticodactylus filisurensis* as another specimen of *Caviramus schesaplanensis* (Vidovic and Martill, 2017, Supplementary Material: S.1.1.4. Table of specimens), without any further comment except for citing Dalla Vecchia (2009a). Dalla Vecchia (2009a) did consider *Raeticodactylus filisurensis* to be congeneric with *Caviramus schesaplanensis* (Dalla Vecchia, 2009a, p. 160), but also "prudently" considered the two species as separate (Dalla Vecchia, 2009a, p. 183). Indeed, Dalla Vecchia (2009b) even mentions '*Raeticodactylus*' *schesaplanensis*. Ősi (2011) also considers the genus *Raeticodactylus* a junior synonym of *Caviramus*, but does not discuss the status of the two species. Differences between *Raeticodactylus filisurensis* and *Caviramus schesaplanensis* are mentioned in Dalla Vecchia (2014, p. 215–217), who retains both *Raeticodactylus filisurensis* and *Caviramus schesaplanensis* as separate genera and species but emphasizes their close similarity. As Vidovic and Martill (2018) provide no additional discussion of the status of *Raeticodactylus filisurensis* and *Caviramus schesaplanensis*, the scaffold tree for Pterosauria is based on Longrich et al. (2018, fig. 16) (who include both taxa as separates OTUs) instead of Vidovic and Martill (2018, fig. 4).

Allkaruen koi is added according to the strict consensus tree of Codorniú et al. (2016, fig. 5), which is based on a modified data matrix of Lü et al. (2010b).

Austriadraco dallavecchiai and *Caelestiventus hanseni* are added according to the strict consensus tree of Britt et al. (2018, fig. 5), which is based on an updated character matrix of Dalla Vecchia (2009b).

The partial mandible SMU 69125 assigned to *Eudimorphodon* sp. (Andres and Myers, 2012) is herein assumed to be the sister taxon of *Eudimorphodon ranzii*.

Dimorphodon weintraubi is assumed to be the sister taxon of *Dimorphodon macronyx* and is placed accordingly.

Dorygnathus mistelgauensis is assumed to be the sister taxon of *Dorygnathus banthensis* and *Campylognathoides indicus* is assumed to to be closely related to the other *Campylognathoides* species. The taxa are placed accordingly.

Alpha taxonomy: The specimen from the Late Triassic Seefeld Formation of Austria, described by Wellnhofer (2003) as *Eudimorphodon cf. E. ranzii*, was assigned to the new genus and new species *Austriadraco dallavecchiai* by Kellner (2015). It is retained as such in the ETD.

The specimen MPUM 6009, previously referred to *Carniadactylus rosenfeldi* (Dalla Vecchia, 2009a, 2014), has been considered to represent the new taxon *Bergamodactylus wildi* (Kellner, 2015). Dalla Vecchia (2018) argues against this interpretation and considers *Bergamodactylus wildi* a junior synonym of *Carniadactylus rosenfeldi*. The taxon is treated accordingly in the database.

Eudimorphodon cromptonellus was assigned to the new genus *Arcticodactylus* by Kellner (2015) and is retained as such in the database. Note, however, that both Vidovic and Martill (2018) and Longrich et al. (2018) retain the previous generic assignment (see also Vidovic and Martill, 2017, Supplementary Material: S.1.3.3. List of synapomorphies).

Due to its palaeobiogeographic and stratigraphic importance the partial mandible SMU 69125 assigned to *Eudimorphodon* sp. (Andres and Myers, 2012) is included in the database.

The specimen MCSNB 8950 from the Late Triassic Argillite di Riva di Solto Formation (Italy), mentioned by Dalla Vecchia (2014) as a possible new pterosaur genus and species form, is not included in the database, awaiting the formal erection of a new genus/species. As MCSNB 8950 probably represents a juvenile specimen (Dalla Vecchia, 2014, p. 159), more specimens are needed, to establish a new taxon with confidence. The specimen MCSNB 2887 from the Late Triassic Zorzino Limestone, which is considered ?Eudimorphodontidae indet. (Dalla Vecchia, 2014, p. 229), is not included in the database.

The specimen MFSN 12545 represents a new genus and new species which is currently described (Dalla Vecchia, 2014, p. 228). It will be incorporated into the ETD upon completion of the description.

The presumed pterosaur teeth from the middle/upper Norian to (lower) Rhaetian of Luxembourg and France, described as *Eudimorphodon* sp. by Cuny et al. (1995) and Godefroit and Cuny (1997), are not included, as it's not even clear, whether they represent pterosaur or cynodont teeth (Dalla Vecchia, 2014, p. 263).

The pterosaur remains from the Argentinian Cañadón Asfalto Formation (Unwin et al., 2004; Codorniú et al., 2010) are not included in the database, awaiting the formal erection of a new taxon. The same applies to the new pterosaur from the Nugget Sandstone (Utah, USA; Britt et al., 2015).

A.38 'Basal' Dinosauromorpha and Dinosauria

Phylogeny: The strict consensus tree of Langer et al. (2017b, fig. 1), which is based on a modified data matrix of Baron et al. (2017a), provides the backbone for the early diverging dinosauromorph and early diverging dinosaurian part of the supertree.

The strict consensus tree of Müller et al. (2018b, fig. 4), which is based on a modified data matrix of Cabreira et al. (2016), is used to modify the internal relationships of Lagerpetidae.

Resolution is improved within Silesauridae for the taxa *Sacisaurus agudoensis* and *Diodorus* *scytobrachion* using the strict consensus tree of Müller et al. (2019, fig. 7B), which is based on a modified character matrix of Bittencourt et al., 2015.

Pisanosaurus mertii is also added as member of Silesauridae following the strict consensus tree of Agnolín and Rozadilla (2018, fig. 18B) (see also Baron, 2017), which is based on a modified character matrix of Bittencourt et al. (2015).

Soumyasaurus aenigmaticus is added according to the strict consensus tree of Sarıgül et al. (2018, fig. 3), which is based on an expanded character matrix of Agnolín and Rozadilla (2018).

Nyasasaurus parringtoni is added as the sister taxon to Dinosauria according to the earliest diverging position in the most parsimonious trees of Nesbitt et al. (2013d, Data Supplement: fig. S11) (see also Nesbitt et al., 2013d, fig. 2).

Technosaurus smalli is a silesaurid (Nesbitt et al., 2007; Martz et al., 2012) that is similar to *Silesaurus opolensis* (Nesbitt et al., 2007; Irmis et al., 2007b). Therefore, it is added as the sister taxon of *Silesaurus opolensis*.

Alpha taxonomy: *Dromomeron gregorii* is also known from the Cooper Canyon Formation of Texas (Martz et al., 2012) and this occurrence is included in the database.

A few analyses of Nesbitt (2011) code *Lewisuchus/Pseudolagosuchus* as a single operational taxonomic unit. According to Bittencourt et al. (2015) *Lewisuchus admixtus* cannot be synonymized with *Pseudolagosuchus major*, because there is not enough overlap between the preserved specimens. Novas et al. (2015) report a new specimen that lends support to the synonymy of the two taxa and Sarıgül et al. (2018) follow this interpretation. *Pseudolagosuchus major* is therefore treated as a junior synonym of *Lewisuchus admixtus*. Note, however, that Cabreira et al. (2016) and Agnolín and Rozadilla (2018) still treat the two species as being separate.

Saltopus elginensis was redescribed by Benton and Walker (2010) and is considered a valid dinosauriform by Langer et al. (2013, Table 1). It is thus included in the database.

Part of the holotype of *Alwalkeria maleriensis* represents a saurischian (Novas et al., 2011; Ezcurra, 2012) and the species is placed accordingly as an early diverging member of Saurischia. Note, that the holotype of this taxon is a chimera (Remes and Rauhut, 2005; Lecuona et al., 2016) and the cranial remains probably belong to a crocodylomorph while the distal half of the femur shows pseudosuchian affinities (Lecuona et al., 2016).

Desojo et al. (2012) and Holz (2015) mention *Teyuwasu barberenai* (Müller et al. (2014, p. 118) mention it as a “problematic” taxon) but it is a *nomen dubium* according to Langer (2004), Langer et al. (2010), and Ezcurra (2012) and the taxon is thus excluded from the database.

Lagosuchus talampayensis is a reported as a *nomen dubium* by Langer et al. (2013, Table 1) and is thus excluded from the ETD.

A.38.1 Sauropodomorpha

Phylogeny: *Buriolestes schultzi*, *Eoraptor lunensis*, *Pampadromaeus barberenai*, *Panphagia protos*, *Saturnalia tupiniquim*, and *Chromogisaurus novasi* are added using the abbreviated strict consensus tree of the third analysis of Müller et al. (2018a, fig. 39C), which is based on a modified character matrix of Cabreira et al. (2016). *Bagualosaurus agudoensis* is added according to the strict consensus tree of Pretto et al. (2019, fig. 11A), which is also based on a modified character matrix of Cabreira et al. (2016).

The scaffold tree for Sauropodomorpha is provided by the reduced strict consensus tree of Bronzati et al. (2018, fig. 2) (based on a modified character matrix of Bronzati and Rauhut, 2018), except for the early diverging sauropodomorph taxa mentioned above. The abbreviated strict consensus tree of McPhee and Choiniere (2018, fig. 15) is quite similar but differs substantially in the position of *Riojasaurus incertus* and other riojasaurid taxa. The authors themselves, however, stress the "provisional nature" (McPhee and Choiniere, 2018, p. 849) of the result and the presented topology is therefore not further considered herein. For the same reason the abbreviated strict consensus tree of Zhang et al. (2018, fig. 7A), which is based on an expanded character matrix of McPhee and Choiniere (2018), is only used except to add *Eucnemesaurus entaxonis* and *Yizhousaurus sunae*. *Ledumahadi mafube* is added according to the abbreviated strict consensus tree of McPhee et al. (2018, fig. 2), which is also based on an expanded character matrix of McPhee and Choiniere (2018).

The reduced strict consensus tree of Otero et al. (2015, fig. 17) is used to add *Plateosaurus ingens*.

Sarahsaurus aurifontanalis, *Sefapanosaurus zastronensis*, *Camelotia borealis*, and *Ingentia prima* are added according to the reduced strict consensus tree of Apaldetti et al. (2018, Supplementary Information: Supplementary fig. 9b), which is based on an updated dataset of Cerda et al. (2017).

The strict consensus tree of Sekiya et al. (2014, fig. 40) is used to further expand the sauropodomorph part of the supertree, adding the taxa *Gyposaurus sinensis*, *Yunnanosaurus robustus*, and *Lamplughsaura dharmaramensis*.

Arcusaurus pereirabdalorum and *Gryponyx africanus* are added according to the strict consensus tree (without constraining *Arcusaurus* to fall within Plateosauria) of Yates et al. (2011, fig. 13A) (see also Peyre de Fabrègues et al., 2015, fig. 2A).

The taxa *Nambalia roychowdhurii*, *Jaklapallisaurus asymmetrica*, and *Pradhania gracilis* are added according to the strict consensus tree of Novas et al. (2011, fig. 4).

Sellosaurus gracilis (which herein is only represented by the specimen SMNS 17928; see below) is added as sister taxon to *Efraasia minor* according to the strict consensus tree of Yates (2003c, fig. 8), which includes the relevant specimen as a separate OTU.

Chuxiongosaurus lufengensis is added according to the most parsimonious tree of Lü et al. (2010a, fig. 5). It should be noted, however, that this analysis is problematic and methodological errors in the outgroup choice can be assumed (see also Mortimer, 2011). Indeed, Ornithischia (and not Sauropodomorpha!) is recovered as sister taxon to Theropoda, thus not recovering the monophyletic Saurischia in the traditional sense (Langer, 2004; Butler et al., 2008; Langer, 2014; but see Baron et al., 2017a).

Massospondylus kaalae is added as the sister taxon of *Massospondylus carinatus* according to the strict consensus tree of Baron et al. (2017a, Extended Data fig. 3).

Xingxiulong chengi is added according to the abbreviated reduced consensus tree of Wang et al. (2017c, fig. 5), which is based on an expanded character matrix of McPhee et al. (2015).

Xixiposaurus suni is added as sister taxon to *Mussaurus patagonicus* according to the 50% majority rule consensus tree of Sekiya (2010, fig. 6).

Meroktenos thabanensis is added according to the majority rule consensus tree of Peyre de Fabrègues and Allain (2016, fig. 9B), which is based on an updated data matrix of Apaldetti et al. (2014).

Chinshakiangosaurus chunghoensis and *Amygdalodon patagonicus* are added according to the strict consensus tree of Upchurch et al. (2015, fig. 15).

Kotasaurus yamanpalliensis is added according to the strict consensus tree of Mocho et al. (2014, fig. 25B).

Tonganosaurus hei is added according to the strict consensus tree of Yang (2013, fig. 4) as a member of Mamenchisauridae.

The single most parsimonious tree of Barrett et al. (2007, fig. 9) or the strict consensus cladogram of Kutty et al. (2007, fig. 20B) could be used to place *Euskelosaurus browni*, but the codings for the OTU are (mainly) based on material that is now assigned to *Plateosauravus cullingworthi*. Therefore, *Euskelosaurus browni* is placed as an early diverging member of Sauropodomorpha, following the interpretation of the holotype of Yates (2003a).

Yimenosaurus youngi is possibly an early diverging sauropod (Upchurch et al., 2007; Barrett and Upchurch, 2007) and is placed accordingly.

Upchurch et al. (2004, Table 13.1) consider *Ohmdenosaurus liasicus* to be a sauropod, and this view is also followed by Nair and Salisbury (2012) and Stumpf et al. (2015), the latter two describing it as being similar to *Rhoetosaurus brownei*. Therefore, *Ohmdenosaurus liasicus* is placed as an early diverging member of sauropods.

Sanpasaurus yaoi is probably the most derived non-eusauropodan sauropod currently known, with affinities to 'vulcanodontids', which are regarded as paraphyletic by McPhee et al. (2016). The taxon is treated accordingly and added to a polytomy consisting of *Vulcanodon karibaensis*, other early diverging sauropods and the clade consisting of later diverging sauropods and Eusauropoda.

Alpha taxonomy: Yates (2003a) considers the type specimen of *Euskelosaurus browni* to be undiagnostic and regards it as a *nomen dubium* (see also Yates, 2003b; Yates, 2007a). Most of the other material, that had been referred to *Euskelosaurus browni* previously, is now referred to *Plateosauravus cullingworthi* and other basal sauropodomorphs (Yates, 2003a; Barrett, 2009a;

McPhee et al., 2014). Otero et al. (2015, Table 2), however, still list the holotype of *Euskelosaurus browni* (BMNH R1625) as a separate taxon, and indeed they treat the taxon in the article implicitly as separate from *Plateosauravus cullingworthi* (see Otero et al., 2015, p. 599). Therefore, *Euskelosaurus browni* is retained in the database (based on the holotype). A few other elements from the Bushveld Sandstone of South Africa and from the Mpandi Formation of Zimbabwe, that have not been reassigned (van Heerden, 1979; Cooper, 1980; Galton and Upchurch, 2004), are also retained in the database for *Euskelosaurus browni*. It should be mentioned, however, that the referral of these specimens might only be based on the previous status of *Euskelosaurus browni* as a 'waste-basket' taxon (McPhee et al., 2014; D. J. Button, pers. comm., 2015). Note, that McPhee et al. (2017) follow Yates (2003a) in considering *Euskelosaurus browni* a *nomen dubium*, but also entertain the idea of an additional *Euskelosaurus* morphotype in the Lower Elliot Formation.

The taxa *Nambalia roychowdhurii* and *Jaklapallisaurus asymmetrica* were erected by Novas et al. (2011) and are also mentioned by Ezcurra and Apaldetti (2012), Kammerer et al. (2016c, fig. 2), and Whiteside et al. (2015, Supporting Information: Table S4). They are thus included in the database.

The figure caption of Galton et al. (2005, fig. 1.1) mentions *Sellosaurus* as being equal to *Efraasia*. Indeed, among others, part of the material that was previously assigned to *Sellosaurus gracilis* was referred to *Efraasia minor* by Yates (2003c). However, Yates (2003c) only created the new combination *Efraasia minor*, not *Efraasia gracilis*. Furthermore, Yates (2003c) referred the holotype of *Sellosaurus gracilis* to the genus *Plateosaurus*, creating the taxon *Plateosaurus gracilis* (see above). The taxon *Efraasia gracilis* is not mentioned in subsequent literature and is thus deleted from the ETD. The taxon *Efraasia minor*, which is mentioned by several publications (e.g., Prieto-Márquez and Norell, 2011; Yates et al., 2012; Delcourt et al., 2012; Otero and Pol, 2013; Holliday and Nesbitt, 2013; Sues and Schoch, 2013c; von Baczko et al., 2014; Apaldetti et al., 2014; Whiteside et al., 2015; Otero et al., 2015) is retained instead. Yates (2003c) also referred the specimen SMNS 17928 to *Efraasia minor*. Ezcurra and Apaldetti (2012, Table 2) assign the same specimen to *Plateosaurus gracilis*. Otero and Pol (2013, Table 1) and Otero et al. (2015, Table 1), on the other hand, retain *Sellosaurus gracilis*, based on the specimen SMNS 17928, as separate from *Efraasia minor*. This view is followed herein and *Sellosaurus gracilis* is retained in the data matrix. As mentioned before, however, the holotype of *Sellosaurus gracilis* remains assigned to *Plateosaurus gracilis* (following Yates, 2003c). SMNS 17928 is also the only specimen of *Sellosaurus gracilis* (previously assigned to *Efraasia gracilis* in the original version of the ETD; see above), that is known from the Lower Stubensandstein (Yates, 2003c). Therefore, *Efraasia minor* is restricted to the Middle Stubensandstein.

The taxonomy of *Plateosaurus* is relatively controversial (e.g., Moser, 2003; Galton and Upchurch, 2004; Prieto-Márquez and Norell, 2011; Galton, 2012; Demirjian, 2012; Sues, 2013; Galton, 2013; Hofmann and Sander, 2014). According to Hofmann and Sander (2014) *Plateosaurus* specimens from Trossingen and Halberstadt (Germany) can be assigned to *Plateosaurus engelhardti*. As these specimens also include the type of *Plateosaurus longiceps* (see also Moser, 2003), *Plateosaurus longiceps* is herein regarded a junior synonym of *Plateosaurus engelhardti* (see also Reiss and Mallison, 2014). Even if Prieto-Márquez and Norell (2011) are right in considering *Plateosaurus longiceps* a junior synonym of *Plateosaurus erlenbergiensis*, the taxon would still be a junior synonym of *Plateosaurus engelhardti* following Moser (2003). Note, however, that Chapelle and Choiniere (2018) treat *Plateosaurus erlenbergiensis* as a valid taxon. Hofmann and Sander (2014) do not mention that the *P. gracilis* specimens from the Löwenstein Formation of Stuttgart (Germany) can be assigned to *Plateosaurus engelhardti*. McPhee et al. (2015, fig. 5) and Bronzati and Rauhut (2018, fig. 13) include *Plateosaurus gracilis* in their phylogenetic analysis as a separate species. Thus, *Plateosaurus gracilis* is retained as a valid species (see also Yates, 2003c). *Plateosaurus ingens* is also included in the database as it is included in the phylogenetic analysis of Otero et al. (2015, fig. 17) and the character matrix of Müller et al. (2016, Appendix 1) as a separate taxon.

Note, that the assignment of specimens from the Fleming Fjord Formation of Greenland to *Plateosaurus engelhardti* (Jenkins et al., 1994) is uncertain (Marzola et al., 2018).

Gyposaurus sinensis is recovered as a separate species from *Anchisaurus polyzelus* in the phylogenetic analysis of Sekiya et al. (2014, fig. 40) and is retained as a separate species in Benson et al. (2014b, Dataset S1). It is thus included in the database.

When describing the cranial osteology of *Lufengosaurus huenei* Barrett et al. (2005) mentioned that an assessment of the taxonomic status of *Lufengosaurus magnus* would be done later on (see also Barrett and Xu, 2012). So far, this work has not been carried out (P. Barrett, pers. comm., 2015). Benson et al. (2014b) mention only *Lufengosaurus magnus*. It is also the only the species of *Lufengosaurus* that they include in their analyses (Benson et al., 2014b, Dataset S1). On the other hand, the dinosaur dataset of Benton (2015b) only includes *Lufengosaurus huenei* (Benton, 2015a, Appendix 3). Sekiya and Dong (2010) mention a juvenile specimen of *Lufengosaurus huenei* that they sought to distinguish from *Lufengosaurus magnus*. However, most authors have regarded *Lufengosaurus magnus* as a junior synonym of *Lufengosaurus huenei* previously (Rozhdestvenskii, 1965; Galton and Upchurch, 2004; Smith and Pol, 2007). This view is followed herein.

Sekiya et al. (2014) report a juvenile specimen of *Yunnanosaurus robustus* from either the Fengjiahe Formation (Early Jurassic) or the Zhanghe Formation (Middle Jurassic). As all other specimens of *Yunnanosaurus robustus* are known from the Lower Jurassic Lufeng Formation, it is assumed herein that the juvenile specimen belongs to the correlated Fengjiahe Formation.

Xixiposaurus suni was erected by Sekiya (2010) and is mentioned by by Xing et al. (2015a, Table 1) and Xing et al. (2015b, Table 1). It is thus included in the database. It was probably found in the "Dull Purplish Beds" of the Lower Lufeng Formation (T. Sekiya, pers. comm., 2015).

Chuxiongosaurus lufengensis was erected by Lü et al. (2010a) and is mentioned by Xing et al.

(2015a, Table 1) and Xing et al. (2015b, Table 1). It is thus included in the database.

A few specimens from the Navajo Sandstone have been referred to *Ammosaurus* (*cf.*) *major* (Galton, 1971, 1976; Galton and Upchurch, 2004) but this referral is probably not correct (Yates, 2004; Irmis, 2005a; Sereno, 2007). The stratigraphic range of the taxon is treated accordingly. Furthermore, *Ammosaurus major* appears to be the junior synonym of *Anchisaurus polyzelus* (Yates, 2004; Fedak and Galton, 2007; Yates, 2010). The taxon is herein treated accordingly. Note, however, that Apaldetti et al. (2013) still treat the two taxa as separate in one of their phylogenetic analyses (Apaldetti et al., 2013, fig. 18).

Rauhut (2003a) considers *Amygdalodon patagonicus* to be of late Toarcian to Aalenian age. The specimens stem from the Cerro Carnereo Formation, which represents the basal formation of the Lonco Trapial Group and is itself overlain by the Lonco Trapial Formation (= Cañadón Puelman) Formation (Rauhut, 2003b). Carballido and Pol (2010) and Otero and Reguero (2013) follow Rauhut (2003b) in his age assignment. New geochronological data of Cúneo et al. (2013) suggest an even older age (early Pliensbachian to early Toarcian; see also Elgorriaga et al., 2015; but see Hauser et al., 2017) for the Lonco Trapial Formation, which they consider to be synonymous with the Lonco Trapial Group. Indeed, Cúneo et al. (2013) mention the Taquetrén Formation, the Cerro Carnerero Formation, and the Cañadón Puelman beds among the various names for different facies of the Lonco Trapial Formation. Thus, the Cerro Carnereo Formation *sensu* Rauhut (2003a) is herein considered to represent the lower part of the Lonco Trapial Formation *sensu* Cúneo et al. (2013). *Amygdalodon patagonicus* is included in the database and its stratigraphic occurrence is treated accordingly.

Ohmdenosaurus liasicus is mentioned by Nair and Salisbury (2012) and Stumpf et al. (2015) and is also considered a valid taxon by Upchurch et al. (2004). Thus, this taxon is included in the database.

Sanpasaurus yaoi is a valid taxon according to McPhee et al. (2016) and is therefore added to the database.

Peyre de Fabrègues and Allain (2016) assign *Melanorosaurus thabanensis* to the new genus *Meroktenos* and report it for the lower member of the Elliot Formation of Lesotho instead of the upper one. It is treated accordingly.

Antetonitrus ingenipes was found in the upper (not lower!) Elliot Formation (Peyre de Fabrègues and Allain, 2016) and its stratigraphic range is updated accordingly.

Isanosaurus attavipachi was found in the Nam Phong Formation which at the time was considered to be late Norian to Rhaetian, thus making the taxon the oldest known sauropod (Buffetaut et al., 2000). A recent analysis (Racey and Goodall, 2009) indicates, however, that the formation can be divided into a lower and upper part, the latter one not being older than Pliensbachian. Due to outcrop conditions it is difficult to say whether *Isanosaurus attavipachi* stems from the late Norian to Rhaetian Lower Nam Phong Formation or from the Jurassic Upper Nam Phong Formation (E. Buffetaut, pers. comm., 2018). The matrix that yielded the type specimens was not analysed for palynomorphs (E. Buffetaut, pers. comm., 2018) and the late Triassic age assignment was based on previous reports from other parts of the Nam Phong Formation (Racey et al., 1996; Buffetaut et al., 2000). Therefore, there is currently no empirical evidence for an assignment of the specimens to the Lower Nam Phong Formation. Considering the phylogenetic position of *Isanosaurus attavipachi*, it is more likely, that the specimens were found in the Upper Phong Formation and are thus of Jurassic age. Following the Early Jurassic (Pliensbachian-Toarcian) age assignment of McPhee et al. (2017) to *Isanosaurus attavipachi* the taxon is herein treated as stemming from the Upper Phong Formation (see also McPhee et al., 2015).

The specimens of *Yunnanosaurus youngi* were found in the lower Middle Jurassic Zhanghe Formation (Yunnan Province, China; Lü et al., 2007; Xing et al., 2015a). This species is therefore deleted from the ETD as its occurrence lies outside the herein analysed timeframe.

Pachysuchus imperfectus is a sauropodomorph that is taxonomically indeterminate at genus and species level according to Barrett and Xu (2012). It is thus excluded from the database.

Zizhongosaurus chuanchengensis is mentioned by Xing et al. (2014b) and Li et al. (2011b), but it is a *nomen dubium* according to Upchurch et al. (2004, Table 13.1) and its preservation quality is too low to allow diagnosis (McPhee et al., 2015). It is thus excluded from the database.

Spinophorosaurus nigerensis is not included in the database, as it is probably of Middle Jurassic age (Remes et al., 2009). It should be noted, however, that the "Argiles de l'Irhazer"/Irhazer Clays Formation (Remes et al., 2009; Van Damme et al., 2015) of the Irhazer Group, in which *Spinophorosaurus nigerensis* was found, might be older (Remes et al., 2009), possibly spanning the time from the Early to early Middle Jurassic (Van Damme et al., 2015).

The two early diverging eusauropods mentioned for the lower part of the Cañadón Asfalto Formation (Chubut Province, Argentina) (Pol et al., 2009; Cúneo et al., 2013; Holwerda et al., 2015) are not included, awaiting the formal erection of new taxa.

A.38.2 Theropoda

Phylogeny: The relationships of early diverging theropods are based on the strict reduced consensus tree of Ezcurra (2017, fig. 12: 2), which is based on an updated and expanded character matrix of Nesbitt et al. (2009a) including the modifications introduced by Ezcurra and Brusatte (2011), You et al. (2014), and Nesbitt and Ezcurra (2015).

Sanjuansaurus gordilloi is added as the sister taxon of *Herrerasaurus ischigualastensis* using the strict consensus tree of Langer et al. (2017b, fig. 1), which also provides the backbone for the early diverging dinosauromorph and early diverging dinosaurian part of the supertree (section A.38).

Caseosaurus crosbyensis is added according to the reduced strict consensus tree of Baron and Williams (2018, fig. 4B), taking also into account the additional analyses of Baron and Williams (2018) and the previous status of the taxon as a putative herrerasaurid (Nesbitt et al., 2007). The associated character matrix is based on the work of Baron et al. (2017a). Note, however, that Baron and Williams (2018, fig. 4A, B) recover Herrerasauria as the sister taxon of Dinosauria and not as the earliest diverging clade of theropods (Müller et al., 2019; Ezcurra, 2017) or the sister taxon of Sauropodomorpha (Baron et al., 2017a).

Non-coelophysoid Neotheropoda, including *Sarcosaurus woodi*, *Zupaysaurus rougieri*, *Lophostropheus airelensis*, *Liliensternus liliensterni*, *Dracovenator regenti*, *Dilophosaurus wetherilli*, and Averostra, are added according to the reduced strict consensus tree of Wang et al. (2017b, Supplemental Information: fig. S2A).

Guaibasaurus candelariensis is added as sister taxon to *Chindesaurus bryansmalli* + other Theropoda and *Agnosphitys cromhallensis* is added as sister taxon to this clade, following the strict consensus tree of Apaldetti et al. (2014, fig. 9D) (for a different placement of *Guaibasaurus candelariensis* see Bittencourt et al. (2015, fig. 13A), Cabreira et al. (2016, fig. S3A), Müller et al. (2019, fig. 7B), and Agnolín and Rozadilla (2018, fig. 18B)).

The single most parsimonious tree (see also S1.5.2. in “S1: Supporting Information” of Martill et al., 2016) of Martill et al. (2016, fig. 28), which is based on an updated data matrix of You et al. (2014), is used to add the taxa *Daemonosaurus chauliodus* and *Dracoraptor hanigani*.

Gojirasaurus quayi is added according to the majority rule consensus tree of Ezcurra and Novas (2007, fig. 12B).

The strict consensus tree of Martínez and Apaldetti (2017, fig. 11), which is based on an updated and expanded character matrix of Nesbitt and Ezcurra (2015), is used to add the taxa *Lucianovenator bonoi* and *Cryolophosaurus ellioti*.

The strict consensus tree of Langer et al. (2014, fig. 4) is used to add the taxon *Tachiraptor admirabilis*.

The enigmatic *Eshanosaurus deguchiianus* is added according to the strict consensus tree of Clark et al. (2004, fig. 7.8A), which reports it as a member of Therizinosauroidea. It should be mentioned, however, that the phylogenetic affinities and the stratigraphic occurrence of the taxon are controversial, as it might represent a sauropodomorph or could actually belong to the Early Cretaceous rather than the Early Jurassic (Xu et al., 2001; Rauhut, 2003b; Barrett, 2009b; Brusatte et al., 2010c; Zanno, 2010).

Smok wawelski is an early predatory dinosaur (Zatoń et al., 2015) and appears to be the sister taxon of Herrerasauridae (G. Niedźwiedzki, pers. comm., 2015). It is added accordingly.

Martill et al. (2016) recover *Dracoraptor hanigani* as the earliest diverging coelophysoid in their analysis. *Podokesaurus holyokensis* is a coelophysoid as well (Tykoski and Rowe, 2004; Carrano et al., 2005; Ezcurra and Cuny, 2007) and is placed accordingly as an early diverging member of Coelophysoidea as recovered by Martill et al. (2016).

The specimen from the Lower Jurassic of Yunnan (China) described as *cf. Megapnosaurus* sp. (Irmis, 2004) and herein retained as “*Megapnosaurus* sp.” is assumed to be the sister taxon of *Megapnosaurus rhodesiensis*, as *Megapnosaurus kayentakatae* probably belongs to a different genus (Ezcurra, 2017, fig. 12). The taxon is placed accordingly.

According to Wang et al. (2017a), who recognize both *Sinosaurus triassicus* and *Sinosaurus sinensis* as valid species, *Shuangbaisaurus anlongbaoensis* is similar to *Sinosaurus*. Herein, *Sinosaurus triassicus* is treated as a *nomen dubium* and *Sinosaurus sinensis* is retained as '*Dilophosaurus*' *sinensis* (see below). *Shuangbaisaurus anlongbaoensis* is therefore added as the sister taxon of '*Dilophosaurus*' *sinensis*.

Alpha taxonomy: Brinkman and Sues (1987) reported *cf. Staurikosaurus* sp. from the Ischigualasto Formation of Argentina, but this specimen was later referred to *Herrerasaurus* (Novas, 1994; Sereno and Novas, 1994) and so far *Staurikosaurus pricei* is only known from the Santa Maria Formation of Brazil (Bittencourt and Kellner, 2009). The data for *Staurikosaurus pricei* in the ETD is modified accordingly.

Agnosphitys cromhallensis is reported as a 'problematic' taxon by Langer et al. (2013, Table 1). However, unlike *Lagosuchus talampayensis*, Langer et al. (2013, Table 1) do not consider *Agnosphitys cromhallensis* to be a *nomen dubium*. It is thus included in the database.

Syntarsus rhodesiensis Raath, 1969 had been assigned to the genus *Coelophysis* (Downs, 2000; Bristowe and Raath, 2004; Ezcurra and Brusatte, 2011; Carrano et al., 2012; Nesbitt and Ezcurra, 2015) but the new results recovered by Ezcurra (2017) indicate that the taxonomic combination *Megapnosaurus rhodesiensis* should be used instead. The taxon is therefore retained in the database as *Megapnosaurus rhodesiensis*. Recent phylogenetic analyses retain "*Syntarsus*" *kayentakatae* (Nesbitt and Ezcurra, 2015, fig. 5; Ezcurra, 2017, fig. 12). It should be mentioned, however, that the genus name *Syntarsus* can no longer be considered valid for this theropod, as it is already preoccupied by a beetle belonging to the Colydiinae (Ivie et al., 2001). Ivie et al. (2001) created the replacement name *Megapnosaurus* for the taxon *Syntarsus* Raath, 1969. Even though this nomenclatural act was deemed controversial (Holden, 2002), the genus name *Syntarsus* Raath, 1969 is clearly not valid for this coelophysoid and thus *S. kayentakatae* is retained in the database as *Megapnosaurus kayentakatae*. Note, however, that the results of Ezcurra (2017, fig. 12) indicate that *M. kayentakatae* belongs to a (new) different genus.

The specimen from the Lower Jurassic of Yunnan (China) described as *cf. Megapnosaurus* sp. (Irmis, 2004) is retained in the database due to its palaeobiogeographic significance as "*Megapnosaurus* sp.".

Carrano and Sampson (2004) consider both *Sarcosaurus woodi* and *Sarcosaurus andrewsi nomina dubia*, but mention also that *Sarcosaurus woodi* is "probably distinct from other known taxa based on its provenance" (Carrano and Sampson, 2004, p. 541). Indeed, Tykoski and Rowe (2004, Table 3.1) report *Sarcosaurus woodi* as a valid taxon (assigned to Ceratosauria *incertae sedis*) and *Sarcosaurus andrewsi* as a *nomen dubium*. Naish and Martill (2007) also consider *Sarcosaurus* a *nomen dubium*. Brusatte et al. (2010c, Table 1) report *Sarcosaurus andrewsi* as a valid taxon and it is also mentioned by Delsate and Ezcurra (2014). However, recent studies only include *Sarcosaurus woodi* (Benson et al., 2014b, Dataset S1; Wang et al., 2017b, Supplemental

Information: fig. S2, S3; Character Matrix; Baron et al., 2017a, Supplementary Information: Table S3). Following Carrano and Sampson (2004) and Tykoski and Rowe (2004), *Sarcosaurus andrewsi* is treated as a *nomen dubium* by Benton (2015a, Appendix 3) and Milner and Barrett (2016). Thus, only *Sarcosaurus woodi* is included in the database. von Huene (1932a, p. 49–51) referred additional material from the lower Lias (Bucklandi zone) of Wilmcote (Warwickshire, UK) to *Sarcosaurus woodi*. According to Carrano and Sampson (2004) general morphological similarity and identical stratigraphic provenance allow to identify the specimen as *cf. Sarcosaurus woodi*, but no uniquely derived feature is shared by the type and the referred material. The type specimen, however, is probably not of Sinemurian age and therefore belongs to a different horizon (Naish and Martill, 2007; see also Martin et al., 1986; contra von Huene (1932a, p. 49); Carrano and Sampson, 2004). Despite this, Naish and Martill (2007), do not argue against the referral of the Wilmcote specimen, which is therefore retained in the database for *Sarcosaurus woodi*.

Dilophosaurus sinensis is often treated as a junior synonym of *Sinosaurus triassicus* (Dong, 2003; Xing et al., 2013, 2014a) but Wang et al. (2017b, Supplemental Information) argue against such an interpretation and consider *Sinosaurus* a *nomen dubium*. Indeed, the holotype of *Sinosaurus triassicus* consists only of a maxilla fragment and is also considered a *nomen dubium* by Irmis (2004). Herein, *Sinosaurus triassicus* is treated as a *nomen dubium*. *Dilophosaurus sinensis*, on the other hand, is considered a valid taxon (Wang et al., 2017b, Supplemental Information), albeit not belonging to the genus *Dilophosaurus*, and is therefore retained as '*Dilophosaurus*' *sinensis* in the database.

Velocipes guerichi, represented by a fragment of a fibula, possibly belongs to Neotheropoda but it can only safely be assigned to Theropoda indet. (Skawiński et al., 2017). The taxon is therefore excluded from further analyses.

'*Saltriosaurus*' is mentioned by Hendrickx et al. (2015) among the first averostrans, but it is a *nomen nudum* (Dal Sasso, 2003; Carrano et al., 2012) and it is thus excluded from the database.

Young (1948) described *Lukousaurus yini* as a coelurosaurian and Xing et al. (2013) mentions it as a faunal element of the Lower Lufeng Formation (Yunnan Province, China). But the affinities of the taxon are unclear and interpretations range from it being a theropod (Young, 1948; Xing et al., 2013) to being a crocodylomorph (Irmis, 2004), possibly a 'sphenosuchian' (Knoll and Rohrberg, 2012). Thus, the taxon is excluded from the database.

A.38.3 Ornithischia

Phylogeny: The strict reduced consensus tree of Baron et al. (2017c, fig. 22), which is based on an updated data matrix of Barrett et al. (2014) (which is itself based on an updated dataset of Butler et al., 2007), is used as scaffold for Ornithischia (for a slightly different phylogeny of Ornithischia see Boyd, 2015, fig. 2). Note that Agnolín and Rozadilla (2018) now recover *Pisanosaurus mertii* as a potential member of Silesauridae and the taxon is treated accordingly (section A.38).

The strict consensus tree of Becerra et al. (2016, fig. 10(2): topology of Heterodontosauridae) is used resolve the phylogenetic relationships of Heterodontosauridae. This analysis is based on an updated and expanded data matrix of Butler et al. (2008), including the modifications of Zheng et al. (2009), Butler et al. (2010), Butler et al. (2011a), Pol et al. (2011), Han et al. (2012) and additional information provided by Sereno (2012).

Alpha taxonomy: Pol et al. (2011) described *Manidens condorensis* for the Cañadón Asfalto Formation (Chubut Province, Argentina), which was initially considered to be of Middle Jurassic age. New high-precision U–PB dating has shown, that the lower part of the formation corresponds to the middle to late Toarcian (Cúneo et al., 2013; Becerra et al., 2014; but see Hauser et al., 2017). Therefore, *Manidens condorensis* is included in the database. Accordingly, occurrences of other taxa reported for this unit are also included (Cúneo et al., 2013; Becerra et al., 2014; Holwerda et al., 2015). The middle and upper part of the Cañadón Asfalto Formation are herein considered as belonging to the early Middle Jurassic, even though a latest Toarcian age cannot be excluded for the lowermost strata of the middle section (Cúneo et al., 2013; see also Hauser et al., 2017). Therefore, the associated fauna is not included in the database.

Lanasaurus scalpridens is a junior synonym of *Lycorhinus angustidens* according to Sereno (2012) (but see Norman et al., 2011 for a different interpretation). This view is followed herein.

Sereno (1991) and Norman et al. (2004) considered *Fabrosaurus australis* to be a *nomen dubium*. Galton (1978) erected the new taxon *Lesothosaurus diagnosticus* for material, that previously had been referred to *Fabrosaurus* by Thulborn (1970, 1971, 1972). As no autapomorphies can be identified in the holotype of *Fabrosaurus australis* (Sereno, 1991) and other referred material probably belongs to *Lesothosaurus diagnosticus* (Galton, 1978; Norman et al., 2004; but see Thulborn, 1992 for a different interpretation) it is treated accordingly in the database. The holotype of *Fabrosaurus australis* is excluded from the ETD and other referred material is assumed as belonging to *Lesothosaurus diagnosticus* (as it was also done by , e.g., Han et al., 2012, p. 1380).

Stormbergia dangershoeki is probably a synonym of *Lesothosaurus diagnosticus* (Knoll et al., 2010; Baron et al., 2017c) and is treated accordingly.

Arbour and Currie (2016, Table 1) list *Bienosaurus lufengensis* as a *nomen dubium*, following the analyses of Irmis and Knoll (2008). It is thus excluded from the database.

According to Norman et al. (2007) *Tatisaurus oehleri* is a *nomen dubium* and this interpretation is followed by Butler et al. (2008) and is also mentioned by, e.g., Arbour and Currie (2016) and by Xing et al. (2016). It is thus excluded from the database.

Isaberrysaura mollensis is not added to the database as the fossil-bearing horizon belongs to the early Bajocian (Salgado et al., 2017).

A.39 'Lepospondyli': Polyphyly hypothesis

Recent phylogenetic analyses recover all (Anderson, 2007; Anderson et al., 2008; Maddin et al., 2012; Huttenlocker et al., 2013) or most (without Adelospondyli; Ruta and Coates, 2007) lepospondyls as monophyletic. Pardo et al. (2017a) offer a different interpretation of lepospondyl relationships, recovering aïstopods as stem tetrapods and recumbirostrans and lysorophians as (potentially eureptilian) amniotes: recumbirostrans and lysorophians are found as sister taxa of captorhinids and diapsids. The analyses of Pardo et al. (2017a) show Lepospondyli as polyphyletic.

Phylogeny: An alternative early tetrapod supertree is generated to account for the findings of Pardo et al. (2017a). The majority-rule consensus tree of Pardo et al. (2017a, Extended Data fig. 7) is used to add Aïstopoda on the tetrapod stem, rootward of the clade consisting of *Whatcheeria deltae*, *Pederpes finneyae*, and *Occidens portlocki*.

The analyses of Pardo et al. (2017a) included only recumbirostrans and lysorophians, but in recent phylogenetic analyses *Asaphestera intermedia* and *Tuditanus punctulatus* formed a grade towards Recumbirostra (Huttenlocker et al., 2013; Olori, 2015, Supporting Information: S2) and these taxa might indeed belong to Recumbirostra (J. D. Pardo, pers. comm., 2017). The clade consisting of *Asaphestera intermedia* + *Boii crassidens*, *Tuditanus punctulatus* + *Crinodon limnophyes*, *Trihecaton howardinus*, recumbirostrans, and lysorophians is therefore added as the sister taxon of *Opisthodontosaurus carrolli* according to Pardo et al. (2017a, Extended Data fig. 7). The resulting clade including *Opisthodontosaurus carrolli* is then added to a polytomy including *Coelostegus prothales* and the clade consisting of later diverging eureptiles. This placement follows again the majority-rule consensus tree of Pardo et al. (2017a, Extended Data fig. 7) and the comments given in Pardo et al. (2017a).

The remaining 'lepospondyls' are kept as a monophyletic clade on the amniote stem, with *Westlothiana lizziae* and *Solenodonsaurus janenschi* forming a grade towards this clade. This position of all other 'lepospondyls' is exactly the same as in the unmodified supertree topology and corresponds to the position of 'Lepospondyli' found in previous analyses (e.g., Anderson et al., 2008; Huttenlocker et al., 2013; Danto et al., 2012; Clack et al., 2016). The placement therefore reflects previous phylogenetic assessments, but new analyses are required to elucidate the evolutionary relationships of these taxa (J. D. Pardo, pers. comm., 2017).

Furthermore, the ingroup relationships of the following taxa are changed according to Pardo et al. (2017a, Extended Data fig. 7): *Opisthodontosaurus carrolli*, *Pantylus cordatus* (and therefore also the clade consisting of *Pantylus cordatus*, *Trachystegos megalodon*, *Stegotretus agyrus*, and *Sparodus validus*), *Llistrofus pricei* (and therefore also the clade consisting of *Llistrofus pricei*, *Hapsidopareion lepton*, *Saxonerpeton geinitzi*, *Ricnodon copei*, and *Ricnodon* sp.), *Nannaroter mckinziei*, *Micraroter erythrogeios*, *Pelodosotis elongatum* (and therefore also *Ostodolepis brevispinatus*), *Brachydectes newberryi* (and therefore also *Brachydectes elongatus*), *Rhynchonkos stovalli*, *Aletrimyti gaskillae*, *Dvellecanus carrolli*, *Carrolla craddocki*, *Quasicaecilia texana* (and therefore also the rest of Brachystelechidae), *Huskerpeton englehorni*, and *Cardiocephalus peabodyi* (and therefore also the clade consisting of *Proxilodon bonneri*, *Tambaroter carrolli*, *Altenglanerpeton schroederi*, *Huskerpeton englehorni*, and Gymnarthridae).

Trihecaton howardinus is kept in the same position, but due to the changes made to Recumbirostra, the taxon is now found immediately rootward of the clade consisting of *Pantylus cordatus*, *Trachystegos megalodon*, *Stegotretus agyrus*, and *Sparodus validus* instead of being found rootward of Hapsidopareiidae.

Except for the above-mentioned changes the alternative scaffold topology for early tetrapods is identical to the original scaffold topology.

A.40 Lissamphibia: Lepospondyl hypothesis (LH)

Most recent phylogenetic analyses recover modern Amphibia (Lissamphibia) as temnospondyls (Ruta and Coates, 2007; Sigurdsen and Green, 2011; Maddin and Anderson, 2012; Maddin et al., 2012; Pardo et al., 2017b,a), often termed the 'temnospondyl hypothesis (TH)' (Marjanović and Laurin, 2009; Maddin and Anderson, 2012; Marjanović and Laurin, 2013, 2019). A few other phylogenetic analyses recover Lissamphibia among lepospondyls (Vallin and Laurin, 2004; Marjanović and Laurin, 2008, 2009; Pyron, 2011; Marjanović and Laurin, 2013, 2019), usually termed the 'lepospondyl hypothesis (LH)' (Marjanović and Laurin, 2009; Maddin and Anderson, 2012; Marjanović and Laurin, 2013, 2019). The most recent iteration of the 'lepospondyl hypothesis' is found in Marjanović and Laurin (2019) who re-evaluate and expand the character matrix of Ruta and Coates (2007). The topology presented in Marjanović and Laurin (2019, fig. 14) also deviates quite substantially for early temnospondyl and ingroup 'leponspondyl' relationships from the topologies recovered in other recent analyses (e.g., Schoch, 2013; Strapasson et al., 2015; Pardo et al., 2017b; Huttenlocker et al., 2013; Olori, 2015).

Phylogeny: Another alternative early tetrapod supertree is generated to account for the findings of Marjanović and Laurin (2019). The representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14) is used to modify the phylogenetic position of the following taxa: *Metaxygnathus denticulus*, *Ventastega curonica*, *Acanthostega gunnari*, *Ymeria denticulata*, *Perittodus apsconditus*, *Ichthyostega stensioi* (and therefore also *Hynerpeton basseti* and the other *Ichthyostega* species), *Ossinodus pueri* and the other members of Whatcheeriidae, *Densignathus rowei* (and therefore also *Sinostega pani* and *Jakubsonia livnensis*), *Tulerpeton curtum*, *Crassigyrinus scoticus* (and therefore also *Tantallognathus woodi*), Colosteidae (and therefore also *Koilops herma*), Baphetidae and Spathicephalidae, *Diploradus austiumensis*, *Sigournea multidentata*, *Doragnathus woodi*, *Edops craigi*, Cochleosauridae, *Nigerpeton ricqlesi*, *Saharastega moradiensis*, *Capetus palustris*, Dvinosauria, Dendrerpetidae, *Palatinerpeton kraetschmeri*, *Iberospondylus schultzei*, Zatracheidae, *Caerorhachis bairdi* (note, that according to Marjanović and Laurin (2019) *Casineria kiddi* might be a synonym of *Caerorhachis bairdi*), *Casineria kiddi*, Chroniosuchia, *Solenodonsaurus janenschi*, Diadectomorpha, *Limnoscelis paludis* (and therefore also *Limnoscelis dynatis*), Synapsida, *Hyloplesion longicostatum*, *Microbrachis pelikani*, Holospondyli, *Scincosaurus crassus* (and therefore also Scincosauridae), Diplocaulidae, *Diceratosaurus brevirostris*, *Keraterpeton galvani* (and therefore also *Keraterpeton longtoni*), *Batrachiderpeton reticulatum*, *Utaherpeton franklini*, *Acherontiscus caledoniae*, Adelogyrinidae, Urocordylidae, Aïstopoda, *Stegotretus agyrus*, *Pantylus cordatus* (and therefore also *Trachystegos megalodon*), *Asaphestera intermedia* (and therefore also *Boii crassidens*), *Tuditanus punctulatus*, *Crinodon limnophyes*, Ostolepidae, Gymnarthridae (and therefore also *Proxilodon bonneri*, *Tambaroter carrolli*, *Altenglanerpeton schroederi*, and *Huskerpeton englehorni*), *Saxonerpeton geinitzi*, *Sparodus validus*, *Odonterpeton triangulare*, *Hapsidopareion lepton* (and therefore also Hapsidopareiidae), *Rhynchonkos stovalli* (and therefore also Rhynchonkidae), *Brachydectes newberryi* (and therefore also *Brachydectes elongatus*), Brachystelechidae, *Carrolla craddocki*, *Quasicaecilia texana*, *Eocaecilia micropodia*, *Triadobatrachus massinoti*, and Batrachia. *Trihecaton howardinus* is kept in the same position, but due to the above-mentioned modifications, the taxon is now found immediately rootward of *Saxonerpeton geinitzi* instead of being found rootward of Hapsidopareiidae.

If not mentioned otherwise, the internal relationships of clades that are listed above are not modified and only the phylogenetic position of the clade itself is changed. Taxa with multiple different positions in the representation of all MPTs from analysis R4 of Marjanović and Laurin (2019, fig. 14) are added at the earliest diverging position, unless noted otherwise.

These changes require also a modified phylogenetic position for a few other taxa, that are not part of the analysis of Marjanović and Laurin (2019, fig. 14). Because of its similarity to *Ventastega curonica* (Gess and Ahlberg, 2018) and following its tentative phylogenetic position in the simplified phylogeny of Gess and Ahlberg (2018, fig. 4) *Umzantsia amazana* has been added initially to a polytomy consisting of *Elpistostege watsoni* and the clade including later diverging tetrapods. Due to the above-mentioned modifications *Umzantsia amazana* is now part of a polytomy including *Metaxygnathus denticulus* and the clade consisting of later diverging tetrapods.

Tutusius umlambo is still found in a polytomy including the clade *Jakubsonia livnensis* + *Sinostega pani* + *Densignathus rowei* and the clade consisting of later diverging tetrapods but due to the above-mentioned modifications it lies now rootward of *Tulerpeton* instead of being placed rootward of *Acanthostega gunnari*.

The phylogenetic position of *Mesanerpeton woodi* remains unchanged but due to the modifications reported above it is now found in a polytomy with *Crassigyrinus scoticus*, *Tantallognathus woodi*, and the clade consisting of later diverging tetrapods.

To account for the new position of Dendrerpetidae and in accordance with the strict consensus tree of Ruta (2009, text-fig. 1) (see also Ruta and Bolt, 2006, fig. 27) *Dendrerpeton confusum* is found rootward of Dendrerpetidae, representing now the sister taxon of the clade including Dendrerpetidae, *Palatinerpeton kraetschmeri*, *Iberospondylus schultzei*, and Dissorophoidea.

The composite cladogram of Clack and Milner (2015, fig. 1) shows *Antlerpeton clarkii* in a polytomy with *Kirktonecta milnerae*, *Casineria kiddi*, and *Westlothiana lizziae*. Due to the above-mentioned modifications *Antlerpeton clarkii* is therefore now placed in a polytomy with *Casineria kiddi* and later diverging tetrapods.

The unnamed 'microsaur' from Mazon Creek (FMNH PR 981) is again added according to the strict consensus tree of Anderson (2007, fig. 5.5), but due to the modified topology it is no longer found rootward of *Odonterpeton triangulare* but as the sister taxon of the clade Holospondyli.

The taxon *Kirktonecta milnerae* represents the first appearance of 'microsaurs' in the fossil record (Clack, 2011b; Clack and Milner, 2015, p. 70, 71) and most closely resembles *Microbrachis pelikani*, *Asaphestera intermedia*, *Saxonerpeton geinitzi*, *Hyloplesion longicostatum*, and *Llistrofus pricei* (Clack, 2011b). Considering its resemblance to other 'microsaurs' and its stratigraphic range, *Kirktonecta milnerae* is added as an early diverging 'microsaur' to a polytomy including the clade consisting of *Microbrachis pelikani*, *Hyloplesion longicostatum*, the unnamed 'microsaur' from Mazon Creek, and Holospondyli, and the clade consisting of the other 'microsaurs', Lysorophia, and Batrachia.

Except for the above-mentioned changes the alternative scaffold topology for early tetrapods is identical to the original scaffold topology.

A.41 Dinosauriformes: Ornithoscelida hypothesis

Baron et al. (2017a) propose a novel interpretation of dinosaur interrelationships, recovering Ornithischia as sister clade of Theropoda and Sauropodomorpha as the sister clade of Herrerasauridae (see also Parry et al., 2017; Langer et al., 2017b; Baron et al., 2017b; Müller and Dias-da-Silva, 2017). Their newly defined clade Dinosauria consists of Ornithoscelida (= Ornithischia + Theropoda) and the newly defined Saurischia (= Herrerasauridae + Sauropodomorpha). They also recover a few enigmatic dinosauriform taxa in novel positions.

Phylogeny: The strict consensus tree of Baron et al. (2017a, fig. 1) is used to provide an alternative scaffold topology for Dinosauriformes. Herrerasauridae is added as the sister taxon of Sauropodomorpha, Theropoda is added as the sister taxon of Ornithischia. The phylogenetic position of the following taxa is changed according to Baron et al. (2017a, fig. 1): *Marasuchus lilloensis*, *Saltopus elginensis*, *Agnosphitys cromhallensis*, *Lewisuchus admixtus* (and therefore also that of *Soumyasaurus aenigmaticus*; see section A.38), *Asilisaurus kongwe* (and therefore also that of *Pisanosaurus mertii*; see section A.38), *Ignotosaurus fragilis*, *Sacisaurus agudoensis*, *Diodorus scytobrachion*, *Eucoelophysis baldwini*, *Silesaurus opolensis*, *Lutungutali sitwensis*, *Staurikosaurus pricei*, *Herrerasaurus ischigualastensis*, *Herrerasaurus ischigualastensis*, *Chindesaurus bryansmalli*, *Sanjuansaurus gordilloi*, *Guaibasaurus candelariensis*, and *Eoraptor lunensis*.

The phylogenetic position of *Nyasasaurus parringtoni* is modified according to the reduced strict consensus tree of Baron et al. (2017a, Extended Data fig. 1) (see also the strict consensus tree set of Baron et al., 2017a, Extended Data fig. 5). Note, that the phylogenetic position of the taxon is, indeed, quite uncertain (e.g., Puttick et al., 2017b).

Alwalkeria maleriensis represents a saurischian (Novas et al., 2011; Ezcurra, 2012) and the species is placed accordingly at the base of Saurischia in the original scaffold topology of Dinosauriformes. Saurischia *sensu* Baron et al. (2017a), however, includes a different set of taxa, making it therefore necessary to change the position of *Alwalkeria maleriensis* in the alternative scaffold topology of Dinosauriformes. *Alwalkeria maleriensis* was initially described as a coelurosaurian podokesaurid (Chatterjee, 1987), was still treated as a theropod by Chatterjee and Creisler (1994) and was considered to have close relationships to *Eoraptor lunensis* by Langer (2004, p. 43). Langer (2004, p. 43) also suggested that the relationship with Herrerasauridae is less close. *Alwalkeria maleriensis* therefore appears to be less closely related to the taxon set of Saurischia *sensu* Baron et al. (2017a). It is therefore added as the sister taxon to all other theropod taxa.

Except for the above-mentioned changes the alternative scaffold topology of Dinosauriformes is identical to the original scaffold topology.

BIBLIOGRAPHY

Abdala, F. (1996). Redescripción del craneo y reconsideración de la validez de *Cynognathus minor* (Eucynodontia-Cynognathidae) del Triásico Inferior de Mendoza. *Ameghiniana*, 33(2):115–126.

Abdala, F. (2000). Catalogue of non-mammalian cynodonts in the Vertebrate Paleontology Collection of the Instituto Miguel Lillo, Universidad Nacional de Tucumán, with comments on species. *Ameghiniana*, 37(4):463–475.

Abdala, F. (2007). Redescription of *Platycraniellus elegans* (Therapsida, Cynodontia) from the Lower Triassic of South Africa, and the cladistic relationships of eutheriodonts. *Palaeontology*, 50(3):591–618.

Abdala, F. and Giannini, N. P. (2002). Chiniquodontid cynodonts: systematic and morphometric considerations. *Palaeontology*, 45(6):1151–1170.

Abdala, F. and Allinson, M. (2005). The taxonomic status of *Parathrinaxodon proops* (Therapsida: Cynodontia), with comments on the morphology of the palate in basal cynodonts. *Palaeontologia africana*, 41:45–52.

Abdala, F. and Smith, R. M. H. (2009). A Middle Triassic cynodont fauna from Namibia and its implications for the biogeography of Gondwana. *Journal of Vertebrate Paleontology*, 29(3):837–851.

Abdala, F. and Ribeiro, A. M. (2010). Distribution and diversity patterns of Triassic cynodonts (Therapsida, Cynodontia) in Gondwana. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 286(3–4):202–217.

Abdala, F. and Ribeiro, A. M. (2012). Padrões de diversidade e distribuição de cinodontes não mamaliaformes do Triássico da América do Sul e África. In Gallo, V., Silva, H. M. A., Brito, P. M., and Figueiredo, F. J., editors, *Paleontologia de Vertebrados: Relações entre América do Sul e África*, pages 101–132. Editora Interciência, Rio de Janeiro.

Abdala, F., Neveling, J., and Welman, J. (2006). A new trirachodontid cynodont from the lower levels of the Burgersdorp Formation (Lower Triassic) of the Beaufort Group, South Africa and the cladistic relationships of Gondwanan gomphodonts. *Zoological Journal of the Linnean Society*, 147(3):383–413.

Abdala, F., Rubidge, B. S., and van den Heever, J. (2008). The oldest therocephalians (Therapsida, Eutheriodonta) and the early diversification of Therapsida. *Palaeontology*, 51(4):1011–1024.

Abdala, F., Jasinoski, S. C., and Fernandez, V. (2013a). Ontogeny of the Early Triassic cynodont *Thrinaxodon liorhinus* (Therapsida): dental morphology and replacement. *Journal of Vertebrate Paleontology*, 33(6):1408–1431.

Abdala, F., Marsicano, C. A., Smith, R. M., and Swart, R. (2013b). Strengthening western Gondwanan correlations: a Brazilian dicynodont (Synapsida, Anomodontia) in the Middle Triassic of Namibia. *Gondwana Research*, 23(3):1151–1162.

Abdala, F., Kammerer, C. F., Day, M. O., Jirah, S., and Rubidge, B. S. (2014a). Adult morphology of the therocephalian *Simorhinella baini* from the middle Permian of South Africa and the taxonomy, paleobiogeography, and temporal distribution of the Lycosuchidae. *Journal of Paleontology*, 88(6):1139–1153.

Abdala, F., Jashashvili, T., Rubidge, B. S., and van den Heever, J. (2014b). New Material of *Microgomphodon oligocynus* (Eutherapsida, Therocephalia) and the Taxonomy of Southern African Bauriidae. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 13, pages 209–231. Springer, Dordrecht.

Abràmoff, M. D., Magalhães, P. J., and Ram, S. J. (2004). Image processing with ImageJ. *Biophotonics International*, 11:36–42.

Adams, D. C. and Collyer, M. L. (2018). Multivariate phylogenetic comparative methods: evaluations, comparisons, and recommendations. *Systematic Biology*, 67(1):14–31.

Agnolín, F. L. and Rozadilla, S. (2018). Phylogenetic reassessment of *Pisanosaurus mertii* Casamiquela, 1967, a basal dinosauriform from the Late Triassic of Argentina. *Journal of Systematic Palaeontology*, 16(10):853–879.

Ahlberg, P. E. (1991a). A re-examination of sarcopterygian interrelationships, with special reference to the Porolepiformes. *Zoological Journal of the Linnean Society*, 103(3):241–287.

Ahlberg, P. E. (1991b). Tetrapod or near-tetrapod fossils from the Upper Devonian of Scotland. *Nature*, 354(6351):298–301.

Ahlberg, P. E. (1995). *Elginerpeton pancheni* and the earliest tetrapod clade. *Nature*, 373(6513):420–425.

Ahlberg, P. E. (1998). Postcranial stem tetrapod remains from the Devonian of Scat Craig, Morayshire, Scotland. *Zoological Journal of the Linnean Society*, 122(1–2):99–141.

Ahlberg, P. E. (2011). Humeral homology and the origin of the tetrapod elbow: a reinterpretation of the enigmatic specimens ANSP 21350 and GSM 104536. *Special Papers in Palaeontology*, 86:17–29.

Ahlberg, P. E. (2019). Follow the footprints and mind the gaps: a new look at the origin of tetrapods. *Earth and Environmental Science Transactions of The Royal Society of Edinburgh*, 109(1–2):115–137.

Ahlberg, P. E. and Clack, J. A. (1998). Lower jaws, lower tetrapods – a review based on the Devonian genus *Acanthostega*. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 89(1):11–46.

Ahlberg, P. E., Lukševičs, E., and Mark-Kurik, E. (2000). A near-tetrapod from the Baltic Middle Devonian. *Palaeontology*, 43(3):533–548.

Ahlberg, P. E., Friedman, M., and Blom, H. (2005a). New light on the earliest known tetrapod jaw. *Journal of Vertebrate Paleontology*, 25(3):720–724.

Ahlberg, P. E., Clack, J. A., and Blom, H. (2005b). The axial skeleton of the Devonian tetrapod *Ichthyostega*. *Nature*, 437(7055):137–140.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, 19(6):716–723.

Albers, P. (2011). New *Nothosaurus* skulls from the Lower Muschelkalk of the western Lower Saxony Basin (Winterswijk, the Netherlands) shed new light on the status of *Nothosaurus winterswijkensis*. *Netherlands Journal of Geosciences*, 90(1):15–22.

Alcober, O. A. and Martínez, R. N. (2010). A new herrerasaurid (Dinosauria, Saurischia) from the Upper Triassic Ischigualasto Formation of northwestern Argentina. *ZooKeys*, 63:55–81.

Alcober, O. (2000). Redescription of the skull of *Saurosuchus galilei* (Archosauria: Rauisuchidae). *Journal of Vertebrate Paleontology*, 20(2):302–316.

Alfaro, M. E., Santini, F., Brock, C., Alamillo, H., Dornburg, A., Rabosky, D. L., Carnevale, G., and Harmon, L. J. (2009). Nine exceptional radiations plus high turnover explain species diversity in jawed vertebrates. *Proceedings of the National Academy of Sciences*, 106(32):13410–13414.

Alifanov, V. and Kurochkin, E. (2011). *Kyrgyzsaurus bukhanchenkoi* gen. et sp. nov., a new reptile from the Triassic of southwestern Kyrgyzstan. *Paleontological Journal*, 45(6):639–647.

Allard, H., Carpenter, S. C., Duffin, C. J., and Benton, M. J. (2015). Microvertebrates from the classic Rhaetian bone beds of Manor Farm Quarry, near Aust (Bristol, UK). *Proceedings of the Geologists' Association*, 126(6):762–776.

Allen, B. J., Stubbs, T. L., Benton, M. J., and Puttick, M. N. (2019). Archosauromorph extinction selectivity during the Triassic-Jurassic mass extinction. *Palaeontology*, 62(2):211–224.

Alroy, J. (2010a). Fair sampling of taxonomic richness and unbiased estimation of origination and extinction rates. *Special Papers of the Paleontological Society*, 16:55–80.

Alroy, J. (2010b). Geographical, environmental and intrinsic biotic controls on Phanerozoic marine diversification. *Palaeontology*, 53(6):1211–1235.

Alroy, J. (2010c). The shifting balance of diversity among major marine animal groups. *Science*, 329(5996):1191–1194.

Amson, E. and Laurin, M. (2011). On the affinities of *Tetraceratops insignis*, an Early Permian synapsid. *Acta Palaeontologica Polonica*, 56(2):301–312.

Anderson, J. S. (2001). The phylogenetic trunk: maximal inclusion of taxa with missing data in an analysis of the Lepospondyli (Vertebrata, Tetrapoda). *Systematic Biology*, 50(2):170–193.

Anderson, J. S. (2002a). Revision of the aïstopod genus *Phlegethontia* (Tetrapoda: Lepospondyli). *Journal of Paleontology*, 76(6):1029–1046.

Anderson, J. S. (2002b). Use of well-known names in phylogenetic nomenclature: a reply to Laurin. *Systematic Biology*, 51(5):822–827.

Anderson, J. S. (2003a). A new aïstopod (Tetrapoda: Lepospondyli) from Mazon Creek, Illinois. *Journal of Vertebrate Paleontology*, 23(1):79–88.

Anderson, J. S. (2003b). Cranial anatomy of *Coloraderpeton brilli*, postcranial anatomy of *Oestocephalus amphiuminus*, and reconsideration of Ophiderpetontidae (Tetrapoda: Lepospondyli: Aistopoda). *Journal of Vertebrate Paleontology*, 23(3):532–543.

Anderson, J. S. (2007). Incorporating Ontogeny into the Matrix: A Phylogenetic Evaluation of Developmental Evidence for the Origin of Modern Amphibians. In Anderson, J. S. and Sues, H.-D., editors, *Major Transitions in Vertebrate Evolution*, pages 182–227. Indiana University Press, Bloomington.

Anderson, J. S. (2008). Focal review: the origin(s) of modern amphibians. *Evolutionary Biology*, 35(4):231–247.

Anderson, J. S. and Reisz, R. R. (2003). A new microsaur (Tetrapoda: Lepospondyli) from the Lower Permian of Richards Spur (Fort Sill), Oklahoma. *Canadian Journal of Earth Sciences*, 40(4):499–505.

Anderson, J. S. and Bolt, J. R. (2013). New information on amphibamids (Tetrapoda, Temnospondyli) from Richards Spur (Fort Sill), Oklahoma. *Journal of Vertebrate Paleontology*, 33(3):553–567.

Anderson, J. S., Carroll, R. L., and Rowe, T. B. (2003). New information on *Lethiscus stocki* (Tetrapoda: Lepospondyli: Aistopoda) from high-resolution computed tomography and a phylogenetic analysis of Aistopoda. *Canadian Journal of Earth Sciences*, 40(8):1071–1083.

Anderson, J. S., Reisz, R. R., Scott, D., Fröbisch, N. B., and Sumida, S. S. (2008). A stem batrachian from the Early Permian of Texas and the origin of frogs and salamanders. *Nature*, 453(7194):515–518.

Anderson, J. S., Smithson, T., Mansky, C. F., Meyer, T., and Clack, J. (2015). A diverse tetrapod fauna at the base of 'Romer's Gap'. *PLoS ONE*, 10(4):e0125446.

Anderson, P. S. L. (2009). Biomechanics, functional patterns, and disparity in Late Devonian arthrodires. *Paleobiology*, 35(3):321–342.

Anderson, P. S. L. and Westneat, M. W. (2007). Feeding mechanics and bite force modelling of the skull of *Dunkleosteus terrelli*, an ancient apex predator. *Biology Letters*, 3(1):76–79.

Anderson, P. S. L., Friedman, M., Brazeau, M. D., and Rayfield, E. J. (2011). Initial radiation of jaws demonstrated stability despite faunal and environmental change. *Nature*, 476(7359):206–209.

Anderson, P. S. L., Friedman, M., and Ruta, M. (2013). Late to the table: diversification of tetrapod mandibular biomechanics lagged behind the evolution of terrestriality. *Integrative and Comparative Biology*, 53(2):197–208.

Andres, B. and Myers, T. S. (2012). Lone star pterosaurs. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):383–398.

Andres, B., Clark, J., and Xu, X. (2014). The earliest pterodactyloid and the origin of the group. *Current Biology*, 24(9):1011–1016.

Andrews, S. M. and Carroll, R. L. (1991). The order Adelospondyli: Carboniferous lepospondyl amphibians. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 82(3):239–275.

Angielczyk, K. D. and Sullivan, C. (2008). *Diictodon feliceps* (Owen, 1876), a dicynodont (Therapsida, Anomodontia) species with a Pangaean distribution. *Journal of Vertebrate Paleontology*, 28(3):788–802.

Angielczyk, K. D. and Ruta, M. (2012). The roots of amphibian morphospace: a geometric morphometric analysis of Paleozoic temnospondyls. *Fieldiana Life and Earth Sciences*, 5:40–58.

Angielczyk, K. D. and Cox, C. B. (2015). Distinctive emydopoid dicynodont (Therapsida, Anomodontia) mandibles from the Permian Ruhuhu and Usili formations (Songea Group), Ruhuhu Basin, Tanzania. *Journal of Vertebrate Paleontology*, 35(6):e1008699.

Angielczyk, K. D. and Kammerer, C. F. (2017a). Data from: The cranial morphology, phylogenetic position and biogeography of the upper Permian dicynodont *Compsodon helmoedi* van Hoepen (Therapsida, Anomodontia). Dryad Digital Repository. https://doi.org/10.5061/dryad.fq3dq.

Angielczyk, K. D. and Kammerer, C. F. (2017b). The cranial morphology, phylogenetic position and biogeography of the upper Permian dicynodont *Compsodon helmoedi* van Hoepen (Therapsida, Anomodontia). *Papers in Palaeontology*, 3(4):513–545.

Angielczyk, K. D., Fröbisch, J., and Smith, R. M. H. (2005). On the stratigraphic range of the dicynodont taxon *Emydops* (Therapsida: Anomodontia) in the Karoo Basin, South Africa. *Palaeontologia africana*, 41:23–33.

Angielczyk, K. D., Sidor, C. A., Nesbitt, S. J., Smith, R. M. H., and Tsuji, L. A. (2009). Taxonomic revision and new observations on the postcranial skeleton, biogeography, and biostratigraphy of the dicynodont genus *Dicynodontoides*, the subjective senior synonym of *Kingoria* (Therapsida, Anomodontia). *Journal of Vertebrate Paleontology*, 29(4):1174–1187.

Angielczyk, K. D., Huertas, S., Smith, R. M. H., Tabor, N. J., Sidor, C. A., Steyer, J.-S., Tsuji, L. A., and Gostling, N. J. (2014a). New dicynodonts (Therapsida, Anomodontia) and updated tetrapod stratigraphy of the Permian Ruhuhu Formation (Songea Group, Ruhuhu Basin) of southern Tanzania. *Journal of Vertebrate Paleontology*, 34(6):1408–1426.

Angielczyk, K. D., Steyer, J.-S., Sidor, C. A., Smith, R. M. H., Whatley, R. L., and Tolan, S. (2014b). Permian and Triassic Dicynodont (Therapsida: Anomodontia) Faunas of the Luangwa Basin, Zambia: Taxonomic Update and Implications for Dicynodont Biogeography and Biostratigraphy. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 7, pages 93–138. Springer, Dordrecht.

Angielczyk, K. D., Rubidge, B. S., Day, M. O., and Lin, F. (2016). A reevaluation of *Brachyprosopus broomi* and *Chelydontops altidentalis*, dicynodonts (Therapsida, Anomodontia) from the middle Permian *Tapinocephalus* Assemblage Zone of the Karoo Basin, South Africa. *Journal of Vertebrate Paleontology*, 36(2):e1078342.

Angielczyk, K. D., Hancox, P. J., and Nabavizadeh, A. (2018). A redescription of the Triassic kannemeyeriiform dicynodont *Sangusaurus* (Therapsida, Anomodontia), with an analysis of its feeding system. *Journal of Vertebrate Paleontology*, 37(6, Supplement):189–227.

Antczak, M. (2016). Late Triassic aetosaur (Archosauria) from Krasiejów (SW Poland): new species or an example of individual variation? *Geological Journal*, 51(5):779–788.

Apaldetti, C., Martinez, R. N., Alcober, O. A., and Pol, D. (2011). A new basal sauropodomorph (Dinosauria: Saurischia) from Quebrada del Barro Formation (Marayes-El Carrizal Basin), northwestern Argentina. *PLoS ONE*, 6(11):e26964.

Apaldetti, C., Pol, D., and Yates, A. (2013). The postcranial anatomy of *Coloradisaurus brevis* (Dinosauria: Sauropodomorpha) from the Late Triassic of Argentina and its phylogenetic implications. *Palaeontology*, 56(2):277–301.

Apaldetti, C., Martínez, R. N., Pol, D., and Souter, T. (2014). Redescription of the skull of *Coloradisaurus brevis* (Dinosauria, Sauropodomorpha) from the Late Triassic Los Colorados Formation of the Ischigualasto-Villa Union Basin, northwestern Argentina. *Journal of Vertebrate Paleontology*, 34(5):1113–1132.

Apaldetti, C., Martínez, R. N., Cerda, I. A., Pol, D., and Alcober, O. (2018). An early trend towards gigantism in Triassic sauropodomorph dinosaurs. *Nature Ecology & Evolution*, 2(8):1227–1232.

Apesteguía, S. and Carballido, J. L. (2014). A new eilenodontine (Lepidosauria, Sphenodontidae) from the Lower Cretaceous of central Patagonia. *Journal of Vertebrate Paleontology*, 34(2):303–317.

Apesteguía, S., Gómez, R. O., and Rougier, G. W. (2012). A basal sphenodontian (Lepidosauria) from the Jurassic of Patagonia: new insights on the phylogeny and biogeography of Gondwanan rhynchocephalians. *Zoological Journal of the Linnean Society*, 166(2):342–360.

Apesteguía, S., Gómez, R. O., and Rougier, G. W. (2014). The youngest South American rhynchocephalian, a survivor of the K/Pg extinction. *Proceedings of the Royal Society of London B: Biological Sciences*, 281(1792):20140811.

Appleby, R. M., Charig, A. J., Cox, C. B., Kermack, K. A., and Tarlo, L. B. H. (1967). Chapter 28: Reptilia. In Harland, W. B., Holland, C. H., House, M. R., Hughes, N. F., Reynolds, A. B., Rudwick, M. J. S., Satterthwaite, G. E., Tarlo, L. B. H., and Willey, E. C., editors, *The Fossil Record*, volume 2, pages 695–731. The Geological Society of London, London.

Arbez, T., Sidor, C. A., and Steyer, J.-S. (2019). *Laosuchus naga* gen. et sp. nov., a new chroniosuchian from South-East Asia (Laos) with internal structures revealed by micro-CT scan and discussion of its palaeobiology. *Journal of Systematic Palaeontology*, 17(14):945–962.

Arbour, V. M. and Currie, P. J. (2016). Systematics, phylogeny and palaeobiogeography of the ankylosaurid dinosaurs. *Journal of Systematic Palaeontology*, 14(5):385–444.

Arcucci, A. B., Marsicano, C. A., and Caselli, A. T. (2004). Tetrapod association and palaeoenvironment of the Los Colorados Formation (Argentina): a significant sample from Western Gondwana at the end of the Triassic. *Geobios*, 37(5):557–568.

Arcucci, A. (1990). Un nuevo Proterochampsidae (Reptilia - Archosauriformes) de la fauna local de Los Chañares (Triásico Medio), La Rioja, Argentina. *Ameghiniana*, 27(3–4):365–378.

Arkhangelsky, M. S. and Sennikov, A. G. (2008). [Subclass Synaptosauria]. In Ivakhnenko, M. F. and Kurochkin, E. N., editors, *[Fossil vertebrates of Russia and adjacent countries: Fossil Reptiles and Birds. Part 1]*, pages 224–243. GEOS, Moscow. [In Russian].

Atayman, S., Rubidge, B. S., and Abdala, F. (2009). Taxonomic re-evaluation of tapinocephalid dinocephalians. *Palaeontologia africana*, 44:87–90.

Averianov, A. O. (2002). Early Cretaceous “symmetrodont” mammal *Gobiotheriodon* from Mongolia and the classification of “Symmetrodonta”. *Acta Palaeontologica Polonica*, 47(4):705–716.

Averianov, A. O., Lopatin, A. V., Krasnolutskii, S. A., and Ivantsov, S. V. (2010). New docodontans from the Middle Jurassic of Siberia and reanalysis of Docodonta interrelationships. *Proceedings of the Zoological Institute of the Russian Academy of Sciences*, 314(2):121–148.

Báez, A. M. and Nicoli, L. (2008). A new species of *Notobatrachus* (Amphibia, Salientia) from the Middle Jurassic of northwestern Patagonia. *Journal of Paleontology*, 82(2):372–376.

Baker, J., Meade, A., Pagel, M., and Venditti, C. (2015). Adaptive evolution toward larger size in mammals. *Proceedings of the National Academy of Sciences*, 112(16):5093–5098.

Baker, J., Meade, A., Pagel, M., and Venditti, C. (2016). Positive phenotypic selection inferred from phylogenies. *Biological Journal of the Linnean Society*, 118(1):95–115.

Bakker, R. T. (1972). Anatomical and ecological evidence of endothermy in dinosaurs. *Nature*, 238(5359):81–85.

Bakker, R. T. (1977). Tetrapod Mass Extinctions – A Model of the Regulation of Speciation Rates and Immigration by Cycles of Topographic Diversity. In Hallam, A., editor, *Patterns of Evolution as Illustrated by the Fossil Record*, volume 5 of *Developments in Palaeontology and Stratigraphy*, chapter 14, pages 439–468. Elsevier, Amsterdam.

Bakker, R. T. (1986). *The Dinosaur Heresies: New Theories Unlocking the Mystery of the Dinosaurs and Their Extinction*. William Morrow and Company, Inc., New York. 481 pp.

Balini, M. and C. Renesto, S. (2012). *Cymbospondylus* vertebrae (Ichthyosauria, Shastasauridae) from the Upper Anisian Prezzo Limestone (Middle Triassic, Southern Alps) with an overview of the chronostratigraphic distribution of the group. *Rivista Italiana di Paleontologia e Stratigrafia*, 118(1):155–172.

Ballell, A., Moon, B. C., Porro, L. B., Benton, M. J., and Rayfield, E. J. (2019). Convergence and functional evolution of longirostry in crocodylomorphs. *Palaeontology*, pages 1–21.

Bandyopadhyay, S. (1999). Gondwana vertebrate faunas of India. *Proceedings of the Indian National Science Academy*, 65(3A):285–313.

Bandyopadhyay, S., Gillette, D. D., Ray, S., and Sengupta, D. P. (2010). Osteology of *Barapasaurus tagorei* (Dinosauria: Sauropoda) from the Early Jurassic of India. *Palaeontology*, 53(3):533–569.

Bapst, D. W. (2012). paleotree: an R package for paleontological and phylogenetic analyses of evolution. *Methods in Ecology and Evolution*, 3(5):803–807.

Bapst, D. W. (2013). A stochastic rate-calibrated method for time-scaling phylogenies of fossil taxa. *Methods in Ecology and Evolution*, 4(8):724–733.

Bapst, D. W. (2014). Assessing the effect of time-scaling methods on phylogeny-based analyses in the fossil record. *Paleobiology*, 40(3):331–351.

Bapst, D. W. and Hopkins, M. J. (2017). Comparing cal3 and other a posteriori time-scaling approaches in a case study with the pterocephaliid trilobites. *Paleobiology*, 43(1):49–67.

Bardet, N., Falconnet, J., Fischer, V., Houssaye, A., Jouve, S., Suberbiola, X. P., Pérez-García, A., Rage, J.-C., and Vincent, P. (2014). Mesozoic marine reptile palaeobiogeography in response to drifting plates. *Gondwana Research*, 26(3–4):869–887.

Barel, C. D. N. (1983). Towards a constructional morphology of cichlid fishes (Teleostei, Perciformes). *Netherlands Journal of Zoology*, 33(4):357–424.

Baron, M. G. (2017). *Pisanosaurus mertii* and the Triassic ornithischian crisis: could phylogeny offer a solution? *Historical Biology*, pages 1–15.

Baron, M. G. and Williams, M. E. (2018). A re-evaluation of the enigmatic dinosauriform *Caseosaurus crosbyensis* from the Late Triassic of Texas, USA and its implications for early dinosaur evolution. *Acta Palaeontologica Polonica*, 63(1):129–145.

Baron, M. G., Norman, D. B., and Barrett, P. M. (2017a). A new hypothesis of dinosaur relationships and early dinosaur evolution. *Nature*, 543(7646):501–506.

Baron, M. G., Norman, D. B., and Barrett, P. M. (2017b). Baron et al. reply. *Nature*, 551(7678):E4–E5.

Baron, M. G., Norman, D. B., and Barrett, P. M. (2017c). Postcranial anatomy of *Lesothosaurus diagnosticus* (Dinosauria: Ornithischia) from the Lower Jurassic of southern Africa: implications for basal ornithischian taxonomy and systematics. *Zoological Journal of the Linnean Society*, 179(1):125–168.

Barrett, P. M. (2009a). A new basal sauropodomorph dinosaur from the upper Elliot Formation (Lower Jurassic) of South Africa. *Journal of Vertebrate Paleontology*, 29(4):1032–1045.

Barrett, P. M. (2009b). The affinities of the enigmatic dinosaur *Eshanosaurus deguchiianus* from the Early Jurassic of Yunnan Province, People's Republic of China. *Palaeontology*, 52(4):681–688.

Barrett, P. M. (2014). Paleobiology of herbivorous dinosaurs. *Annual Review of Earth and Planetary Sciences*, 42(1):207–230.

Barrett, P. M. and Xu, X. (2005). A reassessment of *Dianchungosaurus lufengensis* Yang, 1982a, an enigmatic reptile from the Lower Lufeng Formation (Lower Jurassic) of Yunnan Province, People's Republic of China. *Journal of Paleontology*, 79(5):981–986.

Barrett, P. M. and Upchurch, P. (2007). The evolution of feeding mechanisms in early sauropodomorph dinosaurs. *Special Papers in Palaeontology*, 77:91–112.

Barrett, P. M. and Xu, X. (2012). The enigmatic reptile *Pachysuchus imperfectus* Young, 1951 from the Lower Lufeng Formation (Lower Jurassic) of Yunnan, China. *Vertebrata PalAsiatica*, 50(2):151–159.

Barrett, P. M., Upchurch, P., and Xiao-Lin, W. (2005). Cranial osteology of *Lufengosaurus huenei* Young (Dinosauria: Prosauropoda) from the Lower Jurassic of Yunnan, People's Republic of China. *Journal of Vertebrate Paleontology*, 25(4):806–822.

Barrett, P. M., Upchurch, P., Zhou, X.-D., and Wang, X.-L. (2007). The skull of *Yunnanosaurus huangi* Young, 1942 (Dinosauria: Prosauropoda) from the Lower Lufeng Formation (Lower Jurassic) of Yunnan, China. *Zoological Journal of the Linnean Society*, 150(2):319–341.

Barrett, P. M., Butler, R. J., Mundil, R., Scheyer, T. M., Irmis, R. B., and Sánchez-Villagra, M. R. (2014). A palaeoequatorial ornithischian and new constraints on early dinosaur diversification. *Proceedings of the Royal Society B: Biological Sciences*, 281(1791):20141147.

Barrett, P. M., Nesbitt, S. J., and Peecook, B. R. (2015). A large-bodied silesaurid from the Lifua Member of the Manda beds (Middle Triassic) of Tanzania and its implications for body-size evolution in Dinosauromorpha. *Gondwana Research*, 27(3):925–931.

Bartholomai, A. (1979). New lizard-like reptiles from the Early Triassic of Queensland. *Alcheringa: An Australasian Journal of Palaeontology*, 3(3):225–234.

Battail, B. (1991). Les cynodontes (Reptilia, Therapsida): une phylogénie. *Bulletin du Muséum national d'Histoire naturelle, Paris, 4ème série, section C (Sciences de la Terre, Paléontologie, Géologie, Minéralogie)*, 13(1–2):17–105.

Battail, B. (2000). A comparison of Late Permian Gondwanan and Laurasian amniote faunas. *Journal of African Earth Sciences*, 31(1):165–174.

Battail, B. and Surkov, M. V. (2000). Mammal-like reptiles from Russia. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 86–119. Cambridge University Press, Cambridge.

Beardmore, S. R., Lawlor, E., and Hone, D. W. E. (2017). Using taphonomy to infer differences in soft tissues between taxa: an example using basal and derived forms of Solnhofen pterosaurs. *The Science of Nature*, 104(7–8):65.

Beaulieu, J. M., Jhwueng, D.-C., Boettiger, C., and O'Meara, B. C. (2012). Modeling stabilizing selection: expanding the Ornstein-Uhlenbeck model of adaptive evolution. *Evolution*, 66(8):2369–2383.

Beaumont, E. H. (1977). Cranial morphology of the Loxommatidae (Amphibia: Labyrinthodontia). *Philosophical Transactions of the Royal Society B: Biological Sciences*, 280(971):29–101.

Beaumont, E. H. and Smithson, T. R. (1998). The cranial morphology and relationships of the aberrant Carboniferous amphibian *Spathicephalus mirus* Watson. *Zoological Journal of the Linnean Society*, 122(1–2):187–209.

Becerra, M. G., Pol, D., Marsicano, C. A., and Rauhut, O. W. M. (2014). The dentition of *Manidens condorensis* (Ornithischia; Heterodontosauridae) from the Jurassic Cañadón Asfalto Formation of Patagonia: morphology, heterodonty and the use of statistical methods for identifying isolated teeth. *Historical Biology*, 26(4):480–492.

Becerra, M. G., Pol, D., Rauhut, O. W. M., and Cerda, I. A. (2016). New heterodontosaurid remains from the Cañadón Asfalto Formation: cursoriality and the functional importance of the pes in small heterodontosaurids. *Journal of Paleontology*, 90(3):555–577.

Bell, M. A. (2015). *Package 'geoscale': Geological Time Scale Plotting*. R package version 2.0. 9 pp.

Benjamini, Y. and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, 57(1):289–300.

Benoit, J., Abdala, F., Van den Brandt, M. J., Manger, P. R., and Rubidge, B. S. (2015). Physiological implications of the abnormal absence of the parietal foramen in a late Permian cynodont (Therapsida). *The Science of Nature*, 102(11):69.

Benoit, J., Manger, P. R., Fernandez, V., and Rubidge, B. S. (2016). Cranial bosses of *Choerosaurus dejageri* (Therapsida, Therocephalia): earliest evidence of cranial display structures in eutheriodonts. *PLoS ONE*, 11(8):e0161457.

Benoit, J., Fernandez, V., Manger, P. R., and Rubidge, B. S. (2017). Endocranial casts of pre-mammalian therapsids reveal an unexpected neurological diversity at the deep evolutionary root of mammals. *Brain, Behavior and Evolution*, 90(4):311–333.

Benson, R. B. J. (2012). Interrelationships of basal synapsids: cranial and postcranial morphological partitions suggest different topologies. *Journal of Systematic Palaeontology*, 10(4):601–624.

Benson, R. B. J. (2018). Dinosaur macroevolution and macroecology. *Annual Review of Ecology, Evolution, and Systematics*, 49(1):379–408.

Benson, R. B. J. and Druckenmiller, P. S. (2014). Faunal turnover of marine tetrapods during the Jurassic–Cretaceous transition. *Biological Reviews*, 89(1):1–23.

Benson, R. B. J., Bates, K. T., Johnson, M. R., and Withers, P. J. (2011a). Cranial anatomy of *Thalassiodracon hawkinsii* (Reptilia, Plesiosauria) from the Early Jurassic of Somerset, United Kingdom. *Journal of Vertebrate Paleontology*, 31(3):562–574.

Benson, R. B. J., Ketchum, H. F., Noé, L. F., and Gómez-Pérez, M. (2011b). New information on *Hauffiosaurus* (Reptilia, Plesiosauria) based on a new species from the Alum Shale Member (Lower Toarcian: Lower Jurassic) of Yorkshire, UK. *Palaeontology*, 54(3):547–571.

Benson, R. B. J., Evans, M., and Druckenmiller, P. S. (2012). High diversity, low disparity and small body size in plesiosaurs (Reptilia, Sauropterygia) from the Triassic–Jurassic Boundary. *PLoS ONE*, 7(3):e31838.

Benson, R. B. J., Evans, M., Smith, A. S., Sassoon, J., Moore-Faye, S., Ketchum, H. F., and Forrest, R. (2013). A giant pliosaurid skull from the Late Jurassic of England. *PLoS ONE*, 8(5):e65989.

Benson, R. B. J., Frigot, R. A., Goswami, A., Andres, B., and Butler, R. J. (2014a). Competition and constraint drove Cope's rule in the evolution of giant flying reptiles. *Nature Communications*, 5:3567.

Benson, R. B. J., Campione, N. E., Carrano, M. T., Mannion, P. D., Sullivan, C., Upchurch, P., and Evans, D. C. (2014b). Rates of dinosaur body mass evolution indicate 170 million years of sustained ecological innovation on the avian stem lineage. *PLoS Biology*, 12(5):e1001853.

Benson, R. B. J., Evans, M., and Taylor, M. A. (2015). The anatomy of *Stratesaurus* (Reptilia, Plesiosauria) from the lowermost Jurassic of Somerset, United Kingdom. *Journal of Vertebrate Paleontology*, 35(4):e933739.

Benson, R. B. J., Hunt, G., Carrano, M. T., and Campione, N. (2017). Data from: Cope's rule and the adaptive landscape of dinosaur body size evolution. Dryad Digital Repository. https://doi.org/10.5061/dryad.1t3r4.

Benson, R. B. J., Hunt, G., Carrano, M. T., and Campione, N. (2018). Cope's rule and the adaptive landscape of dinosaur body size evolution. *Palaeontology*, 61(1):13–48.

Benton, M. J. (1983a). Dinosaur success in the Triassic: a noncompetitive ecological model. *Quarterly Review of Biology*, 58(1):29–55.

Benton, M. J. (1983b). The Triassic reptile *Hyperodapedon* from Elgin: functional morphology and relationships. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 302(1112):605–717.

Benton, M. J. (1984). Tooth form, growth, and function in Triassic rhynchosaurs (Reptilia, Diapsida). *Palaeontology*, 27(4):737–776.

Benton, M. J. (1986a). More than one event in the late Triassic mass extinction. *Nature*, 321(6073):857–861.

Benton, M. J. (1986b). The Late Triassic reptile *Teratosaurus* – a rauisuchian, not a dinosaur. *Palaeontology*, 29(2):293–301.

Benton, M. J. (1986c). The Late Triassic tetrapod extinction events. In Padian, K., editor, *The Beginning of the Age of Dinosaurs: Faunal change across the Triassic–Jurassic Boundary*, pages 303–320. Cambridge University Press, Cambridge.

Benton, M. J. (1990). The species of *Rhynchosaurus*, a rhynchosaur (Reptilia, Diapsida) from the Middle Triassic of England. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 328(1247):213–306.

Benton, M. J. (1993). Late Triassic extinctions and the origin of the dinosaurs. *Science*, 260(5109):769–770.

Benton, M. J. (1994a). Late Triassic terrestrial vertebrate extinctions: stratigraphic aspects and the record of the Germanic Basin. *Paleontologia Lombarda della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano, Nuova serie*, 2:19–38.

Benton, M. J. (1994b). Late Triassic to Middle Jurassic extinctions among continental tetrapods: testing the pattern. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 22, pages 366–397. Cambridge University Press, Cambridge.

Benton, M. J. (1996a). On the Nonprevalence of Competitive Replacement in the Evolution of Tetrapods. In Jablonski, D., Erwin, D. H., and Lipps, J. H., editors, *Evolutionary Paleobiology*, chapter 8, pages 185–210. University of Chicago Press, Chicago.

Benton, M. J. (1996b). Testing the roles of competition and expansion in tetrapod evolution. *Proceedings of the Royal Society of London B: Biological Sciences*, 263(1370):641–646.

Benton, M. J. (1999). *Scleromochlus taylori* and the origin of dinosaurs and pterosaurs. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 354(1388):1423–1446.

Benton, M. J. (2004). Origin and Relationships of Dinosauria. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 7–19. University of California Press, Berkeley, Second edition.

Benton, M. J. (2009). The Red Queen and the Court Jester: species diversity and the role of biotic and abiotic factors through time. *Science*, 323(5915):728–732.

Benton, M. J. (2011). Archosaur remains from the Otter Sandstone Formation (Middle Triassic, late Anisian) of Devon, southern UK. *Proceedings of the Geologists' Association*, 122(1):25–33.

Benton, M. J. (2012). No gap in the Middle Permian record of terrestrial vertebrates. *Geology*, 40(4):339–342.

Benton, M. J. (2015a). Data from: Palaeodiversity and formation counts: redundancy or bias? Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.29j8d.

Benton, M. J. (2015b). Palaeodiversity and formation counts: redundancy or bias? *Palaeontology*, 58(6):1003–1029.

Benton, M. J. (2015c). *Vertebrate Palaeontology*. Wiley Blackwell, Oxford, Fourth edition. 468 pp.

Benton, M. J. (2016). The Chinese pareiasaurs. *Zoological Journal of the Linnean Society*, 177(4):813–853.

Benton, M. J. (2018). Hyperthermal-driven mass extinctions: killing models during the Permian–Triassic mass extinction. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376(2130):20170076.

Benton, M. J. and Taylor, M. A. (1984). Marine reptiles from the Upper Lias (Lower Toarcian, Lower Jurassic) of the Yorkshire coast. *Proceedings of the Yorkshire Geological and Polytechnic Society*, 44(4):399–429.

Benton, M. J. and Clark, J. M. (1988). Archosaur phylogeny and the relationships of the Crocodylia. In Benton, M. J., editor, *The Phylogeny and Classification of the Tetrapods. Volume 1: Amphibians, Reptiles, Birds*, volume 35A of *Systematics Association Special Volume*, chapter 8, pages 295–338. Clarendon Press, Oxford.

Benton, M. J. and Spencer, P. S. (1995). *Fossil Reptiles of Great Britain*. Geological Conservation Review Series. Springer-Science+Business Media, Dordrecht. 386 pp.

Benton, M. J. and Allen, J. A. (1997). *Boreopricea* from the Lower Triassic of Russia, and the relationships of the prolacertiform reptiles. *Palaeontology*, 40(4):931–953.

Benton, M. J. and Walker, A. D. (2002). *Erpetosuchus*, a crocodile-like basal archosaur from the Late Triassic of Elgin, Scotland. *Zoological Journal of the Linnean Society*, 136(1):25–47.

Benton, M. J. and Twitchett, R. J. (2003). How to kill (almost) all life: the end-Permian extinction event. *Trends in Ecology & Evolution*, 18(7):358–365.

Benton, M. J. and Walker, A. D. (2010). *Saltopus*, a dinosauriform from the Upper Triassic of Scotland. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):285–299.

Benton, M. J. and Newell, A. J. (2014). Impacts of global warming on Permo-Triassic terrestrial ecosystems. *Gondwana Research*, 25(4):1308–1337.

Benton, M. J., Tverdokhlebov, V. P., and Surkov, M. V. (2004). Ecosystem remodelling among vertebrates at the Permian-Triassic boundary in Russia. *Nature*, 432(7013):97–100.

Benton, M. J., Newell, A. J., Khlyupin, A. Y., Shumov, I. S., Price, G. D., and Kurkin, A. A. (2012). Preservation of exceptional vertebrate assemblages in Middle Permian fluviolacustrine mudstones of Kotel'nich, Russia: stratigraphy, sedimentology, and taphonomy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 319–320:58–83.

Benton, M. J., Ruta, M., Dunhill, A. M., and Sakamoto, M. (2013a). Data from: The first half of tetrapod evolution, sampling proxies, and fossil record quality. Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.44b50.

Benton, M. J., Zhang, Q., Hu, S., Chen, Z.-Q., Wen, W., Liu, J., Huang, J., Zhou, C., Xie, T., Tong, J., and Choo, B. (2013b). Exceptional vertebrate biotas from the Triassic of China, and the expansion of marine ecosystems after the Permo-Triassic mass extinction. *Earth-Science Reviews*, 125:199–243.

Benton, M. J., Ruta, M., Dunhill, A. M., and Sakamoto, M. (2013c). The first half of tetrapod evolution, sampling proxies, and fossil record quality. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 372:18–41.

Benton, M. J., Forth, J., and Langer, M. C. (2014a). Models for the rise of the dinosaurs. *Current Biology*, 24(2):R87–R95.

Benton, M. J., Zhang, Q., Hu, S., Chen, Z.-Q., Wen, W., Liu, J., Huang, J., Zhou, C., Xie, T., Tong, J., and Choo, B. (2014b). Reprint of "Exceptional vertebrate biotas from the Triassic of China, and the expansion of marine ecosystems after the Permo-Triassic mass extinction". *Earth-Science Reviews*, 137:85–128.

Benton, M. J., Donoghue, P. C. J., Asher, R. J., Friedman, M., Near, T. J., and Vinther, J. (2015). Constraints on the timescale of animal evolutionary history. *Palaeontologia Electronica*, 18.1.1FC:1–107.

Benton, M. J., Bernardi, M., and Kinsella, C. (2018). The Carnian Pluvial Episode and the origin of dinosaurs. *Journal of the Geological Society*, 175(6):1019–1026.

Berman, D. S. (1977). A new species of *Dimetrodon* (Reptilia, Pelycosauria) from a non-deltaic facies in the Lower Permian of north-central New Mexico. *Journal of Paleontology*, 51(1):108–115.

Berman, D. S. (1993). Lower Permian vertebrate localities of New Mexico and their assemblages. In Lucas, S. G. and Zidek, J., editors, *Vertebrate Paleontology in New Mexico*, volume 2, pages 11–21. New Mexico Museum of Natural History.

Berman, D. S. and Martens, T. (1993). First occurrence of *Seymouria* (Amphibia: Batrachosauria) in the Lower Permian Rotliegend of central Germany. *Annals of Carnegie Museum*, 62(1):63–79.

Berman, D. S. and Lucas, S. G. (2003). *Aspidosaurus binasser* (Amphibia, Temnospondyli), a new species of Dissorophidae from the Lower Permian of Texas. *Annals of Carnegie Museum*, 72(4):241–262.

Berman, D. S., Reisz, R. R., and Fracasso, M. A. (1981). Skull of the Lower Permian dissorophid amphibian *Platyhystrix rugosus*. *Annals of Carnegie Museum*, 50(17):391–416.

Berman, D. S., Reisz, R. R., and Eberth, D. A. (1987). *Seymouria sanjuanensis* (Amphibia, Batrachosauria) from the Lower Permian Cutler Formation of north-central New Mexico and the occurrence of sexual dimorphism in that genus questioned. *Canadian Journal of Earth Sciences*, 24(9):1769–1784.

Berman, D. S., Sumida, S. S., and Lombard, R. E. (1992). Reinterpretation of the temporal and occipital regions in *Diadectes* and the relationships of diadectomorphs. *Journal of Paleontology*, 66(3):481–499.

Berman, D. S., Reisz, R. R., Bolt, J. R., and Scott, D. (1995). The cranial anatomy and relationships of the synapsid *Varanosaurus* (Eupelycosauria, Ophiacodontidae) from the Early Permian of Texas and Oklahoma. *Annals of Carnegie Museum*, 64(2):99–133.

Berman, D. S., Sumida, S. S., and Martens, T. (1998). *Diadectes* (Diadectomorpha: Diadectidae) from the Early Permian of central Germany, with description of a new species. *Annals of Carnegie Museum*, 67(1):53–93.

Berman, D. S., Henrici, A. C., Sumida, S. S., and Martens, T. (2000). Redescription of *Seymouria sanjuanensis* (Seymouriamorpha) from the Lower Permian of Germany based on complete, mature specimens with a discussion of paleoecology of the Bromacker locality assemblage. *Journal of Vertebrate Paleontology*, 20(2):253–268.

Berman, D. S., Reisz, R. R., Martens, T., and Henrici, A. C. (2001). A new species of *Dimetrodon* (Synapsida: Sphenacodontidae) from the Lower Permian of Germany records first occurrence of genus outside of North America. *Canadian Journal of Earth Sciences*, 38(5):803–812.

Berman, D. S., Henrici, A. C., Sumida, S. S., and Martens, T. (2004). New materials of *Dimetrodon teutonis* (Synapsida: Sphenacodontidae) from the Lower Permian of Germany. *Annals of Carnegie Museum*, 73(2):48–56.

Berman, D. S., Henrici, A. C., Brezinski, D. K., and Kollar, A. D. (2010). A new trematopid amphibian (Temnospondyli: Dissorophoidea) from the Upper Pennsylvanian of Western Pennsylvania: earliest record of terrestrial vertebrates responding to a warmer, drier climate. *Annals of Carnegie Museum*, 78(4):289–318.

Berman, D. S., Henrici, A. C., Martens, T., Sumida, S. S., and Anderson, J. S. (2011). *Rotaryus gothae*, a new trematopid (Temnospondyli: Dissorophoidea) from the Lower Permian of central Germany. *Annals of Carnegie Museum*, 80(1):49–65.

Berman, D. S., Henrici, A. C., and Lucas, S. G. (2013). *Ophiacodon* (Synapsida, Ophiacodontidae) from the Lower Permian Sangre de Cristo Formation of New Mexico. In Lucas, S. G., DiMichele, W. A., Barrick, J. E., Schneider, J. W., and Spielmann, J. A., editors, *The Carboniferous-Permian Transition*, volume 60, pages 36–41. New Mexico Museum of Natural History.

Berman, D. S., Henrici, A. C., Sumida, S. S., Martens, T., and Pelletier, V. (2014). First European Record of a Varanodontine (Synapsida: Varanopidae): Member of a Unique Early Permian Upland Paleoecosystem, Tambach Basin, Central Germany. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 5, pages 69–86. Springer, Dordrecht.

Berman, D. S., Henrici, A. C., and Lucas, S. G. (2015). Pennsylvanian-Permian Red Bed vertebrate localities of New Mexico an their assemblages. In Lucas, S. G. and Sullivan, R. M., editors, *Fossil Vertebrates in New Mexico*, volume 68, pages 65–76. New Mexico Museum of Natural History.

Bernardi, M., Klein, H., Petti, F. M., and Ezcurra, M. D. (2015). The origin and early radiation of archosauriforms: integrating the skeletal and footprint record. *PLoS ONE*, 10(6):e0128449.

Bernardi, M., Gianolla, P., Petti, F. M., Mietto, P., and Benton, M. J. (2018a). Dinosaur diversification linked with the Carnian Pluvial Episode. *Nature Communications*, 9:1499.

Bernardi, M., Petti, F. M., and Benton, M. J. (2018b). Tetrapod distribution and temperature rise during the Permian–Triassic mass extinction. *Proceedings of the Royal Society B: Biological Sciences*, 285(1870):20172331.

Bever, G. S., Lyson, T. R., Field, D. J., and Bhullar, B.-A. S. (2015). Evolutionary origin of the turtle skull. *Nature*, 525(7568):239–242.

Bhullar, B.-A. S. and Bever, G. S. (2009). An archosaur-like laterosphenoid in early turtles (Reptilia: Pantestudines). *Breviora*, 518:1–11.

Bi, S., Wang, Y., Guan, J., Sheng, X., and Meng, J. (2014). Three new Jurassic euharamiyidan species reinforce early divergence of mammals. *Nature*, 514(7524):579–584.

Bickelmann, C., Müller, J., and Reisz, R. R. (2009). The enigmatic diapsid *Acerosodontosaurus piveteaui* (Reptilia: Neodiapsida) from the Upper Permian of Madagascar and the paraphyly of "younginiform' reptiles. *Canadian Journal of Earth Sciences*, 46(9):651–661.

Bittencourt, J. d. S. and Kellner, A. W. A. (2009). The anatomy and phylogenetic position of the Triassic dinosaur *Staurikosaurus pricei* Colbert, 1970. *Zootaxa*, 2079:1–56.

Bittencourt, J. S., Arcucci, A. B., Marsicano, C. A., and Langer, M. C. (2015). Osteology of the Middle Triassic archosaur *Lewisuchus admixtus* Romer (Chañares Formation, Argentina), its inclusivity, and relationships amongst early dinosauromorphs. *Journal of Systematic Palaeontology*, 13(3):189–219.

Bjerring, H. C. (1997). The question of the Eotriassic tetrapod genus *Wetlugasaurus* in Greenland and thoughts on the fossa coniformis entopterygoidea. *Meddelelser om Grønland, Geoscience*, 34:1–24.

Bjerring, H. C. (1999). A new amphibious tetrapod from the Greenlandic Eotriassic. *Meddelelser om Grønland, Geoscience*, 38:1–42.

Blackwell, G. L., Bassett, S. M., and Dickman, C. R. (2006). Measurement error associated with external measurements commonly used in small-mammal studies. *Journal of Mammalogy*, 87(2):216–223.

Blanckenhorn, W. U. (2000). The evolution of body size: what keeps organisms small? *The Quarterly Review of Biology*, 75(4):385–407.

Blom, H. (2005). Taxonomic revision of the Late Devonian tetrapod *Ichthyostega* from East Greenland. *Palaeontology*, 48(1):111–134.

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., and White, J.-S. S. (2009). Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in Ecology & Evolution*, 24(3):127–135.

Bolt, J. R. (1977). Dissorophoid relationships and ontogeny, and the origin of the Lissamphibia. *Journal of Paleontology*, 51(2):235–249.

Bolt, J. R. and Chatterjee, S. (2000). A new temnospondyl amphibian from the Late Triassic of Texas. *Journal of Paleontology*, 74(4):670–683.

Bolt, J. R. and Rieppel, O. (2009). The holotype skull of *Llistrofus pricei* Carroll and Gaskill, 1978 (Microsauria: Hapsidopareiontidae). *Journal of Paleontology*, 83(3):471–483.

Bonaparte, J. F. (1976). *Pisanosaurus mertii* Casamiquela and the origin of the Ornithischia. *Journal of Paleontology*, 50(5):808–820.

Bonaparte, J. F. (1982). Faunal replacement in the Triassic of South America. *Journal of Vertebrate Paleontology*, 2(3):362–371.

Bonaparte, J. F. (2013). Evolution of the Brasilodontidae (Cynodontia-Eucynodontia). *Historical Biology*, 25(5–6):643–653.

Bonaparte, J. F. and Pumares, J. A. (1995). Notas sobre el primer craneo de *Riojasaurus incertus* (Dinosauria, Prosauropoda, Melanorosauridae) del Triásico superior de La Rioja, Argentina. *Ameghiniana*, 32(4):341–349.

Bonaparte, J. F. and Barberena, M. C. (2001). On two advanced carnivorous cynodonts from the Late Triassic of southern Brazil. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 156(1):59–80.

Bonaparte, J. F. and Crompton, A. W. (2018). Origin and relationships of the Ictidosauria to non-mammalian cynodonts and mammals. *Historical Biology*, 30(1–2):174–182.

Bonaparte, J. F., Martinelli, A. G., and Schultz, C. L. (2005). New information on *Brasilodon* and *Brasilitherium* (Cynodontia, Probainognathia) from the Late Triassic of southern Brazil. *Revista Brasileira de Paleontologia*, 8(1):25–46.

Bonaparte, J. F., Schultz, C. L., Soares, M. B., and Martinelli, A. G. (2010). La fauna local de Faxinal do Soturno, Tríasico tardío de Rio Grande do Sul, Brasil. *Revista Brasileira de Paleontologia*, 13(3):233–246.

Bond, D. P. and Grasby, S. E. (2017). On the causes of mass extinctions. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 478:3–29.

Boonstra, L. D. (1935). On some South African reptiles of the suborder Therocephalia preserved in the American Museum of Natural History. *American Museum Novitates*, 771:1–12.

Boonstra, L. D. (1969). The fauna of the *Tapinocephalus* Zone (Beaufort Beds of the Karoo). *Annals of the South African Museum*, 56(1):1–73.

Boos, A. D. S., Schultz, C. L., Vega, C. S., and Aumond, J. J. (2013). On the presence of the Late Permian dicynodont *Endothiodon* in Brazil. *Palaeontology*, 56(4):837–848.

Boos, A. D. S., Kammerer, C. F., Schultz, C. L., Soares, M. B., and Ilha, A. L. R. (2016). A new dicynodont (Therapsida: Anomodontia) from the Permian of southern Brazil and its implications for bidentalian origins. *PLoS ONE*, 11(5):e0155000.

Boos, A., Kammerer, C., Schultz, C., and Neto, V. P. (2015). A tapinocephalid dinocephalian (Synapsida, Therapsida) from the Rio do Rasto Formation (Paraná Basin, Brazil): taxonomic, ontogenetic and biostratigraphic considerations. *Journal of South American Earth Sciences*, 63:375–384.

Borsuk-Białynicka, M. and Evans, S. E. (2009a). A long-necked archosauromorph from the Early Triassic of Poland. *Palaeontologia Polonica*, 65:203–234.

Borsuk-Białynicka, M. and Sennikov, A. G. (2009). Archosauriform postcranial remains from the Early Triassic karst deposits of southern Poland. *Palaeontologia Polonica*, 65:283–328.

Borsuk-Białynicka, M. and Evans, S. E. (2009b). Cranial and mandibular osteology of the Early Triassic archosauriform *Osmolskina czatkowicensis* from Poland. *Palaeontologia Polonica*, 65:235–281.

Borsuk-Białynicka, M. and Lubka, M. (2009). Procolophonids from the Early Triassic of Poland. *Palaeontologia Polonica*, 65:107–144.

Bossy, K. A. and Milner, A. C. (1998). Order Nectridea Miall 1875. In Carroll, R. L., Bossy, K. A., Milner, A. C., Andrews, S. M., and Wellstead, C. F., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 1: Lepospondyli*, pages 73–131. Verlag Dr. Friedrich Pfeil, München.

Botha, J. and Smith, R. (2006). Rapid vertebrate recuperation in the Karoo Basin of South Africa following the End-Permian extinction. *Journal of African Earth Sciences*, 45(4–5):502–514.

Botha, J. and Angielczyk, K. D. (2007). An integrative approach to distinguishing the Late Permian dicynodont species *Oudenodon bainii* and *Tropidostoma microtrema* (Therapsida: Anomodontia). *Palaeontology*, 50(5):1175–1209.

Botha, J., Abdala, F., and Smith, R. (2007). The oldest cynodont: new clues on the origin and early diversification of the Cynodontia. *Zoological Journal of the Linnean Society*, 149(3):477–492.

Botha-Brink, J. and Abdala, F. (2008). A new cynodont record from the *Tropidostoma* Assemblage Zone of the Beaufort Group: implications for the early evolution of cynodonts in South Africa. *Palaeontologia africana*, 43:1–6.

Botha-Brink, J. and Modesto, S. P. (2011). A new skeleton of the therocephalian synapsid *Olivierosuchus parringtoni* from the Lower Triassic South African Karoo Basin. *Palaeontology*, 54(3):591–606.

Botha-Brink, J. and Smith, R. M. H. (2011). Osteohistology of the Triassic archosauromorphs *Prolacerta*, *Proterosuchus*, *Euparkeria*, and *Erythrosuchus* from the Karoo Basin of South Africa. *Journal of Vertebrate Paleontology*, 31(6):1238–1254.

Botha-Brink, J., Abdala, F., and Chinsamy-Turan, A. (2012). The Radiation and Osteohistology of Nonmammaliaform Cynodonts. In Chinsamy-Turan, A., editor, *Forerunners Of Mammals: Radiation, Histology, Biology*, chapter 9, pages 223–246. Indiana University Press, Bloomington, Indiana.

Botha-Brink, J., Huttenlocker, A. K., and Modesto, S. P. (2014). Vertebrate Paleontology of Nooitgedacht 68: A *Lystrosaurus maccaigi*-rich Permo-Triassic Boundary Locality in South Africa. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 17, pages 289–304. Springer, Dordrecht.

Botha-Brink, J., Codron, D., Huttenlocker, A. K., Angielczyk, K. D., and Ruta, M. (2016). Breeding young as a survival strategy during Earth's greatest mass extinction. *Scientific Reports*, 6:24053.

Boulvain, F., Belanger, I., Delsate, D., Dosquet, D., Ghysel, P., Godefroit, P., Laloux, M., Roche, M., Teerlynck, H., and Thorez, J. (2000). New lithostratigraphical, sedimentological, mineralogical and palaeontological data on the Mesozoic of Belgian Lorraine: a progress report. *Geologica Belgica*, 3(1–2):3–33.

Bourget, H. and Anderson, J. S. (2011). A new amphibamid (Temnospondyli: Dissorophoidea) from the Early Permian of Texas. *Journal of Vertebrate Paleontology*, 31(1):32–49.

Boy, J. A. (1978). Die Tetrapodenfauna (Amphibia, Reptilia) des saarpfälzischen Rotliegenden (Unter-Perm; SW-Deutschland). 1. *Branchiosaurus*. *Mainzer geowissenschaftliche Mitteilungen*, 7:27–76.

Boy, J. A. (1987). Studien über die Branchiosauridae (Amphibia: Temnospondyli; Ober-Karbon – Unter-Perm) 2. Systematische Übersicht. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 174(1):75–104.

Boy, J. A. (1989). Über einige Vertreter der Eryopoidea (Amphibia: Temnospondyli) aus dem europäischen Rotliegend (?höchstes Oberkarbon – Perm). 2. *Acanthostomatops*. *Paläontologische Zeitschrift*, 63(1–2):133–151.

Boy, J. A. (1993). Über einige Vertreter der Eryopoidea (Amphibia: Temnospondyli) aus dem europäischen Rotliegend (?höchstes Karbon – Perm). 4. *Cheliderpeton latirostre*. *Paläontologische Zeitschrift*, 67(1–2):123–143.

Boy, J. A. (1996). Ein neuer Eryopoide (Amphibia: Temnospondyli) aus dem saarpfälzischen Rotliegend (Unter-Perm; Südwest-Deutschland). *Mainzer geowissenschaftliche Mitteilungen*, 25:7–26.

Boy, J. A. (2002). Über die Micromelerpetontidae (Amphibia: Temnospondyli). 3. *Eimerisaurus* n. g. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 225(3):425–452.

Boy, J. A. and Bandel, K. (1973). *Bruktererpeton fiebigi* n. gen. n. sp. (Amphibia: Gephyrostegida). Der erste Tetrapode aus dem Rheinisch-Westfälischen Karbon (Namur B; W.-Deutschland). *Palaeontographica Abteilung A*, 145(1–3):39–77.

Boyd, C. A. (2015). The systematic relationships and biogeographic history of ornithischian dinosaurs. *PeerJ*, 3:e1523.

Brandes, T. (1914). Plesiosauriden aus dem Unteren Lias von Halberstadt. *Palaeontographica*, 61(1–2):41–56.

Brink, A. S. (1961). On some small therocephalians. *Palaeontologia africana*, 7:155–182.

Brink, K. S. and Reisz, R. R. (2012). Morphology of the palate and braincase of *Dimetrodon milleri*. *Historical Biology*, 24(5):453–459.

Brink, K. S. and Reisz, R. R. (2014). Hidden dental diversity in the oldest terrestrial apex predator *Dimetrodon*. *Nature Communications*, 5:3269.

Brink, K. S., Campione, N. E., and Hawthorn, J. R. (2013). Amniote faunal revision of the Pictou Group (Permo-Carboniferous), Prince Edward Island, Canada. *Comptes Rendus Palevol*, 12(7–8):473–485.

Brink, K. S., LeBlanc, A. R., and Reisz, R. R. (2014). First record of plicidentine in Synapsida and patterns of tooth root shape change in Early Permian sphenacodontians. *Naturwissenschaften*, 101(11):883–892.

Brink, K. S., Maddin, H. C., Evans, D. C., and Reisz, R. R. (2015). Re-evaluation of the historic Canadian fossil *Bathygnathus borealis* from the Early Permian of Prince Edward Island. *Canadian Journal of Earth Sciences*, 52(12):1109–1120.

Brinkman, D. B. and Sues, H.-D. (1987). A staurikosauird dinosaur from the Upper Triassic Ischigualasto Formation of Argentina and the relationships of the Staurikosauridae. *Palaeontology*, 30(3):493–503.

Brinkman, D. B., Berman, D. S., and Eberth, D. A. (1984). A new araeoscelid reptile, *Zarcasaurus tanyderus*, from the Cutler Formation (Lower Permian) of north-central New Mexico. *New Mexico Geology*, 6(2):34–39.

Brinkman, D. (1988). A weigeltisaurid reptile from the Lower Triassic of British Columbia. *Palaeontology*, 31(4):951–955.

Brinkman, D. and Eberth, D. A. (1986). The anatomy and relationships of *Stereophallodon* and *Baldwinonus* (Reptilia, Pelycosauria). *Breviora*, 485:1–34.

Brinkmann, W. (1997). Die Ichthyosaurier (Reptilia) aus der Mitteltrias des Monte San Giorgio (Tessin, Schweiz) und von Besano (Lombardei, Italien) - der aktuelle Forschungsstand. *Vierteljahresschrift der naturforschenden Gesellschaft in Zürich*, 142(2):69–78.

Brinkmann, W. (1998). Die Ichthyosaurier (Reptilia) aus der Grenzbitumenzone (Mitteltrias) des Monte San Giorgio (Tessin, Schweiz) - neue Ergebnisse. *Vierteljahresschrift der naturforschenden Gesellschaft in Zürich*, 143(4):165–177.

Bristowe, A. and Raath, M. A. (2004). A juvenile coelophysoid skull from the Early Jurassic of Zimbabwe, and the synonymy of *Coelophysis* and *Syntarsus*. *Palaeontologia africana*, 40:31–41.

Britt, B. B., Chure, D., Engelmann, G., Dalla Vecchia, F., Scheetz, R., Meek, S., Thelin, C., and Chambers, M. (2015). A new, large, non-pterodactyloid pterosaur from a Late Triassic interdunal desert environment within the eolian Nugget Sandstone of northeastern Utah, USA indicates early pterosaurs were ecologically diverse and geographically widespread. *SVP Program and Abstracts Book*, page 97.

Britt, B. B., Dalla Vecchia, F. M., Chure, D. J., Engelmann, G. F., Whiting, M. F., and Scheetz, R. D. (2018). *Caelestiventus hanseni* gen. et sp. nov. extends the desert-dwelling pterosaur record back 65 million years. *Nature Ecology & Evolution*, 2(9):1386–1392.

Broadley, M. W., Barry, P. H., Ballentine, C. J., Taylor, L. A., and Burgess, R. (2018). End-Permian extinction amplified by plume-induced release of recycled lithospheric volatiles. *Nature Geoscience*, 11(9):682–687.

Brocklehurst, N. (2015). *The early evolution of Synapsida (Vertebrata, Amniota) and the quality of their fossil record*. PhD thesis, Lebenswissenschaftliche Fakultät, Humboldt-Universität zu Berlin, Berlin. 497 pp.

Brocklehurst, N. (2016). Rates and modes of body size evolution in early carnivores and herbivores: a case study from Captorhinidae. *PeerJ*, 4:e1555.

Brocklehurst, N. (2018). An examination of the impact of Olson,Äôs extinction on tetrapods from Texas. *PeerJ*, 6:e4767.

Brocklehurst, N. and Fröbisch, J. (2017). A re-examination of the enigmatic Russian tetrapod *Phreatophasma aenigmaticum* and its evolutionary implications. *Fossil Record*, 20(1):87–93.

Brocklehurst, N. and Brink, K. S. (2017). Selection towards larger body size in both herbivorous and carnivorous synapsids during the Carboniferous. *FACETS*, 2:68–84.

Brocklehurst, N. and Fröbisch, J. (2018). A reexamination of *Milosaurus mccordi*, and the evolution of large body size in Carboniferous synapsids. *Journal of Vertebrate Paleontology*, 38(5):e1508026.

Brocklehurst, N., Kammerer, C. F., and Fröbisch, J. (2013a). Data from: The early evolution of synapsids, and the influence of sampling on their fossil record. Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.cq376.

Brocklehurst, N., Kammerer, C. F., and Fröbisch, J. (2013b). The early evolution of synapsids, and the influence of sampling on their fossil record. *Paleobiology*, 39(3):470–490.

Brocklehurst, N., Ruta, M., Müller, J., and Fröbisch, J. (2015). Elevated extinction rates as a trigger for diversification rate shifts: early amniotes as a case study. *Scientific Reports*, 5:17104.

Brocklehurst, N., Reisz, R. R., Fernandez, V., and Fröbisch, J. (2016a). A re-description of '*Mycterosaurus*' *smithae*, an Early Permian eothyridid, and its impact on the phylogeny of pelycosaurian-grade synapsids. *PLoS ONE*, 11(6):e0156810.

Brocklehurst, N., Romano, M., and Fröbisch, J. (2016b). Principal component analysis as an alternative treatment for morphometric characters: phylogeny of caseids as a case study. *Palaeontology*, 59(6):877–886.

Brocklehurst, N., Day, M. O., Rubidge, B. S., and Fröbisch, J. (2017). Olson's Extinction and the latitudinal biodiversity gradient of tetrapods in the Permian. *Proceedings of the Royal Society B: Biological Sciences*, 284(1852):20170231.

Brocklehurst, N., Dunne, E. M., Cashmore, D. D., and Fröbisch, J. (2018). Physical and environmental drivers of Paleozoic tetrapod dispersal across Pangaea. *Nature Communications*, 9:5216.

Broili, F. and Schröder, J. (1937). Beobachtungen an Wirbeltieren der Karrooformation. XXVIII. Über einige neue Anomodontier aus der *Tapinocephalus*-Zone. *Sitzungsberichte der mathematisch-naturwissenschaftlichen Abteilung der Bayerischen Akademie der Wissenschaften zu München*, 1937(2):118–168.

Bronzati, M. and Rauhut, O. W. M. (2018). Braincase redescription of *Efraasia minor* Huene, 1908 (Dinosauria: Sauropodomorpha) from the Late Triassic of Germany, with comments on the evolution of the sauropodomorph braincase. *Zoological Journal of the Linnean Society*, 182(1):173–224.

Bronzati, M., Montefeltro, F. C., and Langer, M. C. (2015). Diversification events and the effects of mass extinctions on Crocodyliformes evolutionary history. *Royal Society Open Science*, 2(5):140385.

Bronzati, M., Benson, R. B. J., and Rauhut, O. W. M. (2018). Rapid transformation in the braincase of sauropod dinosaurs: integrated evolution of the braincase and neck in early sauropods? *Palaeontology*, 61(2):289–302.

Broom, R. (1909). Notice of some new South African fossil amphibians and reptiles. *Annals of the South African Museum*, 7(3):270–278.

Broom, R. (1912). On some new fossil reptiles from the Permian and Triassic Beds of South Africa. *Proceedings of the Zoological Society of London*, 82(4):859–876.

Broom, R. (1913). On the structure and affinities of *Bolosaurus*. *Bulletin of the American Museum of Natural History*, 32(33):509–516.

Broom, R. (1915). Catalogue of types and figured specimens of fossil vertebrates in the American Museum of Natural History. II.—Permian, Triassic and Jurassic reptiles of South Africa. *Bulletin of the American Museum of Natural History*, 25(2):105–164.

Broom, R. (1924). On some points in the structure of the pareiasaurian skull. *Proceedings of the Zoological Society of London*, 94(2):499–508.

Broom, R. (1932). *The Mammal-like Reptiles of South Africa and the Origin of Mammals*. H. F. & G. Witherby, London. 376 pp.

Broom, R. (1936a). On the structure of the skull in the mammal-like reptiles of the suborder Therocephalia. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 226(529):1–42.

Broom, R. (1936b). The South African Procolophonia. *Annals of the Transvaal Museum*, 18:387–391.

Broom, R. (1940). Some new Karroo reptiles from the Graaff-Reinet District. *Annals of the Transvaal Museum*, 20(2):71–87.

Broom, R. (1941). Some new Karroo reptiles, with notes on a few others. *Annals of the Transvaal Museum*, 20(3):193–213.

Brown, C. M., Evans, D. C., Campione, N. E., O'Brien, L. J., and Eberth, D. A. (2013). Evidence for taphonomic size bias in the Dinosaur Park Formation (Campanian, Alberta), a model Mesozoic terrestrial alluvial-paralic system. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 372:108–122.

Brown, J. H., Marquet, P. A., and Taper, M. L. (1993). Evolution of body size: consequences of an energetic definition of fitness. *The American Naturalist*, 142(4):573–584.

Brown, J. H., Hall, C. A. S., and Sibly, R. M. (2018). Equal fitness paradigm explained by a trade-off between generation time and energy production rate. *Nature Ecology & Evolution*, 2(2):262–268.

Brunner, E. and Munzel, U. (2000). The nonparametric Behrens-Fisher problem: asymptotic theory and a small-sample approximation. *Biometrical Journal*, 42(1):17–25.

Brusatte, S. L., Benton, M. J., Ruta, M., and Lloyd, G. T. (2008a). Superiority, competition, and opportunism in the evolutionary radiation of dinosaurs. *Science*, 321(5895):1485–1488.

Brusatte, S. L., Benton, M. J., Ruta, M., and Lloyd, G. T. (2008b). The first 50 Myr of dinosaur evolution: macroevolutionary pattern and morphological disparity. *Biology Letters*, 4(6):733–736.

Brusatte, S. L., Benton, M. J., Lloyd, G. T., Ruta, M., and Wang, S. C. (2010a). Macroevolutionary patterns in the evolutionary radiation of archosaurs (Tetrapoda: Diapsida). *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(Special Issue 3–4):367–382.

Brusatte, S. L., Benton, M. J., Desojo, J. B., and Langer, M. C. (2010b). The higher-level phylogeny of Archosauria (Tetrapoda: Diapsida). *Journal of Systematic Palaeontology*, 8(1):3–47.

Brusatte, S. L., Nesbitt, S. J., Irmis, R. B., Butler, R. J., Benton, M. J., and Norell, M. A. (2010c). The origin and early radiation of dinosaurs. *Earth-Science Reviews*, 101(1–2):68–100.

Brusatte, S. L., Sakamoto, M., Montanari, S., and Harcourt Smith, W. E. H. (2012). The evolution of cranial form and function in theropod dinosaurs: insights from geometric morphometrics. *Journal of Evolutionary Biology*, 25(2):365–377.

Brusatte, S. L., Butler, R. J., Niedźwiedzki, G., Sulej, T., Bronowicz, R., and Satkūnas, J. (2013). First record of Mesozoic terrestrial vertebrates from Lithuania: phytosaurs (Diapsida: Archosauriformes) of probable Late Triassic age, with a review of phytosaur biogeography. *Geological Magazine*, 150(1):110–122.

Brusatte, S. L., Lloyd, G. T., Wang, S. C., and Norell, M. A. (2014). Gradual assembly of avian body plan culminated in rapid rates of evolution across the dinosaur-bird transition. *Current Biology*, 24(20):2386–2392.

Brusatte, S. L., Butler, R. J., Mateus, O., and Steyer, J. S. (2015a). A new species of *Metoposaurus* from the Late Triassic of Portugal and comments on the systematics and biogeography of metoposaurid temnospondyls. *Journal of Vertebrate Paleontology*, 35(3):e912988.

Brusatte, S. L., Young, M. T., Challands, T. J., Clark, N. D. L., Fischer, V., Fraser, N. C., Liston, J. J., MacFadyen, C. C. J., Ross, D. A., Walsh, S., and Wilkinson, M. (2015b). Ichthyosaurs from the Jurassic of Skye, Scotland. *Scottish Journal of Geology*, 51(1):43–55.

Buchwitz, M., Foth, C., Kogan, I., and Voigt, S. (2012). On the use of osteoderm features in a phylogenetic approach on the internal relationships of the Chroniosuchia (Tetrapoda: Reptiliomorpha). *Palaeontology*, 55(3):623–640.

Buffetaut, E., Suteethorn, V., Cuny, G., Tong, H., Le Loeuff, J., Khansubha, S., and Jongautchariyakul, S. (2000). The earliest known sauropod dinosaur. *Nature*, 407(6800):72–74.

Bulanov, V. V. (2002a). *Karpinskiosaurus ultimus* (Seymouriamorpha, Parareptilia) from the Upper Permian of European Russia. *Paleontological Journal*, 36(1):72–79.

Bulanov, V. V. (2002b). New data on procolophons from the Permian of Eastern Europe. *Paleontological Journal*, 36(5):525–530.

Bulanov, V. V. (2003). Evolution and systematics of seymouriamorph parareptiles. *Paleontological Journal*, 37:S1–S105.

Bulanov, V. V. (2014). New finds of *Microphon exiguus* (Seymouriamorpha, Kotlassiidae) in the Severodvinian beds of the Sukhona River Basin, Russia. *Paleontological Journal*, 48(6):633–644.

Bulanov, V. V. and Sennikov, A. G. (2010). New data on the morphology of Permian gliding weigeltisaurid reptiles of Eastern Europe. *Paleontological Journal*, 44(6):682–694.

Bulanov, V. V. and Sennikov, A. G. (2015a). *Glaurung schneideri* gen. et sp. nov., a new weigeltisaurid (Reptilia) from the Kupfershiefer (Upper Permian) of Germany. *Paleontological Journal*, 49(12):1353–1364.

Bulanov, V. V. and Sennikov, A. G. (2015b). Substantiation of validity of the Late Permian genus *Weigeltisaurus* Kuhn, 1939 (Reptilia, Weigeltisauridae). *Paleontological Journal*, 49(10):1101–1111.

Burgess, S. D. and Bowring, S. A. (2015). High-precision geochronology confirms voluminous magmatism before, during, and after Earth's most severe extinction. *Science Advances*, 1(7):e1500470.

Burnham, K. P. and Anderson, D. R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer, New York, Second edition. 488 pp.

Busbey, A. B. I. and Gow, C. (1984). A new protosuchian crocodile from the Upper Triassic Elliot Formation of South Africa. *Palaeontologia africana*, 25:127–149.

Butler, M. A. and King, A. A. (2004). Phylogenetic comparative analysis: a modeling approach for adaptive evolution. *The American Naturalist*, 164(6):683–695.

Butler, P. M. and Hooker, J. J. (2005). New teeth of allotherian mammals from the English Bathonian, including the earliest multituberculates. *Acta Palaeontologica Polonica*, 50(2):185–207.

Butler, P. M. and Sigogneau-Russell, D. (2016). Diversity of triconodonts in the Middle Jurassic of Great Britain. *Palaeontologia Polonica*, 67:35–65.

Butler, R. J. (2010). The anatomy of the basal ornithischian dinosaur *Eocursor parvus* from the lower Elliot Formation (Late Triassic) of South Africa. *Zoological Journal of the Linnean Society*, 160(4):648–684.

Butler, R. J. (2013). '*Francosuchus*' *trauthi* is not *Paleorhinus*: implications for Late Triassic vertebrate biostratigraphy. *Journal of Vertebrate Paleontology*, 33(4):858–864.

Butler, R. J., Smith, R. M. H., and Norman, D. B. (2007). A primitive ornithischian dinosaur from the Late Triassic of South Africa, and the early evolution and diversification of Ornithischia. *Proceedings of the Royal Society B: Biological Sciences*, 274(1621):2041–2046.

Butler, R. J., Upchurch, P., and Norman, D. B. (2008). The phylogeny of the ornithischian dinosaurs. *Journal of Systematic Palaeontology*, 6(1):1–40.

Butler, R. J., Galton, P. M., Porro, L. B., Chiappe, L. M., Henderson, D. M., and Erickson, G. M. (2010). Lower limits of ornithischian dinosaur body size inferred from a new Upper Jurassic heterodontosaurid from North America. *Proceedings of the Royal Society B: Biological Sciences*, 277:375–381.

Butler, R. J., Liyong, J., Jun, C., and Godefroit, P. (2011a). The postcranial osteology and phylogenetic position of the small ornithischian dinosaur *Changchunsaurus parvus* from the Quantou Formation (Cretaceous: Aptian-Cenomanian) of Jilin Province, north-eastern China. *Palaeontology*, 54(3):667–683.

Butler, R. J., Brusatte, S. L., Reich, M., Nesbitt, S. J., Schoch, R. R., and Hornung, J. J. (2011b). The sail-backed reptile *Ctenosauriscus* from the latest Early Triassic of Germany and the timing and biogeography of the early archosaur radiation. *PLoS ONE*, 6(10):e25693.

Butler, R. J., Sullivan, C., Ezcurra, M. D., Liu, J., Lecuona, A., and Sookias, R. B. (2014a). New clade of enigmatic early archosaurs yields insights into early pseudosuchian phylogeny and the biogeography of the archosaur radiation. *BMC Evolutionary Biology*, 14:128.

Butler, R. J., Rauhut, O. W. M., Stocker, M. R., and Bronowicz, R. (2014b). Redescription of the phytosaurs *Paleorhinus* (‘*Francosuchus*’) *angustifrons* and *Ebrachosuchus neukami* from Germany, with implications for Late Triassic biochronology. *Zoological Journal of the Linnean Society*, 170(1):155–208.

Butler, R. J., Ezcurra, M. D., Montefeltro, F. C., Samathi, A., and Sobral, G. (2015). A new species of basal rhynchosaur (Diapsida: Archosauromorpha) from the early Middle Triassic of South Africa, and the early evolution of Rhynchosauria. *Zoological Journal of the Linnean Society*, 174(3):571–588.

Butler, R. J., Nesbitt, S. J., Charig, A. J., Gower, D. J., and Barrett, P. M. (2018). *Mandasuchus tanyauchen*, gen. et sp. nov., a pseudosuchian archosaur from the Manda Beds (?Middle Triassic) of Tanzania. *Journal of Vertebrate Paleontology*, 37(6, Supplement):96–121.

Button, D. J., Rayfield, E. J., and Barrett, P. M. (2014). Cranial biomechanics underpins high sauropod diversity in resource-poor environments. *Proceedings of the Royal Society of London B: Biological Sciences*, 281(1795):20142114.

Button, D. J., Lloyd, G. T., Ezcurra, M. D., and Butler, R. J. (2017). Mass extinctions drove increased global faunal cosmopolitanism on the supercontinent Pangaea. *Nature Communications*, 8:733.

Cabreira, S., Schultz, C., Bittencourt, J., Soares, M., Fortier, D., Silva, L. R., and Langer, M. C. (2011). New stem-sauropodomorph (Dinosauria, Saurischia) from the Triassic of Brazil. *Naturwissenschaften*, 98(12):1035–1040.

Cabreira, S., Kellner, A., Dias-da-Silva, S., Roberto da Silva, L., Bronzati, M., Marsola, J., Müller, R., Bittencourt, J., Batista, B., Raugust, T., Carrilho, R., Brodt, A., and Langer, M. (2016). A unique Late Triassic dinosauromorph assemblage reveals dinosaur ancestral anatomy and diet. *Current Biology*, 26(22):3090–3095.

Caine, H. and Benton, M. J. (2011). Ichthyosauria from the Upper Lias of Strawberry Bank, England. *Palaeontology*, 54(5):1069–1093.

Caldwell, M. W. (2003). “Without a leg to stand on”: on the evolution and development of axial elongation and limblessness in tetrapods. *Canadian Journal of Earth Sciences*, 40(4):573–588.

Callaway, J. M. (1989). *Systematics, phytogeny, and ancestry of Triassic ichthyosaurs (Reptilla, Ichthyosauria)*. Unpublished PhD thesis, University of Rochester, Rochester, New York. 204 pp.

Callaway, J. M. and Massare, J. A. (1989). *Shastasaurus altispinus* (Ichthyosauria, Shastasauridae) from the Upper Triassic of the El Antimonio district, northwestern Sonora, Mexico. *Journal of Paleontology*, 63(6):930–939.

Callier, V., Clack, J. A., and Ahlberg, P. E. (2009). Contrasting developmental trajectories in the earliest known tetrapod forelimbs. *Science*, 324(5925):364–367.

Camp, C. L. (1930). A study of the phytosaurs with description of new material from western North America. *Memoirs of the University of California*, 10:1–174.

Camp, J. A. (2010). Morphological variation and disparity in *Lystrosaurus* (Therapsida: Dicynodontia). Master's thesis, University of Iowa. 141 pp.

Campione, N. E. and Reisz, R. R. (2010). *Varanops brevirostris* (Eupelycosauria: Varanopidae) from the Lower Permian of Texas, with discussion of varanopid morphology and interrelationships. *Journal of Vertebrate Paleontology*, 30(3):724–746.

Campione, N. and Evans, D. (2012). A universal scaling relationship between body mass and proximal limb bone dimensions in quadrupedal terrestrial tetrapods. *BMC Biology*, 10:60.

Cantalapiedra, J. L., Prado, J. L., Fernández, M. H., and Alberdi, M. T. (2017). Decoupled ecomorphological evolution and diversification in Neogene-Quaternary horses. *Science*, 355(6325):627–630.

Cantrell, A. K., Suazo, T. L., Berman, D. S., Spielmann, J. A., Lucas, S. G., Henrici, A. C., and Rinehart, L. F. (2013). The Gallina Well locality, an Early Permian (Middle Wolfcampian) vertebral fossil site in Socorro County, New Mexico. In Lucas, S. G., Nelson, W. J., DiMichele, W. A., Spielmann, J. A., Krainer, K., Barrick, J. E., Elrick, S., and Voigt, S., editors, *Carboniferous-Permian transition in central New Mexico*, volume 59, pages 253–264. New Mexico Museum of Natural History.

Carballido, J. L. and Pol, D. (2010). The dentition of *Amygdalodon patagonicus* (Dinosauria: Sauropoda) and the dental evolution in basal sauropods. *Comptes Rendus Palevol*, 9(3):83–93.

Carrano, M. T. (2006). Body-Size Evolution in the Dinosauria. In Carrano, M. T., Gaudin, T. J., Blob, R. W., and Wible, J. R., editors, *Amniote Paleobiology: Perspectives on the Evolution of Mammals, Birds, and Reptiles*, chapter 8, pages 225–268. University of Chicago Press, Chicago.

Carrano, M. T. and Sampson, S. D. (2004). A review of coelophysoid (Dinosauria: Theropoda) from the Early Jurassic of Europe, with comments on the late history of the Coelophysoidea. *Neues Jahrbuch für Geologie und Paläontologie - Monatshefte*, 2004(9):537–558.

Carrano, M. T., Hutchinson, J. R., and Sampson, S. D. (2005). New information on *Segisaurus halli*, a small theropod dinosaur from the Early Jurassic of Arizona. *Journal of Vertebrate Paleontology*, 25(4):835–849.

Carrano, M. T., Benson, R. B. J., and Sampson, S. D. (2012). The phylogeny of Tetanurae (Dinosauria: Theropoda). *Journal of Systematic Palaeontology*, 10(2):211–300.

Carroll, R. L. (1964a). Early evolution of the dissorophid amphibians. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 131(7):161–250.

Carroll, R. L. (1964b). The earliest reptiles. *Journal of the Linnean Society of London, Zoology*, 45(304):61–83.

Carroll, R. L. (1967). A limnoscelid reptile from the Middle Pennsylvanian. *Journal of Paleontology*, 41(5):1256–1261.

Carroll, R. L. (1972). I. Gephyrostegida, Solenodonsauridae. In Carroll, R. L., Kuhn, O., and Tatarinov, L. P., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 5B: Batrachosauria (Anthracosauria) Gephyrostegida – Chroniosuchida*, pages 1–19. Verlag Dr. Friedrich Pfeil, München.

Carroll, R. L. (1977). Patterns of Amphibian Evolution: An Extended Example of the Incompleteness of the Fossil Record. In Hallam, A., editor, *Patterns of Evolution as Illustrated by the Fossil Record*, volume 5 of *Developments in Palaeontology and Stratigraphy*, chapter 13, pages 405–437. Elsevier, Amsterdam.

Carroll, R. L. (1987). *Heleosuchus*: an enigmatic diapsid reptile from the Late Permian or Early Triassic of southern Africa. *Canadian Journal of Earth Sciences*, 24(4):664–667.

Carroll, R. L. (1988). *Vertebrate Paleontology and Evolution*. W. H. Freeman and Company, New York. 698 pp.

Carroll, R. L. (1998a). Order Aïstopoda Miall 1875. In Carroll, R. L., Bossy, K. A., Milner, A. C., Andrews, S. M., and Wellstead, C. F., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 1: Lepospondyli*, pages 163–182. Verlag Dr. Friedrich Pfeil, München.

Carroll, R. L. (1998b). Order Microsauria Dawson 1863. In Carroll, R. L., Bossy, K. A., Milner, A. C., Andrews, S. M., and Wellstead, C. F., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 1: Lepospondyli*, pages 1–72. Verlag Dr. Friedrich Pfeil, München.

Carroll, R. L. (2009). *The Rise of Amphibians: 365 Million Years of Evolution*. Johns Hopkins University Press, Baltimore. 360 pp.

Carroll, R. L. (2012). The importance of recognizing our limited knowledge of the fossil record in the analysis of phylogenetic relationships among early tetrapods. *Fieldiana Life and Earth Sciences*, 5:5–16.

Carroll, R. L. (2013). Problems of the Ancestry of Turtles. In Brinkman, D. B., Holroyd, P. A., and Gardner, J. D., editors, *Morphology and Evolution of Turtles*, Vertebrate Paleobiology and Paleoanthropology, chapter 3, pages 19–36. Springer, Dordrecht.

Carroll, R. L. and Gaskill, P. (1978). The order Microsauria. *Memoirs of the American Philosophical Society*, 126:1–211.

Carroll, R. L. and Thompson, P. (1982). A bipedal lizardlike reptile from the Karroo. *Journal of Paleontology*, 56(1):1–10.

Carroll, R. L. and Andrews, S. M. (1998). Order Adelospondyli Watson 1929. In Carroll, R. L., Bossy, K. A., Milner, A. C., Andrews, S. M., and Wellstead, C. F., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 1: Lepospondyli*, pages 149–162. Verlag Dr. Friedrich Pfeil, München.

Case, E. C. (1917). Notes on the possible evidence of the presence of a *Pareiasaurus*-like reptile in the Conemaugh Series of West Virginia. *West Virginia Geological Survey: Braxton and Clay Counties*, pages 817–821.

Case, E. C. (1924). Some new specimens of Triassic vertebrates in the Museum of Geology of the University of Michigan. *Papers of the Michigan Academy of Science, Arts and Letters*, 4(1):419–423.

Case, E. C. (1929). Description of a nearly complete skeleton of *Ostodolepis brevispinatus* Williston. *Contributions from the Museum of Paleontology, University of Michigan*, 3(5):81–107.

Case, E. C. (1930). On the lower jaw of *Brachysuchus megalodon*. *Contributions from the Museum of Paleontology, University of Michigan*, 3(8):155–161.

Case, E. C. (1931). Description of a new species of *Buettneria*, with a discussion of the brain case. *Contributions from the Museum of Paleontology, University of Michigan*, 3(11):187–206.

Castanhinha, R., Araújo, R., Júnior, L. C., Angielczyk, K. D., Martins, G. G., Martins, R. M. S., Chaouiya, C., Beckmann, F., and Wilde, F. (2013). Bringing dicynodonts back to life: paleobiology and anatomy of a new emydopoid genus from the Upper Permian of Mozambique. *PLoS ONE*, 8(12):e80974.

Cerda, I. A., Sterli, J., and Scheyer, T. M. (2016). Bone shell microstructure of *Condorchelys antiqua* Sterli, 2008, a stem turtle from the Jurassic of Patagonia. *Comptes Rendus Palevol*, 15(1–2):128–141.

Cerda, I. A., Chinsamy, A., Pol, D., Apaldetti, C., Otero, A., Powell, J. E., and Martínez, R. N. (2017). Novel insight into the origin of the growth dynamics of sauropod dinosaurs. *PLoS ONE*, 12(6):e0179707.

Chakravorti, S. and Sengupta, D. P. (2016). Indian metoposaurid amphibians: morphometry, taxonomy and dispersal. In Holwerda, F., Madern, A., Voeten, D., van Heteren, A., Meijer, H., and den Ouden, N., editors, *XIV Annual Meeting of the European Association of Vertebrate*

Palaeontologists, 6-10 July 2016, Programme and Abstract Book, page 96. Haarlem, The Netherlands.

Chapelle, K. E. J. and Choiniere, J. N. (2018). A revised cranial description of *Massospondylus carinatus* Owen (Dinosauria: Sauropodomorpha) based on computed tomographic scans and a review of cranial characters for basal Sauropodomorpha. *PeerJ*, 6:e4224.

Charig, A. J. (1980). Differentiation of lineages among Mesozoic tetrapods. *Mémoires de la Société Géologique de France, Nouvelle Série*, 59(139):207–210.

Chatterjee, S. (1980). *Malerisaurus*, a new eosuchian reptile from the Late Triassic of India. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 291(1048):163–200.

Chatterjee, S. (1987). A new theropod dinosaur from India with remarks on the Gondwana-Laurasia connection in the Late Triassic. In McKenzie, G. D., editor, *Gondwana Six: Stratigraphy, Sedimentology and Paleontology*, number 41 in Geophysical Monograph Series, pages 183–189. American Geophysical Union, Washington.

Chatterjee, S. (1991). Cranial anatomy and relationships of a new Triassic bird from Texas. *Philosophical Transactions: Biological Sciences*, 332(1265):277–342.

Chatterjee, S. and Majumdar, P. K. (1987). *Tikisuchus romeri*, a new rauisuchid reptile from the Late Triassic of India. *Journal of Paleontology*, 61(4):787–793.

Chatterjee, S. and Creisler, B. S. (1994). *Alwalkeria* (Theropoda) and *Morturneria* (Plesiosauria), new names for preoccupied *Walkeria* Chatterjee, 1987 and *Turneria* Chatterjee and Small, 1989. *Journal of Vertebrate Paleontology*, 14(1):142.

Chen, D., Alavi, Y., Brazeau, M. D., Blom, H., Millward, D., and Ahlberg, P. E. (2018). A partial lower jaw of a tetrapod from "Romer's Gap". *Earth and Environmental Science Transactions of The Royal Society of Edinburgh*, 108(1):55–65.

Chen, J., Bever, G. S., Yi, H.-Y., and Norell, M. A. (2016). A burrowing frog from the late Paleocene of Mongolia uncovers a deep history of spadefoot toads (Pelobatoidea) in East Asia. *Scientific Reports*, 6:19209.

Chen, X.-h., Cheng, L., and Sander, P. M. (2007). A new species of *Callawayia* (Reptilia: Ichthyosauria) from the Late Triassic in Guanling, Guizhou. *Geology in China*, 34(6):974–982. [In Chinese with English abstract].

Chen, X.-h., Motani, R., Cheng, L., Jiang, D.-y., and Rieppel, O. (2014). The enigmatic marine reptile *Nanchangosaurus* from the Lower Triassic of Hubei, China and the phylogenetic affinities of Hupehsuchia. *PLoS ONE*, 9(7):e102361.

Chen, Z.-Q. and Benton, M. J. (2012). The timing and pattern of biotic recovery following the end-Permian mass extinction. *Nature Geoscience*, 5(6):375–383.

Cheng, L., Chen, X., Zhan, B., and Cai, Y. (2011). New study of *Anshunsaurus huangnihensis* Cheng, 2007 (Reptilia: Thalattosauria): revealing its transitional position in Askeptosauridae. *Acta Geologica Sinica - English Edition*, 85(6):1231–1237.

Cheng, L., Chen, X.-H., Shang, Q.-H., and Wu, X.-C. (2014). A new marine reptile from the Triassic of China, with a highly specialized feeding adaptation. *Naturwissenschaften*, 101(3):251–259.

Cheng, Y.-n., Wu, X.-c., Sato, T., and Shan, H.-y. (2016). *Dawazisaurus brevis*, a new eosauropterygian from the Middle Triassic of Yunnan, China. *Acta Geologica Sinica (English Edition)*, 90(2):401–424.

Chiari, Y., Cahais, V., Galtier, N., and Delsuc, F. (2012). Phylogenomic analyses support the position of turtles as the sister group of birds and crocodiles (Archosauria). *BMC Biology*, 10:65.

Chira, A. M., Cooney, C. R., Bright, J. A., Capp, E. J. R., Hughes, E. C., Moody, C. J. A., Nouri, L. O., Varley, Z. K., and Thomas, G. H. (2018). Correlates of rate heterogeneity in avian ecomorphological traits. *Ecology Letters*, 21(10):1505–1514.

Christiansen, P. and Fariña, R. A. (2004). Mass prediction in theropod dinosaurs. *Historical Biology*, 16(2–4):85–92.

Chudinov, P. K. (1955). [Cotylosaurs from the Shikhovo-Chirki site]. *Doklady Akademii Nauk SSSR*, 103(5):913–916. [In Russian].

Cisneros, J. C. (2008a). New basal procolophonid reptile from the Katberg Formation (Lower Triassic) of the South African Karoo. *Palaeoworld*, 17:126–134.

Cisneros, J. C. (2008b). Phylogenetic relationships of procolophonid parareptiles with remarks on their geological record. *Journal of Systematic Palaeontology*, 6(3):345–366.

Cisneros, J. C. (2008c). Taxonomic status of the reptile genus *Procolophon* from the Gondwanan Triassic. *Palaeontologia africana*, 43:7–17.

Cisneros, J. C., Damiani, R., Schultz, C., da Rosa, Á., Schwanke, C., Neto, L. W., and Aurélio, P. L. P. (2004). A procolophonoid reptile with temporal fenestration from the Middle Triassic of Brazil. *Proceedings of the Royal Society of London B: Biological Sciences*, 271(1547):1541–1546.

Cisneros, J. C., Rubidge, B. S., Mason, R., and Dube, C. (2008). Analysis of millerettid parareptile relationships in the light of new material of *Broomia perplexa* Watson, 1914, from the Permian of South Africa. *Journal of Systematic Palaeontology*, 6(4):453–462.

Cisneros, J. C., Abdala, F., Rubidge, B. S., Dentzien-Dias, P. C., and Bueno, A. d. O. (2011). Dental occlusion in a 260-million-year-old therapsid with saber canines from the Permian of Brazil. *Science*, 331(6024):1603–1605.

Cisneros, J. C., Abdala, F., Atayman-Güven, S., Rubidge, B. S., Şengör, A. M. C., and Schultz, C. L. (2012). Carnivorous dinocephalian from the Middle Permian of Brazil and tetrapod dispersal in Pangaea. *Proceedings of the National Academy of Sciences*, 109(5):1584–1588.

Cisneros, J. C., Marsicano, C., Angielczyk, K. D., Smith, R. M. H., Richter, M., Fröbisch, J., Kammerer, C. F., and Sadleir, R. W. (2015a). New Permian fauna from tropical Gondwana. *Nature Communications*, 6:8676.

Cisneros, J. C., Abdala, F., Jashashvili, T., Bueno, A. d. O., and Dentzien-Dias, P. (2015b). *Tiarajudens eccentricus* and *Anomocephalus africanus*, two bizarre anomodonts (Synapsida, Therapsida) with dental occlusion from the Permian of Gondwana. *Royal Society Open Science*, 2(7):150090.

Clack, J. A. (1987a). *Pholiderpeton scutigerum* Huxley, an amphibian from the Yorkshire Coal Measures. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 318(1188):1–107.

Clack, J. A. (1987b). Two new specimens of *Anthracosaurus* (Amphibia: Anthracosauria) from the Northumberland Coal Measures. *Palaeontology*, 30(1):15–26.

Clack, J. A. (1994). *Silvanerpeton miripedes*, a new anthracosauroid from the Viséan of East Kirkton, West Lothian, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 84(3-4):369–376.

Clack, J. A. (2001). *Eucritta melanolimnetes* from the Early Carboniferous of Scotland, a stem tetrapod showing a mosaic of characteristics. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 92(1):75–95.

Clack, J. A. (2002). An early tetrapod from 'Romer's Gap'. *Nature*, 418(6893):72–76.

Clack, J. A. (2011a). A Carboniferous embolomere tail with supraneural radials. *Journal of Vertebrate Paleontology*, 31(5):1150–1153.

Clack, J. A. (2011b). A new microsaur from the Early Carboniferous (Viséan) of East Kirkton, Scotland, showing soft tissue evidence. *Special Papers in Palaeontology*, 86:45–56.

Clack, J. A. (2012). *Gaining Ground, Second Edition: The Origin and Evolution of Tetrapods*. Indiana University Press, Bloomington. 523 pp.

Clack, J. A. and Milner, A. R. (1993). *Platyrhinops* from the Upper Carboniferous of Linton and Nýřany and the family Amphibamidae (Amphibia: Temnospondyli). In Heidtke, U., editor, *New Research on Permo-Carboniferous Faunas*, volume 29 of *Pollichia-Buch*, pages 185–191. Bad Dürkheim.

Clack, J. A. and Coates, M. I. (1995). *Acanthostega gunnari*, a primitive, aquatic tetrapod? *Bulletin du Muséum national d'Histoire naturelle, Paris, 4ème série, section C (Sciences de la Terre, Paléontologie, Géologie, Minéralogie)*, 17(1–4):359–372.

Clack, J. A. and Ahlberg, P. E. (2004). A new stem tetrapod from the Early Carboniferous of Northern Ireland. In Arratia, G., Wilson, M. V. H., and Cloutier, R., editors, *Recent Advances in the Origin and Early Radiation of Vertebrates*, pages 309–320. Verlag Dr. Friedrich Pfeil, München.

Clack, J. A. and Finney, S. M. (2005). *Pederpes finneyae*, an articulated tetrapod from the Tournaisian of western Scotland. *Journal of Systematic Palaeontology*, 2(4):311–346.

Clack, J. A. and Klembara, J. (2009). An articulated specimen of *Chroniosaurus dongusensis*, and the morphology and relationships of the chroniosuchids. *Special Papers in Palaeontology*, 81:15–42.

Clack, J. A. and Milner, A. R. (2010). Morphology and systematics of the Pennsylvanian amphibian *Platyrhinops lyelli* (Amphibia: Temnospondyli). *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 100(3):275–295.

Clack, J. A. and Milner, A. R. (2015). *Handbook of Paleoherpetology Part 3A1: Basal Tetrapoda*. Verlag Dr. Friedrich Pfeil, München, Germany. 92 pp.

Clack, J. A., Ahlberg, P. E., Blom, H., and Finney, S. M. (2012). A new genus of Devonian tetrapod from North-East Greenland, with new information on the lower jaw of *Ichthyostega*. *Palaeontology*, 55(1):73–86.

Clack, J. A., Bennett, C. E., Carpenter, D. K., Davies, S. J., Fraser, N. C., Kearsey, T. I., Marshall, J. E. A., Millward, D., Otoo, B. K. A., Reeves, E. J., Ross, A. J., Ruta, M., Smithson, K. Z., Smithson, T. R., and Walsh, S. A. (2016). Phylogenetic and environmental context of a Tournaisian tetrapod fauna. *Nature Ecology & Evolution*, 1:0002.

Clark, J. M. (1986). *Phylogenetic relationships of the crocodylomorph archosaurs*. PhD thesis, University of Chicago, Chicago. 556 pp.

Clark, J. M. and Fastovsky, D. E. (1986). Vertebrate biostratigraphy of the Glen Canyon Group in northern Arizona. In Padian, K., editor, *The Beginning of the Age of Dinosaurs: Faunal change across the Triassic–Jurassic Boundary*, chapter 23, pages 285–301. Cambridge University Press, Cambridge.

Clark, J. M., Sues, H.-D., and Berman, D. S. (2001). A new specimen of *Hesperosuchus agilis* from the Upper Triassic of New Mexico and the interrelationships of basal crocodylomorph archosaurs. *Journal of Vertebrate Paleontology*, 20(4):683–704.

Clark, J. M., Maryańska, T., and Barsbold, R. (2004). Therizinosauroidea. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 151–164. University of California Press, Berkeley, Second edition.

Clauss, M., Nurutdinova, I., Meloro, C., Gunga, H.-C., Jiang, D., Koller, J., Herkner, B., Sander, P. M., and Hellwich, O. (2017). Reconstruction of body cavity volume in terrestrial tetrapods. *Journal of Anatomy*, 230(2):325–336.

Clavel, J. and Morlon, H. (2017). Accelerated body size evolution during cold climatic periods in the Cenozoic. *Proceedings of the National Academy of Sciences*, 114(16):4183–4188.

Cleal, C. J. and Thomas, B. A. (2005). Palaeozoic tropical rainforests and their effect on global climates: is the past the key to the present? *Geobiology*, 3(1):13–31.

Cleal, C. J., Opluštil, S., Thomas, B. A., and Tenchov, Y. (2009). Late Moscovian terrestrial biotas and palaeoenvironments of Variscan Euramerica. *Netherlands Journal of Geosciences*, 88(4):181–278.

Cleary, T. J., Moon, B. C., Dunhill, A. M., and Benton, M. J. (2015a). Data from: The fossil record of ichthyosaurs, completeness metrics and sampling biases. Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.657cc.

Cleary, T. J., Moon, B. C., Dunhill, A. M., and Benton, M. J. (2015b). The fossil record of ichthyosaurs, completeness metrics and sampling biases. *Palaeontology*, 58(3):521–536.

Cleary, T. J., Benson, R. B. J., Evans, S. E., and Barrett, P. M. (2018). Lepidosaurian diversity in the Mesozoic – Paleogene: the potential roles of sampling biases and environmental drivers. *Royal Society Open Science*, 5(3):171830.

Clemens, W. A. (1979). A problem in morganucodontid taxonomy (Mammalia). *Zoological Journal of the Linnean Society*, 66(1):1–14.

Clemens, W. A. (1980). Rhaeto-Liassic mammals from Switzerland and West Germany. *Zitteliana*, 5:51–92.

Clemens, W. A. (2007). Early Jurassic allotherians from South Wales (United Kingdom). *Fossil Record*, 10(1):50–59.

Clemens, W. A. (2011). New morganucodontans from an Early Jurassic fissure filling in Wales (United Kingdom). *Palaeontology*, 54(5):1139–1156.

Clemens, W. A. and Martin, T. (2014). Review of the non-tritylodontid synapsids from bone beds in the Rhaetic Sandstone, southern Germany. *Paläontologische Zeitschrift*, 88(4):461–479.

Clément, G. and Lebedev, O. (2014). Revision of the early tetrapod *Obruchevichthys* Vorobyeva, 1977 from the Frasnian (Upper Devonian) of the North-western East European Platform. *Paleontological Journal*, 48(10):1082–1091.

Clemmensen, L. B., Milan, J., Adolfssen, J. S., Estrup, E. J., Frobose, N., Klein, N., Mateus, O., and Wings, O. (2016). The vertebrate-bearing Late Triassic Fleming Fjord Formation of central East Greenland revisited: stratigraphy, palaeoclimate and new palaeontological data. *Geological Society, London, Special Publications*, 434:31–47.

Close, R. A., Evers, S. W., Alroy, J., and Butler, R. J. (2018). How should we estimate diversity in the fossil record? Testing richness estimators using sampling-standardised discovery curves. *Methods in Ecology and Evolution*, 9(6):1386–1400.

Cloutier, R. and Béchard, I. (2013). A new piece of the Devonian fish-to-tetrapod puzzle: the discovery of a complete specimen of *Elpistostege*. *SVP Program and Abstracts Book*, page 107.

Cluver, M. A. and Hotton III, N. (1981). The genera *Dicynodon* and *Diictodon* and their bearing on the classification or the Dicynodontia (Reptilia, Therapsida). *Annals of the South African Museum*, 83(6):99–146.

Cluver, M. A. and King, G. M. (1983). A reassessment of the relationships of Permian Dicynodontia (Reptilia, Therapsida) and a new classification of dicynodonts. *Annals of the South African Museum*, 91(3):195–273.

Coates, M. I. (1996). The Devonian tetrapod *Acanthostega gunnari* Jarvik: postcranial anatomy, basal tetrapod interrelationships and patterns of skeletal evolution. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 87(3):363–421.

Coates, M. I. (2009). Beyond the Age of Fishes. *Nature*, 458(7237):413–414.

Coates, M. I. and Clack, J. A. (1990). Polydactyly in the earliest known tetrapod limbs. *Nature*, 347(6288):66–69.

Coates, M. I. and Clack, J. A. (1991). Fish-like gills and breathing in the earliest known tetrapod. *Nature*, 352(6332):234–236.

Coates, M. I. and Clack, J. A. (1995). Romer's gap: tetrapod origins and terrestriality. *Bulletin du Muséum national d'Histoire naturelle, Paris, 4ème série, section C (Sciences de la Terre, Paléontologie, Géologie, Minéralogie)*, 17(1–4):373–388.

Coates, M. I., Ruta, M., and Friedman, M. (2008). Ever since Owen: Changing perspectives on the early evolution of tetrapods. *Annual Review of Ecology, Evolution, and Systematics*, 39(1):571–592.

Codorniú, L., Rauhut, O. W. M., and Pol, D. (2010). Osteological features of Middle Jurassic pterosaurs from Patagonia (Argentina). *Acta Geoscientica Sinica*, 31(Supp. 1):12–13.

Codorniú, L., Carabajal, A. P., Pol, D., Unwin, D., and Rauhut, O. W. M. (2016). A Jurassic pterosaur from Patagonia and the origin of the pterodactyloid neurocranium. *PeerJ*, 4:e2311.

Codron, J., Botha-Brink, J., Codron, D., Huttenlocker, A. K., and Angielczyk, K. D. (2017). Predator-prey interactions among Permo-Triassic terrestrial vertebrates as a deterministic factor influencing faunal collapse and turnover. *Journal of Evolutionary Biology*, 30(1):40–54.

Cohen, K. M., Finney, S. C., Gibbard, P. L., and Fan, J.-X. (2013). The ICS international chronostratigraphic chart. *Episodes*, 36(3):199–204.

Colbert, E. H. (1946). *Hypsognathus*, a Triassic reptile from New Jersey. *Bulletin of the American Museum of Natural History*, 86(5):225–274.

Colbert, E. H. (1947). Studies of the phytosaurs *Machaeroprosopus* and *Rutiodon*. *Bulletin of the American Museum of Natural History*, 88(2):53–96.

Colbert, E. H. and Kitching, J. W. (1977). Triassic cynodont reptiles from Antarctica. *American Museum Novitates*, 2611:1–30.

Colbert, E. H. and Kitching, J. W. (1981). Scaloposaurian reptiles from the Triassic of Antarctica. *American Museum Novitates*, 2709:1–22.

Collette, J., Getty, P., and Hagadorn, J. (2011). Insights into an Early Jurassic dinosaur habitat: ichnofacies and enigmatic structures from the Portland Formation, Hoover Quarry, Massachusetts, U.S.A. *Atlantic Geology*, 47:81–98.

Conrad, J. L. (2018). A new lizard (Squamata) was the last meal of *Compsognathus* (Theropoda: Dinosauria) and is a holotype in a holotype. *Zoological Journal of the Linnean Society*, 183(3):584–634.

Cooney, C. R., Bright, J. A., Capp, E. J. R., Chira, A. M., Hughes, E. C., Moody, C. J. A., Nouri, L. O., Varley, Z. K., and Thomas, G. H. (2017). Mega-evolutionary dynamics of the adaptive radiation of birds. *Nature*, 542(7641):344–347.

Cooper, M. R. (1980). The first record of the prosauropod dinosaur *Euskelosaurus* from Zimbabwe. *Arnoldia Zimbabwe*, 9(3):1–17.

Cooper, N., Thomas, G. H., Venditti, C., Meade, A., and Freckleton, R. P. (2016a). A cautionary note on the use of Ornstein Uhlenbeck models in macroevolutionary studies. *Biological Journal of the Linnean Society*, 118(1):64–77.

Cooper, N., Thomas, G. H., and FitzJohn, R. G. (2016b). Shedding light on the ‘dark side’ of phylogenetic comparative methods. *Methods in Ecology and Evolution*, 7(6):693–699.

Cope, E. D. (1896). Second contributions to the history of the Cotylosauria. *Proceedings of the American Philosophical Society*, 35(151):122–139.

Cosgriff, J. W. and Zawiskie, J. M. (1979). A new species of the Rhytidosteidae from the *Lystrosaurus* Zone and a review of the Rhytidosteoidea. *Palaeontologia africana*, 22:1–27.

Cox, C. B. (1968). The Chañares (Argentina) Triassic fauna. IV. The dicynodont fauna. *Breviora*, 295:1–27.

Cox, C. B. (1991). The Pangaea dicynodont *Rechnisaurus* and the comparative biostratigraphy of Triassic dicynodont faunas. *Palaeontology*, 34(4):767–784.

Cox, C. B. and Angielczyk, K. D. (2015). A new endothiodont dicynodont (Therapsida, Anomodontia) from the Permian Ruhuhu Formation (Songea Group) of Tanzania and its feeding system. *Journal of Vertebrate Paleontology*, 35(4):e935388.

Crawford, N. G., Faircloth, B. C., McCormack, J. E., Brumfield, R. T., Winker, K., and Glenn, T. C. (2012). More than 1000 ultraconserved elements provide evidence that turtles are the sister group of archosaurs. *Biology Letters*, 8(5):783–786.

Crawford, N. G., Parham, J. F., Sellas, A. B., Faircloth, B. C., Glenn, T. C., Papenfuss, T. J., Henderson, J. B., Hansen, M. H., and Simison, W. B. (2015). A phylogenomic analysis of turtles. *Molecular Phylogenetics and Evolution*, 83:250–257.

Crompton, A. W. (1955a). A revision of the Scaloposauridae with special reference to kinetism in this family. *Navorsinge van die Nasionale Museum*, 1(7):149–183.

Crompton, A. W. (1955b). On some Triassic cynodonts from Tanganyika. *Proceedings of the Zoological Society of London*, 125(3–4):617–669.

Crozier, E. A. (1970). Preliminary report on two Triassic dicynodonts from Zambia. *Palaeontologia africana*, 13:39–45.

Cruickshank, A. R. I. (1975). The skeleton of the Triassic anomodont *Kannemeyeria wilsoni* Broom. *Palaeontologia africana*, 18:137–142.

Cúneo, R., Ramezani, J., Scasso, R., Pol, D., Escapa, I., Zavattieri, A. M., and Bowring, S. A. (2013). High-precision U–Pb geochronology and a new chronostratigraphy for the Cañadón Asfalto Basin, Chubut, central Patagonia: Implications for terrestrial faunal and floral evolution in Jurassic. *Gondwana Research*, 24(3–4):1267–1275.

Cuny, G. (2004). A Late Triassic cynodont from Holwell Quarries (Somerset, England). *Oryctos*, 5:69–73.

Cuny, G., Godefroit, P., and Martin, M. (1995). Micro-restes de Vertébres dans le Trias Superieur du Rinckebierg (Medernach, G-D Luxembourg). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 196(1):45–67.

Currie, P. J. (1977). A new haptodontine sphenacodont (Reptilia: Pelycosauria) from the Upper Pennsylvanian of North America. *Journal of Paleontology*, 51(5):927–942.

Currie, P. J. (1979). The osteology of haptodontine sphenacodonts (Reptilia: Pelycosauria). *Palaeontographica Abteilung A*, 163(4–6):130–168.

Currie, P. J. (1981). *Hovasaurus boulei*, an aquatic eosuchian from the Upper Permian of Madagascar. *Palaeontologia africana*, 24:99–168.

Currie, P. J. (2003). Allometric growth in tyrannosaurids (Dinosauria: Theropoda) from the Upper Cretaceous of North America and Asia. *Canadian Journal of Earth Sciences*, 40(4):651–665.

Currie, P. J. and Carroll, R. L. (1984). Ontogenetic changes in the eosuchian reptile *Thadeosaurus*. *Journal of Vertebrate Paleontology*, 4(1):68–84.

Cuthbertson, R. S., Russell, A. P., and Anderson, J. S. (2014). The first substantive evidence of *Utatsusaurus* (Ichthyopterygia) from the Sulphur Mountain Formation (Lower–Middle Triassic) of British Columbia, Canada: a skull roof description in comparison with other early taxa. *Canadian Journal of Earth Sciences*, 51(2):180–185.

Cys, J. M. (1967). Osteology of the pristerognathid *Cynariognathus platyrhinus* (Reptilia: Theriodontia). *Journal of Paleontology*, 41(3):776–790.

Daegling, D. J. (2001). Biomechanical scaling of the hominoid mandibular symphysis. *Journal of Morphology*, 250(1):12–23.

Dahoumane, A., Nedjari, A., Aït-Ouali, R., Taquet, P., Vacant, R., and Steyer, J.-S. (2016). A new mastodonsauroid temnospondyl from the Triassic of Algeria: implications for the biostratigraphy and palaeoenvironments of the Zarzaïtine Series, northern Sahara. *Comptes Rendus Palevol*, 15(8):918–926.

Dal Sasso, C. (2003). Dinosaurs of Italy. *Comptes Rendus Palevol*, 2(1):45–66.

Dal Sasso, C. and Pinna, G. (1996). *Besanosaurus leptorhynchus* n. gen. n. sp., a new shastasaurid ichthyosaur from the Middle Triassic of Besano (Lombardy, N. Italy). *Paleontologia Lombarda, Nuova serie*, 4:1–23.

Dal Sasso, C., Pasini, G., Fleury, G., and Maganuco, S. (2017). *Razanandrongobe sakalavae*, a gigantic mesoeucrocodylian from the Middle Jurassic of Madagascar, is the oldest known notosuchian. *PeerJ*, 5:e3481.

Dalla Vecchia, F. M. (2009a). Anatomy and systematics of the pterosaur *Carniadactylus* gen. n. *rosenfeldi* (Dalla Vecchia, 1995). *Rivista Italiana di Paleontologia e Stratigrafia*, 115(2):159–188.

Dalla Vecchia, F. M. (2009b). The first Italian specimen of *Austriadactylus cristatus* (Diapsida, Pterosauria) from the Norian (Upper Triassic) of the Carnic Prealps. *Rivista Italiana di Paleontologia e Stratigrafia*, 115(3):291–304.

Dalla Vecchia, F. M. (2013). Triassic pterosaurs. *Geological Society, London, Special Publications*, 379:119–155.

Dalla Vecchia, F. M. (2014). *Gli pterosauri triassici*. Number 54 in Memorie del Museo Friulano di Storia Naturale. Museo Friulano di Storia Naturale, Udine. 319 pp.

Dalla Vecchia, F. M. (2018). Comments on Triassic pterosaurs with a commentary on the "ontogenetic stages" of Kellner (2015) and the validity of *Bergamodactylus wildi*. *Rivista Italiana di Paleontologia e Stratigrafia*, 124(2):317–341.

Dalla Vecchia, F. M. and Avanzini, M. (2002). New findings of isolated remains of Triassic reptiles from Northeastern Italy. *Bollettino della Societa Italiana Paleontologica Italiana*, 41(2–3):215–235.

Dalton, R. (2008). Fossil reptiles mired in controversy. *Nature*, 451(7178):510.

Damiani, R. J. (2001). A systematic revision and phylogenetic analysis of Triassic mastodonsauroids (Temnospondyli: Stereospondyli). *Zoological Journal of the Linnean Society*, 133(4):379–482.

Damiani, R. J. (2002). *Parotosuchus* (Amphibia, Temnospondyli) from the *Cynognathus* Assemblage Zone (Early Triassic) of South Africa: cranial morphology and relationships. *Alcheringa*, 25(4):351–379.

Damiani, R. J. (2004). Temnospondyls from the Beaufort Group (Karoo Basin) of South Africa and their biostratigraphy. *Gondwana Research*, 7(1):165–173.

Damiani, R. J. and Jeannot, A. M. (2002). A brachyopid temnospondyl from the lower *Cynognathus* Assemblage Zone in the northern Karoo Basin, South Africa. *Palaeontologia africana*, 38:57–69.

Damiani, R. J. and Kitching, J. W. (2003). A new brachyopid temnospondyl from the *Cynognathus* Assemblage Zone, Upper Beaufort Group, South Africa. *Journal of Vertebrate Paleontology*, 23(1):67–78.

Damiani, R. J. and Rubidge, B. S. (2003). A review of the South African temnospondyl amphibian record. *Palaeontologia africana*, 39:21–36.

Damiani, R. J. and Hancox, P. J. (2003). New mastodonsaurid temnospondyls from the *Cynognathus* Assemblage Zone (Upper Beaufort Group; Karoo Basin) of South Africa. *Journal of Vertebrate Paleontology*, 23(1):54–66.

Damiani, R. J. and Yates, A. M. (2003). The Triassic amphibian *Thoosuchus yakovlevi* and the relationships of the Trematosauroidea (Temnospondyli: Stereospondyli). *Records of the Australian Museum*, 55(3):331–342.

Damiani, R. J., Neveling, J., and Hancox, P. J. (2001). First record of a mastodonsaurid (Temnospondyli, Stereospondyli) from the Early Triassic *Lystrosaurus* Assemblage Zone (Karoo Basin) of South Africa. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 221(1):133–144.

Damiani, R. (2008). A giant skull of the temnospondyl *Xenotosuchus africanus* from the Middle Triassic of South Africa and its ontogenetic implications. *Acta Palaeontologica Polonica*, 53(1):75–84.

Damiani, R., Neveling, J., Modesto, S., and Yates, A. (2003). Barendskraal, a diverse aamniote locality from the *Lystrosaurus* Assemblage Zone, Early Triassic of South Africa. *Palaeontologia africana*, 39:53–62.

Damiani, R., Sidor, C. A., Steyer, J. S., Smith, R. M. H., Larsson, H. C. E., Maga, A., and Ide, O. (2006). The vertebrate fauna of the Upper Permian of Niger. V. The primitive temnospondyl *Saharastega moradiensis*. *Journal of Vertebrate Paleontology*, 26(3):559–572.

Damuth, J. (1981). Population density and body size in mammals. *Nature*, 290(5808):699–700.

Dana, J. D. (1863). On the higher subdivisions in the classification of mammals. *Annals and Magazine of Natural History, Series 3*, 11(63):207–214.

Danto, M., Witzmann, F., and Müller, J. (2012). Redescription and phylogenetic relationships of *Solenodonsaurus janenschi* Broili, 1924, from the Late Carboniferous of Nýřany, Czech Republic. *Fossil Record*, 15(2):45–59.

Danto, M., Witzmann, F., and Fröbisch, N. B. (2016). Vertebral development in Paleozoic and Mesozoic tetrapods revealed by paleohistological data. *PLoS ONE*, 11(4):e0152586.

Darwin, C. (1859). *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. John Murray, London, UK, 1st edition. 502 pp.

Das, D. P. and Gupta, A. (2012). A new cynodont record from the Lower Triassic Panchet Formation, Damodar Valley. *Journal of the Geological Society of India*, 79(2):175–180.

Dassie, E. C. G. (2014). Tetrápodes triássico brasileiros: uma investigação envolvendo banco de dados e análise de cluster. Master's thesis, Departamento de Biologia Comparada, Universidade de São Paulo, Ribeirão Preto. 108 pp.

Datta, P. M. and Das, D. P. (2001). *Indozostrodon simpsoni*, gen. et sp. nov., an Early Jurassic megazostrodontid mammal from India. *Journal of Vertebrate Paleontology*, 21(3):528–534.

Datta, P. M. and Ray, S. (2006). Earliest lizard from the Late Triassic (Carnian) of India. *Journal of Vertebrate Paleontology*, 26(4):795–800.

Datta, P. M., Manna, P., Ghosh, S. C., and Das, D. P. (2000). The first Jurassic turtle from India. *Palaeontology*, 43(1):99–109.

Datta, P. M., Das, D. P., and Luo, Z.-X. (2004). A Late Triassic dromatheriid (Synapsida: Cynodontia) from India. *Annals of Carnegie Museum*, 73(2):72–84.

Davies, J. H. F. L., Marzoli, A., Bertrand, H., Youbi, N., Ernesto, M., and Schaltegger, U. (2017). End-Triassic mass extinction started by intrusive CAMP activity. *Nature Communications*, 8:15596.

Day, M. O. (2013). *Middle Permian continental biodiversity changes as reflected in the Beaufort Group of South Africa: a bio- and lithostratigraphic review of the Eodicynodon, Tapinocephalus and Pristerognathus assemblage zones*. PhD thesis, University of the Witwatersrand, Johannesburg. 387 pp.

Day, M. O., Ramezani, J., Bowring, S. A., Sadler, P. M., Erwin, D. H., Abdala, F., and Rubidge, B. S. (2015a). When and how did the terrestrial mid-Permian mass extinction occur? Evidence from the tetrapod record of the Karoo Basin, South Africa. *Proceedings of the Royal Society B: Biological Sciences*, 282(1811):20150834.

Day, M. O., Güven, S., Abdala, F., Jirah, S., Rubidge, B., and Almond, J. (2015b). Youngest dinocephalian fossils extend the *Tapinocephalus* Zone, Karoo Basin, South Africa. *South African Journal of Science*, 111(3–4):1–5.

Day, M. O., Smith, R. M. H., Benoit, J., Fernandez, V., and Rubidge, B. S. (2018a). A new species of burnetiid (Therapsida, Burnetiamorpha) from the early Wuchiapingian of South Africa and implications for the evolutionary ecology of the family Burnetiidae. *Papers in Palaeontology*, 4(3):453–475.

Day, M. O., Benson, R. B. J., Kammerer, C. F., and Rubidge, B. S. (2018b). Evolutionary rates of mid-Permian tetrapods from South Africa and the role of temporal resolution in turnover reconstruction. *Paleobiology*, 44(3):347–367.

Day, M., Rubidge, B., and Abdala, F. (2016). A new mid-Permian burnetiamorph therapsid from the Main Karoo Basin of South Africa and a phylogenetic review of Burnetiamorpha. *Acta Palaeontologica Polonica*, 61(4):701–719.

de Buffrénil, V., Clarac, F., Canoville, A., and Laurin, M. (2016). Comparative data on the differentiation and growth of bone ornamentation in gnathostomes (Chordata: Vertebrata). *Journal of Morphology*, 277(5):634–670.

de França, M. A. G., Ferigolo, J., and Langer, M. C. (2011). Associated skeletons of a new middle Triassic "Rauisuchia" from Brazil. *Naturwissenschaften*, 98(5):389–395.

de França, M. A. G., Langer, M. C., and Ferigolo, J. (2013). The skull anatomy of *Decuriasuchus quartacolonia* (Pseudosuchia: Suchia: Loricata) from the middle Triassic of Brazil. *Geological Society, London, Special Publications*, 379(1):469–501.

de França, M. A. G., Langer, M. C., and Ferigolo, J. (2011). Incorporating *Decuriasuchus quartacolonia* (Pseudosuchia) into the archosaur phylogeny. *Ameghiniana*, 48(Supplement to 4):R63.

de la Fuente, M. S., Sterli, J., and Maniel, I. (2014). *Origin, Evolution and Biogeographic History of South American Turtles*. Springer, Cham. 168 pp.

de Miguel Chaves, C., Pérez-García, A., Cobos, A., Royo-Torres, R., Ortega, F., and Alcalá, L. (2015). A diverse Late Triassic tetrapod fauna from Manzanera (Teruel, Spain). *Geobios*, 48(6):479–490.

de Miguel Chaves, C., Ortega, F., and Pérez-García, A. (2018a). A new placodont from the Upper Triassic of Spain provides new insights on the acquisition of the specialized skull of Henodontidae. *Papers in Palaeontology*, 4(4):567–576.

de Miguel Chaves, C., Ortega, F., and Pérez-García, A. (2018b). New highly pachyostotic nothosauroid interpreted as a filter-feeding Triassic marine reptile. *Biology Letters*, 14(8):20180130.

de Oliveira, T. V., Martinelli, A. G., and Soares, M. B. (2011). New information about *Irajatherium hernandezi* Martinelli, Bonaparte, Schultz & Rubert 2005 (Eucynodontia, Tritheledontidae) from the upper triassic (Caturrita Formation, Paraná Basin) of Brazil. *Paläontologische Zeitschrift*, 85(1):67–82.

de Queiroz, K. (2007). Toward an integrated system of clade names. *Systematic Biology*, 56(6):956–974.

de Queiroz, K. and Gauthier, J. (1990). Phylogeny as a central principle in taxonomy: phylogenetic definitions of taxon names. *Systematic Biology*, 39(4):307–322.

Dean, C. D., Mannion, P. D., and Butler, R. J. (2016). Preservational bias controls the fossil record of pterosaurs. *Palaeontology*, 59(2):225–247.

deBraga, M. (2003). The postcranial skeleton, phylogenetic position, and probable lifestyle of the Early Triassic reptile *Procolophon trigoniceps*. *Canadian Journal of Earth Sciences*, 40(4):527–556.

deBraga, M. and Reisz, R. R. (1995). A new diapsid reptile form the uppermost Carboniferous (Stephanian) of Kansas. *Palaeontology*, 38(1):199–212.

deBraga, M. and Reisz, R. R. (1996). The Early Permian reptile *Acleistorhinus pteroticus* and its phylogenetic position. *Journal of Vertebrate Paleontology*, 16(3):384–395.

deBraga, M. and Rieppel, O. (1997). Reptile phylogeny and the interrelationships of turtles. *Zoological Journal of the Linnean Society*, 120(3):281–354.

Debuysschere, M. (2016). A reappraisal of *Theroteinus* (Haramiyida, Mammaliaformes) from the Upper Triassic of Saint-Nicolas-de-Port (France). *PeerJ*, 4:e2592.

Debuysschere, M. (2017). The Kuehneotheriidae (Mammaliaformes) from Saint-Nicolas-de-Port (Upper Triassic, France): a systematic Review. *Journal of Mammalian Evolution*, 24(2):127–146.

Debuysschere, M., Gheerbrant, E., and Allain, R. (2015). Earliest known European mammals: a review of the Morganucodonta from Saint-Nicolas-de-Port (Upper Triassic, France). *Journal of Systematic Palaeontology*, 13(10):825–855.

Deenen, M., Ruhl, M., Bonis, N., Krijgsman, W., Kuerschner, W., Reitsma, M., and van Bergen, M. (2010). A new chronology for the end-Triassic mass extinction. *Earth and Planetary Science Letters*, 291(1–4):113–125.

Delcourt, R., Azevedo, S. A. K. d., Grillo, O. N., and Deantoni, F. O. (2012). Biomechanical comments about Triassic dinosaurs from Brazil. *Papéis Avulsos de Zoologia (São Paulo)*, 52(29):341–347.

Delsate, D. and Ezcurra, M. D. (2014). The first Early Jurassic (late Hettangian) theropod dinosaur remains from the Grand Duchy of Luxembourg. *Geologica Belgica*, 17(2):175–181.

DeMar, R. E. (1967). Two new species of *Broiliellus* (amphibians) from the Permian of Texas. *Fieldiana: Geology*, 16(5):117–129.

DeMar, R. (1968). The Permian labyrinthodont amphibian *Dissorophus multicinctus*, and adaptations and phylogeny of the family Dissorophidae. *Journal of Paleontology*, 42(5):1210–1242.

Demirjian, V. (2012). Comment on the proposed replacement of unidentifiable name-bearing type by a neotype for *Plateosaurus engelhardti* von Meyer, 1837 (Dinosauria, Sauropodomorpha) (Case 3560). *Bulletin of Zoological Nomenclature*, 69(4):295–296.

Desojo, J. B. and Báez, A. M. (2007). Cranial morphology of the Late Triassic South American archosaur *Neoaetosauroides engaeus*: evidence for aetosaurian diversity. *Palaeontology*, 50(1):267–276.

Desojo, J. B. and Rauhut, O. (2008). New insights on 'rauisuchian' taxa (Archosauria: Crurotarsi) from Brazil. In Dyke, G., Naish, D., and Parkes, M., editors, *SVPCA 2008 Dublin: Programme & Abstracts*, pages 18–19. National Museum of Ireland, Dublin.

Desojo, J. B. and Vizcaíno, S. F. (2009). Jaw biomechanics in the South American aetosaur *Neoaetosauroides engaeus*. *Paläontologische Zeitschrift*, 83(4):499–510.

Desojo, J. B. and Ezcurra, M. D. (2011). A reappraisal of the taxonomic status of *Aetosauroides* (Archosauria, Aetosauria) specimens from the Late Triassic of South America and their proposed synonymy with *Stagonolepis*. *Journal of Vertebrate Paleontology*, 31(3):596–609.

Desojo, J. B., Ezcurra, M. D., and Schultz, C. L. (2011). An unusual new archosauriform from the Middle–Late Triassic of southern Brazil and the monophyly of Doswelliidae. *Zoological Journal of the Linnean Society*, 161(4):839–871.

Desojo, J. B., Ezcurra, M. D., and Kischlat, E. E. (2012). A new aetosaur genus (Archosauria: Pseudosuchia) from the early Late Triassic of southern Brazil. *Zootaxa*, 3166:1–33.

Desojo, J. B., Heckert, A. B., Martz, J. W., Parker, W. G., Schoch, R. R., Small, B. J., and Sulej, T. (2013). Aetosauria: a clade of armoured pseudosuchians from the Upper Triassic continental beds. *Geological Society, London, Special Publications*, 379(1):203–239.

Desojo, J. and Rauhut, O. (2009). The taxonomic status and phylogenetic position of the late Triassic Brazilian rauisuchian *Prestosuchus*. *Journal of Vertebrate Paleontology*, 29(Suppl. to 3):87A–88A.

Dias, E. V. and Barberena, M. C. (2001). A temnospondyl amphibian from the Rio do Rasto Formation, Upper Permian of southern Brazil. *Anais da Academia Brasileira de Ciências*, 73(1):135–143.

Dias-da-Silva, S. (2012). Middle–Late Permian tetrapods from the Rio do Rasto Formation, Southern Brazil: a biostratigraphic reassessment. *Lethaia*, 45(1):109–120.

Dias-da-Silva, S. and Marsicano, C. (2011). Phylogenetic reappraisal of Rhytidosteidae (Stereospondyli: Trematosauria), temnospondyl amphibians from the Permian and Triassic. *Journal of Systematic Palaeontology*, 9(2):305–325.

Dias-da-Silva, S. and Dias, E. V. (2013). A comprehensive survey of Triassic stereospondyls from the southern Brazil with comments on their oveover significance. In Lawrence H. Tanner, J. A. S. and Lucas, S. G., editors, *The Triassic System: New Developments in Stratigraphy and Paleontology*, volume 61, pages 93–103. New Mexico Museum of Natural History.

Dias-da-Silva, S. and Hewison, R. (2013). Phylogenetic analysis and palaeobiogeography of the Pangaean Lower Triassic Lydekkerinidae (Temnospondyli, Stereospondyli). *SVP Program and Abstracts Book*, page 116.

Dias-da-Silva, S., Sengupta, D. P., Cabreira, S. F., and Da Silva, L. R. (2012). The presence of *Compsocerops* (Brachyopoidea: Chigutisauridae) (Late Triassic) in southern Brazil with comments on chigutisaurid palaeobiogeography. *Palaeontology*, 55(1):163–172.

Dick, D. G. and Maxwell, E. E. (2015). Ontogenetic tooth reduction in *Stenopterygius quadriscissus* (Reptilia: Ichthyosauria): negative allometry, changes in growth rate, and early senescence of the dental lamina. *PLoS ONE*, 10(11):e0141904.

Diedrich, C. G. (2012). The Middle Triassic marine reptile biodiversity in the Germanic Basin, in the centre of the Pangaean world. *Central European Journal of Geosciences*, 4(1):9–46.

Diedrich, C. G. (2013). The marine pachypleurosaur *Serpianosaurus germanicus* nov. spec. – skeleton and isolated bone remains from the Pelsonian (Middle Triassic) of the European Germanic Basin carbonate intertidals and its paleobiology and taphonomy. In Tanner, L. H., Spielmann, J. A., and Lucas, S. G., editors, *The Triassic System*, volume 61, pages 159–168. New Mexico Museum of Natural History.

Diedrich, C. G. (2014). Marine *Lariosaurus* (Sauropterygia) records from the Middle Triassic of the Germanic Basin - stratigraphic and paleobiogeographic importance for Tethyan and Germanic Basin correlation. *Albertiana*, 42:22–32.

Diedrich, C. G. (2015). The vertebrates from the Lower Ladinian (Middle Triassic) bonebed of Lamerden (Germany) as palaeoenvironment indicators in the Germanic Basin. *Open Geosciences*, 7(1):755–782.

Diedrich, C. G. and Gradinaru, E. (2013). Distribution of basal Middle Triassic fossil reptile placodonts in the Germanic Basin and northern Tethys. In Tanner, L. H., Spielmann, J. A., and

Lucas, S. G., editors, *The Triassic System*, volume 61, pages 216–227. New Mexico Museum of Natural History.

Dilkes, D. W. (1990). A new trematopsid amphibian (Temnospondyli: Dissorophoidea) from the Lower Permian of Texas. *Journal of Vertebrate Paleontology*, 10(2):222–243.

Dilkes, D. W. (1998). The early Triassic rhynchosaur *Mesosuchus browni* and the interrelationships of basal archosauromorph reptiles. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 353(1368):501–541.

Dilkes, D. (2015a). Carpus and tarsus of Temnospondyli. *Vertebrate Anatomy Morphology Palaeontology*, 1(1):51–87.

Dilkes, D. (2015b). '*Dissorophus*' *angustus* (Temnospondyli, Dissorophoidea) and increasing variability of dissorophid osteoderms. *SVP Program and Abstracts Book*, page 117.

DiMichele, W. A., Falcon-Lang, H. J., Nelson, W. J., Elrick, S. D., and Ames, P. R. (2007). Ecological gradients within a Pennsylvanian mire forest. *Geology*, 35(5):415–418.

Dodick, J. T. and Modesto, S. P. (1995). The cranial anatomy of the captorhinid reptile *Labidosaurikos meachami* from the Lower Permian of Oklahoma. *Palaeontology*, 38(3):687–711.

Dollman, K. N., Viglietti, P. A., and Choiniere, J. N. (2019). A new specimen of *Orthosuchus stormbergi* (Nash 1968) and a review of the distribution of Southern African Lower Jurassic crocodylomorphs. *Historical Biology*, 31(5):653–664.

Domnanovich, N. S. and Marsicano, C. A. (2012). The Triassic dicynodont *Vinceria* (Therapsida, Anomodontia) from Argentina and a discussion on basal Kannemeyeriiformes. *Geobios*, 45(2):173–186.

Domnanovich, N. and Marsicano, C. (2009). Therapsid dicynodonts (Amniota, Synapsida) from Argentina. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 29(sup3):89A.

Dong, L., Roček, Z., Wang, Y., and Jones, M. E. H. (2013). Anurans from the Lower Cretaceous Jehol Group of Western Liaoning, China. *PLoS ONE*, 8(7):e69723.

Dong, Z. (2003). Contributions of new dinosaur materials from China to dinosaurology. *Memoir of the Fukui Prefectural Dinosaur Museum*, 2:123–131.

Downs, A. (2000). *Coelophysis bauri* and *Syntarsus rhodesiensis* compared, with comments on the preparation and preservation of fossils from the Ghost Ranch *Coelophysis* quarry. In Lucas, S. G. and Heckert, A. B., editors, *Dinosaurs of New Mexico*, volume 17, pages 33–38. New Mexico Museum of Natural History.

Druckenmiller, P. S. and Knutsen, E. M. (2012). Phylogenetic relationships of Upper Jurassic (Middle Volgian) plesiosaurians (Reptilia: Sauropterygia) from the Agardhfjellet Formation of central Spitsbergen, Norway. *Norwegian Journal of Geology*, 92(2–3):277–284.

Drymala, S. M. and Zanno, L. E. (2016). Osteology of *Carnufex carolinensis* (Archosauria: Psuedosuchia) from the Pekin Formation of North Carolina and its implications for early crocodylomorph evolution. *PLoS ONE*, 11(6):e0157528.

Duchen, P., Leuenberger, C., Szilagyi, S. M., Harmon, L., Eastman, J., Schweizer, M., and Wegmann, D. (2017). Inference of evolutionary jumps in large phylogenies using Levy processes. *Systematic Biology*, 66(6):950–963.

Duffin, C. J. (1979). The Bath geological collections. The Moore collection of Upper Liassic crocodiles: a history. *Geological Curators Group Newsletter*, 2(5):235–252.

Duffin, C. J. (1995). The first sphenodontian remains (Lepidosauromorpha, Reptilia) from the Late Triassic of the Gaume (Southern Belgium): Jurassic - Triassic vertebrates. *Bulletin de la Société belge de Géologie*, 104(1–2):35–41.

Dunhill, A. M. and Wills, M. A. (2015). Geographic range did not confer resilience to extinction in terrestrial vertebrates at the end-Triassic crisis. *Nature Communications*, 6:7980.

Dunhill, A. M., Hannisdal, B., Brocklehurst, N., and Benton, M. J. (2018). On formation-based sampling proxies and why they should not be used to correct the fossil record. *Palaeontology*, 61(1):119–132.

Dunne, E. M., Close, R. A., Button, D. J., Brocklehurst, N., Cashmore, D. D., Lloyd, G. T., and Butler, R. J. (2018). Diversity change during the rise of tetrapods and the impact of the 'Carboniferous rainforest collapse'. *Proceedings of the Royal Society B: Biological Sciences*, 285(1872):20172730.

Dutuit, J.-M. (1976). Il est probable que les Rhynchocéphales sont représentés dans la faune du Trias marocain. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences Paris, Série D: Sciences Naturelles*, 283:483–486.

Dzik, J. (2003). A beaked herbivorous archosaur with dinosaur affinities from the early Late Triassic of Poland. *Journal of Vertebrate Paleontology*, 23(3):556–574.

Dzik, J. and Sulej, T. (2007). A review of the early Late Triassic Krasiejów biota from Silesia, Poland. *Palaeontologia Polonica*, 64:3–27.

Dzik, J. and Sulej, T. (2016). An early Late Triassic long-necked reptile with a bony pectoral shield and gracile appendages. *Acta Palaeontologica Polonica*, 61(4):805–823.

Dzik, J., Sulej, T., and Niedźwiedzki, G. (2008). A dicynodont-theropod association in the Latest Triassic of Poland. *Acta Palaeontologica Polonica*, 53(4):733–738.

Eastman, J. M., Alfaro, M. E., Joyce, P., Hipp, A. L., and Harmon, L. J. (2011). A novel comparative method for identifying shifts in the rate of character evolution on trees. *Evolution*, 65(12):3578–3589.

Ebel, K., Falkenstein, F., Haderer, F.-O., and Wild, R. (1998). *Ctenosauriscus koeneni* (v. Huene) und der Rauisuchier von Waldshut – Biomechanische Deutung der Wirbelsäule und Beziehungen zu *Chirotherium sickerli* Kaup. *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 261:1–18.

Edwards, B. and Evans, S. E. (2006). A Late Triassic microvertebrate assemblage from Ruthin quarry, Wales. In Barrett, P. M. and Evans, S. E., editors, *Ninth International Symposium on Mesozoic Terrestrial Ecosystems and Biota, Abstracts and Proceedings*, pages 33–35. Natural History Museum, London.

Efremov, I. A. and V'yushkov, B. P. (1955). [Catalogue of the Permian and Triassic terrestrial vertebrates from the territory of the USSR]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 46:1–186. [In Russian].

Elgorriaga, A., Escapa, I. H., Bomfleur, B., Cúneo, R., and Ottone, E. G. (2015). Reconstruction and phylogenetic significance of a new *Equisetum* Linnaeus species from the Lower Jurassic of Cerro Bayo (Chubut Province, Argentina). *Ameghiniana*, 52(1):135–152.

Eltink, E. and Langer, M. C. (2014). A new specimen of the temnospondyl *Australerpeton cosgriffi* from the late Permian of Brazil (Rio do Rasto Formation, Paraná Basin): comparative anatomy and phylogenetic relationships. *Journal of Vertebrate Paleontology*, 34(3):524–538.

Eltink, E., Dias, E. V., Dias-da-Silva, S., Schultz, C. L., and Langer, M. C. (2016). The cranial morphology of the temnospondyl *Australerpeton cosgriffi* (Tetrapoda: Stereospondyli) from the Middle–Late Permian of Paraná Basin and the phylogenetic relationships of Rhinesuchidae. *Zoological Journal of the Linnean Society*, 176(4):835–860.

Eltink, E., Da-Rosa, Á. A. S., and Dias-da-Silva, S. (2017). A capitosauroid from the Lower Triassic of South America (Sanga do Cabral Supersequence: Paraná Basin), its phylogenetic relationships and biostratigraphic implications. *Historical Biology*, 29(7):863–874.

Englehorn, J., Small, B. J., and Huttenlocker, A. (2008). A redescription of *Acroplous vorax* (Temnospondyli: Dvinosauria) based on new specimens from the Early Permian of Nebraska and Kansas, U.S.A. *Journal of Vertebrate Paleontology*, 28(2):291–305.

Erwin, D. H. (1990). The end-Permian mass extinction. *Annual Review of Ecology and Systematics*, 21(1):69–91.

Erwin, D. H. (1993). *The Great Paleozoic Crisis: Life and Death in the Permian*. Columbia University Press, New York. 327 pp.

Erwin, D. H. (1994). The Permo–Triassic extinction. *Nature*, 367(6460):231–236.

Erwin, D. H. (1996). The mother of mass extinctions. *Scientific American*, 275(1):72–78.

Evans, M. (2012). *A new genus of plesiosaur (Reptilia: Sauropterygia) from the Pliensbachian (Early Jurassic) of England, and a phylogeny of the Plesiosauria*. PhD thesis, Department of Geology, University of Leicester. 397 pp.

Evans, S. E. (1985). A new diapsid reptile from the Upper Permian of South Africa. *Neues Jahrbuch für Geologie und Paläontologie - Monatshefte*, 1985(7):87–99.

Evans, S. E. (1988a). The early history and relationships of the Diapsida. In Benton, M. J., editor, *The Phylogeny and Classification of the Tetrapods. Volume 1: Amphibians, Reptiles, Birds*, volume 35A of *Systematics Association Special Volume*, chapter 6, pages 221–260. Clarendon Press, Oxford.

Evans, S. E. (1988b). The Upper Permian reptile *Adelosaurus* from Durham. *Palaeontology*, 31(4):957–964.

Evans, S. E. (2001). The Early Triassic 'lizard' *Colubrifer campi*: a reassessment. *Palaeontology*, 44(5):1033–1041.

Evans, S. E. (2003). At the feet of the dinosaurs: the early history and radiation of lizards. *Biological Reviews*, 78:513–551.

Evans, S. E. (2009). An early kuehneosaurid reptile (Reptilia: Diapsida) from the Early Triassic of Poland. *Palaeontologia Polonica*, 65:145–178.

Evans, S. E. and Haubold, H. (1987). A review of the Upper Permian genera *Coelurosauravus*, *Weigeltisaurus* and *Gracilisaurus* (Reptilia: Diapsida). *Zoological Journal of the Linnean Society*, 90(3):275–303.

Evans, S. E. and King, M. S. (1993). A new specimen of *Protorosaurus* (Reptilia: Diapsida) from the Marl Slate (late Permian) of Britain. *Proceedings of the Yorkshire Geological and Polytechnic Society*, 49(3):229–234.

Evans, S. E. and Borsuk-Białynicka, M. (2009). A small lepidosauromorph reptile from the Early Triassic of Poland. *Palaeontologia Polonica*, 65:179–202.

Evans, S. E. and Jones, M. E. H. (2010). The Origin, Early History and Diversification of Lepidosauromorph Reptiles. In *New Aspects of Mesozoic Biodiversity*, volume 132 of *Lecture Notes in Earth Sciences*, pages 27–44. Springer Berlin Heidelberg.

Evans, S. E., Prasad, G. V. R., and Manhas, B. K. (2002). Fossil lizards from the Jurassic Kota Formation of India. *Journal of Vertebrate Paleontology*, 22(2):299–312.

Ewer, R. F. (1965). The anatomy of the thecodont reptile *Euparkeria capensis* Broom. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 248(751):379–435.

Ezcurra, M. D. (2010). A new early dinosaur (Saurischia: Sauropodomorpha) from the Late Triassic of Argentina: a reassessment of dinosaur origin and phylogeny. *Journal of Systematic Palaeontology*, 8(3):371–425.

Ezcurra, M. D. (2012). Comments on the taxonomics diversity and paleobiogeography of the earliest known dinosaurs assemblages (late Carnian–earliest Norian). *Historia Natural, Tercera Serie*, 2(1):49–71.

Ezcurra, M. D. (2014). The osteology of the basal archosauromorph *Tasmaniosaurus triassicus* from the Lower Triassic of Tasmania, Australia. *PLoS ONE*, 9(1):e86864.

Ezcurra, M. D. (2015). *Systematics and evolutionary history of proterosuchian archosauriforms*. PhD thesis, University of Birmingham, Birmingham. 575 pp.

Ezcurra, M. D. (2016). The phylogenetic relationships of basal archosauromorphs, with an emphasis on the systematics of proterosuchian archosauriforms. *PeerJ*, 4:e1778.

Ezcurra, M. D. (2017). A new early coelophysoid neotheropod from the Late Triassic of northwestern Argentina. *Ameghiniana*, 54(5):506–538.

Ezcurra, M. D. and Novas, F. E. (2007). Phylogenetic relationships of the Triassic theropod *Zupaysaurus rougieri* from NW Argentina. *Historical Biology*, 19(1):35–72.

Ezcurra, M. D. and Cuny, G. (2007). The coelophysoid *Lophostropheus airelensis*, gen. nov.: a review of the systematics of "*Liliensternus*" *airelensis* from the Triassic–Jurassic outcrops of Normandy (France). *Journal of Vertebrate Paleontology*, 27(1):73–86.

Ezcurra, M. D. and Brusatte, S. L. (2011). Taxonomic and phylogenetic reassessment of the early neotheropod dinosaur *Camposaurus arizonensis* from the Late Triassic of North America. *Palaeontology*, 54(4):763–772.

Ezcurra, M. D. and Apaldetti, C. (2012). A robust sauropodomorph specimen from the Upper Triassic of Argentina and insights on the diversity of the Los Colorados Formation. *Proceedings of the Geologists' Association*, 123(1):155–164.

Ezcurra, M. D. and Butler, R. J. (2015a). Post-hatchling cranial ontogeny in the Early Triassic diapsid reptile *Proterosuchus fergusi*. *Journal of Anatomy*, 226(5):387–402.

Ezcurra, M. D. and Butler, R. J. (2015b). Taxonomy of the proterosuchid archosauriforms (Diapsida: Archosauromorpha) from the earliest Triassic of South Africa, and implications for the early archosauriform radiation. *Palaeontology*, 58(1):141–170.

Ezcurra, M. D. and Butler, R. J. (2018). The rise of the ruling reptiles and ecosystem recovery from the Permo-Triassic mass extinction. *Proceedings of the Royal Society B: Biological Sciences*, 285(1880):20180361.

Ezcurra, M. D., Lecuona, A., and Martinelli, A. (2010). A new basal archosauriform diapsid from the Lower Triassic of Argentina. *Journal of Vertebrate Paleontology*, 30(5):1433–1450.

Ezcurra, M. D., Butler, R. J., and Gower, D. J. (2013). 'Proterosuchia': the origin and early history of Archosauriformes. *Geological Society, London, Special Publications*, 379(1):9–33.

Ezcurra, M. D., Scheyer, T. M., and Butler, R. J. (2014). The origin and early evolution of Sauria: reassessing the Permian saurian fossil record and the timing of the crocodile-lizard divergence. *PLoS ONE*, 9(2):e89165.

Ezcurra, M. D., Desojo, J. B., and Rauhut, O. W. M. (2015). Redescription and phylogenetic relationships of the proterochampsid *Rhadinosuchus gracilis* (Diapsida: Archosauriformes) from the early Late Triassic of southern Brazil. *Ameghiniana*, 52(4):391–417.

Ezcurra, M. D., Montefeltro, F., and Butler, R. J. (2016). The early evolution of rhynchosaurs. *Frontiers in Ecology and Evolution*, 3:142.

Ezcurra, M. D., Fiorelli, L. E., Martinelli, A. G., Rocher, S., von Baczko, M. B., Ezpeleta, M., Taborda, J. R. A., Hechenleitner, E. M., Trotteyn, M. J., and Desojo, J. B. (2017). Deep faunistic turnovers preceded the rise of dinosaurs in southwestern Pangaea. *Nature Ecology & Evolution*, 1:1477–1483.

Ezcurra, M. D., Gower, D. J., Sennikov, A. G., and Butler, R. J. (2019). The osteology of the holotype of the early erythrosuchid *Garjainia prima* (Diapsida: Archosauromorpha) from the upper Lower Triassic of European Russia. *Zoological Journal of the Linnean Society*, 185(3):717–783.

Falcon-Lang, H. J., Benton, M. J., Braddy, S. J., and Davies, S. J. (2006). The Pennsylvanian tropical biome reconstructed from the Joggins Formation of Nova Scotia, Canada. *Journal of the Geological Society*, 163(3):561–576.

Falconnet, J. (2012). First evidence of a bolosaurid parareptile in France (latest Carboniferous-earliest Permian of the Autun basin) and the spatiotemporal distribution of the Bolosauridae. *Bulletin de la Société Géologique de France*, 183(6):495–508.

Falconnet, J. (2014). An evaluation of French amniote diversity through the Pennsylvanian-Cisuralian boundary. *Annales de Paléontologie*, 100(2):119–130.

Falconnet, J. (2015). The sphenacodontid synapsid *Neosaurus cynodus*, and related material, from the Permo-Carboniferous of France. *Acta Palaeontologica Polonica*, 60(1):169–182.

Falconnet, J. and Steyer, J. S. (2007). Revision, osteology, and locomotion of *Aphelosaurus*, an enigmatic reptile from the Lower Permian of France. *Journal of Morphology, ICVM-8 abstracts*, 268(12):1071–1072.

Falconnet, J., Andriamihaja, M., Läng, É., and Steyer, J.-S. (2012). First procolophonid (Reptilia, Parareptilia) from the Lower Triassic of Madagascar. *Comptes Rendus Palevol*, 11(5):357–369.

Farlow, J. O., Hurlburt, G. R., Elsey, R. M., Britton, A. R. C., and Langston, W. (2005). Femoral dimensions and body size of *Alligator mississippiensis*: estimating the size of extinct mesoeucrocodylians. *Journal of Vertebrate Paleontology*, 25(2):354–369.

Fedak, T. J. and Galton, P. M. (2007). New information on the braincase and skull of *Anchisaurus polyzelus* (Lower Jurassic, Connecticut, USA; Saurischia: Sauropodomorpha): implications for sauropodomorph systematics. *Special Papers in Palaeontology*, 77:245–260.

Fedak, T. J., Sues, H.-D., and Olsen, P. E. (2015). First record of the tritylodontid cynodont *Oligokyphus* and cynodont postcranial bones from the McCoy Brook Formation of Nova Scotia, Canada. *Canadian Journal of Earth Sciences*, 52(4):244–249.

Felice, R. N. and Angielczyk, K. D. (2014). Was *Ophiacodon* (Synapsida, Eupelycosauria) a Swimmer? A Test Using Vertebral Dimensions. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 3, pages 25–51. Springer, Dordrecht.

Felice, R. N. and Goswami, A. (2018). Developmental origins of mosaic evolution in the avian cranium. *Proceedings of the National Academy of Sciences*, 115(3):555–560.

Felsenstein, J. (1973). Maximum-likelihood estimation of evolutionary trees from continuous characters. *American Journal of Human Genetics*, 25(5):471–492.

Felsenstein, J. (1985). Phylogenies and the comparative method. *The American Naturalist*, 125(1):1–15.

Fernández-Coll, M., Arbez, T., Bernardini, F., and Fortuny, J. (2019). Cranial anatomy of the Early Triassic trematosaurine *Angusaurus* (Temnospondyli: Stereospondyli): 3D endocranial insights and phylogenetic implications. *Journal of Iberian Geology*, 45(2):269–286.

Field, D. J., Gauthier, J. A., King, B. L., Pisani, D., Lyson, T. R., and Peterson, K. J. (2014). Toward consilience in reptile phylogeny: miRNAs support an archosaur, not lepidosaur, affinity for turtles. *Evolution & Development*, 16(4):189–196.

Findlay, G. H. (1970). Skin structure of small pareiasaurs - with comments on their taxonomy in the *Cistecephalus* zone. *Palaeontologia africana*, 13:15–23.

Fiorelli, L. E., Leardi, J. M., Hechenleitner, E. M., Pol, D., Basilici, G., and Grellet-Tinner, G. (2016). A new Late Cretaceous crocodyliform from the western margin of Gondwana (La Rioja Province, Argentina). *Cretaceous Research*, 60:194–209.

Fischer, V., Appleby, R. M., Naish, D., Liston, J., Riding, J. B., Brindley, S., and Godefroit, P. (2013). A basal thunnosaurian from Iraq reveals disparate phylogenetic origins for Cretaceous ichthyosaurs. *Biology Letters*, 9(4):20130021.

Fischer, V., Arkhangelsky, M. S., Stenshin, I. M., Uspensky, G. N., Zverkov, N. G., and Benson, R. B. J. (2015). Peculiar macrophagous adaptations in a new Cretaceous pliosaurid. *Royal Society Open Science*, 2(12):150552.

Fischer, V., Bardet, N., Benson, R. B. J., Arkhangelsky, M. S., and Friedman, M. (2016). Extinction of fish-shaped marine reptiles associated with reduced evolutionary rates and global environmental volatility. *Nature Communications*, 7:10825.

Fischer, V., Benson, R. B. J., Zverkov, N. G., Soul, L. C., Arkhangelsky, M. S., Lambert, O., Stenshin, I. M., Uspensky, G. N., and Druckenmiller, P. S. (2017). Plasticity and convergence in the evolution of short-necked plesiosaurs. *Current Biology*, 27(11):1667–1676.

Fleck, J. (2008a). Museum boss faces ethics charge. *Albuquerque Journal*. February 3, http://www.abqjournal.com/news/metro/282358metro02-03-08.htm.

Fleck, J. (2008b). Museum ethics spat may get new review. *Albuquerque Journal*. February 8, http://www.abqjournal.com/news/state/283786nm02-08-08.htm.

Flynn, J. J., Nesbitt, S. J., Michael Parrish, J., Ranivoharimanana, L., and Wyss, A. R. (2010). A new species of *Azendohsaurus* (Diapsida: Archosauromorpha) from the Triassic Isalo Group of southwestern Madagascar: cranium and mandible. *Palaeontology*, 53(3):669–688.

Foffa, D., Young, M. T., Stubbs, T. L., Dexter, K. G., and Brusatte, S. L. (2018). The long-term ecology and evolution of marine reptiles in a Jurassic seaway. *Nature Ecology & Evolution*, 2(10):1548–1555.

Folinsbee, K. E., Müller, J., and Reisz, R. R. (2007). Canine grooves: morphology, function, and relevance to venom. *Journal of Vertebrate Paleontology*, 27(2):547–551.

Fong, J. J., Brown, J. M., Fujita, M. K., and Boussau, B. (2012). A phylogenomic approach to vertebrate phylogeny supports a turtle-archosaur affinity and a possible paraphyletic Lissamphibia. *PLoS ONE*, 7(11):e48990.

Ford, D. P. and Benson, R. B. J. (2019). A redescription of *Orovenator mayorum* (Sauropsida, Diapsida) using high-resolution μCT, and the consequences for early amniote phylogeny. *Papers in Palaeontology*, 5(2):197–239.

Fortuny, J., Galobart, À., and De Santisteban, C. (2011a). A new capitosaur from the Middle Triassic of Spain and the relationships within the Capitosauria. *Acta Palaeontologica Polonica*, 56(3):553–566.

Fortuny, J., Marcé-Nogué, J., de Esteban-Trivigno, S., Gil, L., and Galobart, Á. (2011b). Temnospondyli bite club: ecomorphological patterns of the most diverse group of early tetrapods. *Journal of Evolutionary Biology*, 24(9):2040–2054.

Fortuny, J., Bolet, A., Sellés, A. G., and Galobart, À. (2014). A potential record of a procolophonid parareptile from the Triassic of the Iberian Peninsula. *Geologica Acta*, 12(2):121–126.

Fortuny, J., Gastou, S., Escuillié, F., Ranivoharimanana, L., and Steyer, J.-S. (2018). A new extreme longirostrine temnospondyl from the Triassic of Madagascar: phylogenetic and palaeobiogeographical implications for trematosaurids. *Journal of Systematic Palaeontology*, 16(8):675–688.

Foth, C. and Rauhut, O. W. M. (2013). Macroevolutionary and morphofunctional patterns in theropod skulls: a morphometric approach. *Acta Palaeontologica Polonica*, 58(1):1–16.

Foth, C., Ezcurra, M. D., Sookias, R. B., Brusatte, S. L., and Butler, R. J. (2016). Unappreciated diversification of stem archosaurs during the Middle Triassic predated the dominance of dinosaurs. *BMC Evolutionary Biology*, 16:188.

Fourie, H. (2013). The postcranial description of *Ictidosuchoides* (Therapsida: Therocephalia: Baurioidea). *Annals of the Ditsong National Museum of Natural History*, 3:1–10.

Fox, R. C. (1985). Upper molar structure in the Late Cretaceous symmetrodont *Symmetrodontoides* Fox, and a classification of the Symmetrodonta (Mammalia). *Journal of Paleontology*, 59(1):21–26.

Fraas, E. (1896). *Die schwäbischen Trias-Saurier nach dem Material der Kgl. Naturalien-Sammlung in Stuttgart zusammengestellt*. Schweizerbart, Stuttgart. 18 pp.

Fraser, N. C. (1986). New Triassic sphenodontids from the south-west England and a review of their classification. *Palaeontology*, 29(1):165–186.

Fraser, N. C. (1988). The osteology and relationships of *Clevosaurus* (Reptilia: Sphenodontida). *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 321(1204):125–178.

Fraser, N. C. and Rieppel, O. (2006). A new protorosaur (Diapsida) from the Upper Buntsandstein of the Black Forest, Germany. *Journal of Vertebrate Paleontology*, 26(4):866–871.

Fraser, N. C., Walkden, G. M., and Stewart, V. (1985). The first pre-Rhaetic therian mammal. *Nature*, 314(6007):161–163.

Fraser, N. C., Irmis, R. B., and Elliott, D. K. (2005). A procolophonid (Parareptilia) from the Owl Rock Member, Chinle Formation of Utah, USA. *Palaeontologia Electronica*, 8(8.1.13):7 pp.

Fraser, N. C., Olsen, P. E., Jr., A. C. D., and Ryan, T. R. (2007). A new gliding tetrapod (Diapsida: ?Archosauromorpha) from the Upper Triassic (Carnian) of Virginia. *Journal of Vertebrate Paleontology*, 27(2):261–265.

Freckleton, R. P. (2012). Fast likelihood calculations for comparative analyses. *Methods in Ecology and Evolution*, 3(5):940–947.

Friedman, M. and Brazeau, M. D. (2011). Sequences, stratigraphy and scenarios: what can we say about the fossil record of the earliest tetrapods? *Proceedings of the Royal Society B: Biological Sciences*, 278(1704):432–439.

Friedman, M. and Sallan, L. C. (2012). Five hundred million years of extinction and recovery: a Phanerozoic survey of large-scale diversity patterns in fishes. *Palaeontology*, 55(4):707–742.

Fröbisch, J. (2007). The cranial anatomy of *Kombuisia frerensis* Hotton (Synapsida, Dicynodontia) and a new phylogeny of anomodont therapsids. *Zoological Journal of the Linnean Society*, 150(1):117–144.

Fröbisch, J. (2008a). Global taxonomic diversity of anomodonts (Tetrapoda, Therapsida) and the terrestrial rock record across the Permian-Triassic boundary. *PLoS ONE*, 3(11):e3733.

Fröbisch, J. (2008b). *Taxonomic, phylogenetic, and morphological diversity of anomodonts (Tetrapoda, Therapsida)*. PhD thesis, Department of Ecology and Evolutionary Biology, University of Toronto, Toronto. 374 pp.

Fröbisch, J. (2009). Composition and similarity of global anomodont-bearing tetrapod faunas. *Earth-Science Reviews*, 95(3-4):119–157.

Fröbisch, J. (2014a). Anomodontia: Introduction. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 6, pages 89–92. Springer, Dordrecht.

Fröbisch, J. (2014b). Synapsid Diversity and the Rock Record in the Permian-Triassic Beaufort Group (Karoo Supergroup), South Africa. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 18, pages 305–319. Springer, Dordrecht.

Fröbisch, J. and Reisz, R. R. (2008). A new species of *Emydops* (Synapsida, Anomodontia) and a discussion of dental variability and pathology in dicynodonts. *Journal of Vertebrate Paleontology*, 28(3):770–787.

Fröbisch, J. and Reisz, R. R. (2009). The Late Permian herbivore *Suminia* and the early evolution of arboreality in terrestrial vertebrate ecosystems. *Proceedings of the Royal Society of London B: Biological Sciences*, 276(1673):3611–3618.

Fröbisch, J. and Reisz, R. R. (2011). The postcranial anatomy of *Suminia getmanovi* (Synapsida: Anomodontia), the earliest known arboreal tetrapod. *Zoological Journal of the Linnean Society*, 162(3):661–698.

Fröbisch, J. and Kammerer, C. (2014). Diversity of small-bodied dicynodonts (Therapsida, Anomodontia) from the Late Permian of South Africa. *SVP Program and Abstracts Book*, page 133.

Fröbisch, J., Angielczyk, K. D., and Sidor, C. A. (2010). The Triassic dicynodont *Kombuisia* (Synapsida, Anomodontia) from Antarctica, a refuge from the terrestrial Permian-Triassic mass extinction. *Naturwissenschaften*, 97(2):187–196.

Fröbisch, J., Schoch, R. R., Müller, J., Schindler, T., and Schweiss, D. (2011). A new basal sphenacodontid synapsid from the Late Carboniferous of the Saar-Nahe Basin, Germany. *Acta Palaeontologica Polonica*, 56(1):113–120.

Fröbisch, N. B. and Fröbisch, J. (2006). A new basal pterosaur genus from the Upper Triassic of the Northern Calcareous Alps of Switzerland. *Palaeontology*, 49(5):1081–1090.

Fröbisch, N. B. and Schoch, R. R. (2009). Testing the impact of miniaturization on phylogeny: Paleozoic dissorophoid amphibians. *Systematic Biology*, 58(3):312–327.

Fröbisch, N. B. and Reisz, R. R. (2012). A new species of dissorophid (*Cacops woehri*) from the Lower Permian Dolese Quarry, near Richards Spur, Oklahoma. *Journal of Vertebrate Paleontology*, 32(1):35–44.

Fröbisch, N. B., Sander, P. M., and Rieppel, O. (2006). A new species of *Cymbospondylus* (Diapsida, Ichthyosauria) from the Middle Triassic of Nevada and a re-evaluation of the skull osteology of the genus. *Zoological Journal of the Linnean Society*, 147(4):515–538.

Fröbisch, N. B., Fröbisch, J., Sander, P. M., Schmitz, L., and Rieppel, O. (2013). Macropredatory ichthyosaur from the Middle Triassic and the origin of modern trophic networks. *Proceedings of the National Academy of Sciences*, 110(4):1393–1397.

Gaetano, L. C. (2013). *Argentoconodon fariasorum, un mamaliaforme del Jurásico de Patagonia, Argentina: descripción, relaciones filogenéticas e implicancias evolutivas y paleobiogeográficas*. PhD thesis, Universidad de Buenos Aires, Buenos Aires. 379 pp.

Gaetano, L. C. and Rougier, G. W. (2011). New materials of *Argentoconodon fariasorum* (Mammaliaformes, Triconodontidae) from the Jurassic of Argentina and its bearing on triconodont phylogeny. *Journal of Vertebrate Paleontology*, 31(4):829–843.

Gaetano, L. C. and Rougier, G. W. (2012). First amphilestid from South America: a molariform from the Jurassic Cañadón Asfalto Formation, Patagonia, Argentina. *Journal of Mammalian Evolution*, 19(4):235–248.

Gaetano, L. C. and Abdala, F. (2015). The stapes of gomphodont cynodonts: insights into the middle ear structure of non-mammaliaform cynodonts. *PLoS ONE*, 10(7):e0131174.

Gaetano, L. C., Mocke, H., Abdala, F., and Hancox, P. J. (2012). Complex multicusped postcanine teeth from the Lower Triassic of South Africa. *Journal of Vertebrate Paleontology*, 32(6):1411–1420.

Gaetano, L. C., Abdala, F., and Govender, R. (2017). The postcranial skeleton of the Lower Jurassic *Tritylodon longaevus* from Southern Africa. *Ameghiniana*, 54(1):1–35.

Gaffney, E. S. (1979). Tetrapod monophyly: a phylogenetic analysis. *Bulletin of the Carnegie Museum of Natural History*, 13:92–105.

Gaffney, E. S. and McKenna, M. C. (1979). A late Permian captorhinid from Rhodesia. *American Museum Novitates*, 2688:1–15.

Gaffney, E. S., Rich, T. H., Vickers-Rich, P., Constantine, A., Vacca, R., and Kool, L. (2007). *Chubutemys*, a new eucryptodiran turtle from the Early Cretaceous of Argentina, and the relationships of the Meiolaniidae. *American Museum Novitates*, 3599:1–35.

Galton, P. M. G., van Heerden, J., and Yates, A. M. (2005). Postcranial Anatomy of Referred Specimens of the Sauropodomorph Dinosaur *Melanorosaurus* from the Upper Triassic of South Africa. In Tidwell, V. and Carpenter, K., editors, *Thunder-Lizards: The Sauropodomorph Dinosaurs*, pages 1–37. Indiana University Press, Bloomington.

Galton, P. M. (1971). The prosauropod dinosaur *Ammosaurus*, the crocodile *Protosuchus*, and their bearing on the age of the Navajo Sandstone of northeastern Arizona. *Journal of Paleontology*, 45(5):781–795.

Galton, P. M. (1976). Prosauropod dinosaurs (Reptilia: Saurischia) of North America. *Postilla*, 169:1–98.

Galton, P. M. (1978). Fabrosauridae, the basal family of ornithischian dinosaurs (Reptilia: Ornithopoda). *Paläontologische Zeitschrift*, 52(1-2):138–159.

Galton, P. M. (2012). Case 3560 *Plateosaurus engelhardti* Meyer, 1837 (Dinosauria, Sauropodomorpha): proposed replacement of unidentifiable namebearing type by a neotype. *Bulletin of Zoological Nomenclature*, 69(3):203–212.

Galton, P. M. (2013). Comment on *Plateosaurus* Meyer, 1837 (Dinosauria, Sauropodomorpha): proposed replacement of unidentifiable name-bearing type by a neotype (Case 3560). *Bulletin of Zoological Nomenclature*, 70(3):205–206.

Galton, P. M. and Upchurch, P. (2004). Prosauropoda. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 232–258. University of California Press, Berkeley, Second edition.

Galton, P. M. and Kermack, D. (2010). The anatomy of *Pantydraco caducus*, a very basal sauropodomorph dinosaur from the Rhaetian (Upper Triassic) of South Wales, UK. *Revue de Paléobiologie, Genève*, 29(2):341–404.

Gand, G., Bourillot, R., Brigaud, B., Steyer, J.-S., and Peyrouse, J.-B. (2012). Les reptiles et synapsides fossiles de Bourgogne. *Revue Scientifique Bourgogne-Nature, Hors-série*, 12:33–97.

Gao, C.-L., Wilson, G. P., Luo, Z.-X., Maga, A. M., Meng, Q., and Wang, X. (2010a). A new mammal skull from the Lower Cretaceous of China with implications for the evolution of obtuse-angled molars and 'amphilestid' eutriconodonts. *Proceedings of the Royal Society B: Biological Sciences*, 277(1679):237–246.

Gao, K.-Q., Fox, R. C., Zhou, C.-F., and Li, D.-Q. (2010b). A new nonmammalian eucynodont (Synapsida: Therapsida) from the Triassic of Northern Gansu Province, China, and its biostratigraphic and biogeographic implications. *American Museum Novitates*, 3685:1–25.

Gao, K. (1989). Pareiasaurs from the Upper Permian of north China. *Canadian Journal of Earth Sciences*, 26(6):1234–1240.

Garland, Jr., T. and Ives, A. R. (2000). Using the past to predict the present: confidence intervals for regression equations in phylogenetic comparative methods. *The American Naturalist*, 155(3):346–364.

Gastwirth, J. L., Gel, Y. R., Wallace Hui, W. L., Lyubchich, V., Miao, W., and Noguchi, K. (2017). *Package 'lawstat': tools for biostatistics, public policy, and law*. R package version 3.2. 44 pp.

Gaudry, A. (1880). Sur un reptile très perfectionné trouvé dans le terrain permien. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences Paris*, 91(18):669–671.

Gauthier, A. G., Kluge, A. G., and Rowe, T. (1988). The early evolution of the Amniota. In Benton, M. J., editor, *The Phylogeny and Classification of the Tetrapods. Volume 1: Amphibians, Reptiles,* *Birds*, volume 35A of *Systematics Association Special Volume*, chapter 4, pages 103–155. Clarendon Press, Oxford.

Gay, R. J. and Aude, I. S. (2015). The first occurrence of the enigmatic archosauriform *Crosbysaurus* Heckert 2004 from the Chinle Formation of southern Utah. *PeerJ*, 3:e905.

Gearty, W., McClain, C. R., and Payne, J. L. (2018). Energetic tradeoffs control the size distribution of aquatic mammals. *Proceedings of the National Academy of Sciences*, 115(16):4194–4199.

Gebauer, E. V. I. (2007). *Phylogeny and evolution of the Gorgonopsia with a special reference to the skull and skeleton of GPIT/RE/7113 ('Aelurognathus?' parringtoni)*. PhD thesis, Eberhard-Karls Universität Tübingen, Tübingen. 316 pp.

Gebauer, E. V. I. (2014). Re-assessment of the Taxonomic Position of the Specimen GPIT/RE/7113 (*Sauroctonus parringtoni* comb. nov., Gorgonopsia). In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 12, pages 185–207. Springer, Dordrecht.

Gee, B. M. (2018). Reappraisal of the early Permian dissorophid *Alegeinosaurus* from Texas, USA. *Paläontologische Zeitschrift*, 92(4):661–669.

Gee, B. M. and Parker, W. G. (2017). A juvenile *Koskinonodon perfectus* (Temnospondyli: Metoposauridae) from the Late Triassic of Arizona and its implications for the taxonomy of North American metoposaurids. *Journal of Paleontology*, 91(5):1047–1059.

Gee, B. M., Parker, W. G., and Marsh, A. D. (2017). Microanatomy and paleohistology of the intercentra of North American metoposaurids from the Upper Triassic of Petrified Forest National Park (Arizona, USA) with implications for the taxonomy and ontogeny of the group. *PeerJ*, 5:e3183.

Gegenbaur, C. (1898). *Vergleichende Anatomie der Wirbelthiere mit Berücksichtigung der Wirbellosen*, volume 1. Verlag von Wilhelm Engelmann, Leipzig. 978 pp.

Gegenbaur, C. (1901). *Vergleichende Anatomie der Wirbelthiere mit Berücksichtigung der Wirbellosen*, volume 2. Verlag von Wilhelm Engelmann, Leipzig. 696 pp.

Gentil, A. R. and Ezcurra, M. D. (2018). Reconstruction of the masticatory apparatus of the holotype of the rhynchosaur *Hyperodapedon sanjuanensis* (Sill, 1970) from the Late Triassic of Argentina: implications for the diagnosis of the species. *Ameghiniana*, 55(2):137–149.

Germain, D. (2008). A new phlegethontiid specimen (Lepospondyli, Aistopoda) from the Late Carboniferous of Montceau-les-Mines (Saône-et-Loire, France). *Geodiversitas*, 30(4):669–680.

Germain, D. (2010). The Moroccan diplocaulid: the last lepospondyl, the single one on Gondwana. *Historical Biology*, 22(1-3):4–39.

Gess, R. and Ahlberg, P. E. (2018). A tetrapod fauna from within the Devonian Antarctic Circle. *Science*, 360(6393):1120–1124.

Getmanov, S. N. (1989). [Triassic amphibians of the East European Platform: family Benthosuchidae Efremov]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 236:1–102. [In Russian].

Gill, P. G., Säilä, L. K., Corfe, I. J., Challans, T. J., Williams, M., and Clemens, W. A. (2006). The fauna and palaeoenvironment of St. Bride's Island fissure fills of South Wales. In Barrett, P. M. and Evans, S. E., editors, *Ninth International Symposium on Mesozoic Terrestrial Ecosystems and Biota, Abstracts and Proceedings*, pages 48–51. Natural History Museum, London.

Gillooly, J. F., Brown, J. H., West, G. B., Savage, V. M., and Charnov, E. L. (2001). Effects of size and temperature on metabolic rate. *Science*, 293(5538):2248–2251.

Glasspool, I. J. and Scott, A. C. (2010). Phanerozoic concentrations of atmospheric oxygen reconstructed from sedimentary charcoal. *Nature Geoscience*, 3(9):627–630.

Glienke, S. (2012). A new "microsaur" (Amphibia; Lepospondyli) from the Rotliegend of the Saar–Palatinate region (Carboniferous/Permian transition; West Germany). *Paläontologische Zeitschrift*, 86(3):297–311.

Glienke, S. (2015). Two new species of the genus *Batropetes* (Tetrapoda, Lepospondyli) from the Central European Rotliegend (basal Permian) in Germany. *Journal of Vertebrate Paleontology*, 35(2):e918041.

Godefroit, P. (1992). Présence de *Leptopterygius tenuirostris* (Reptilia, Ichthyosauria) dans le Lias moyen de Lorraine belge. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre [Bulletin van het Koninklijk Belgisch Instituut voor Natuurwetenschappen, Aardwetenschappen]*, 62:163–170.

Godefroit, P. (1996). Un crâne d'*Ichthyosaurus communis* (Reptilia, Ichthyosauria) du Sinémurien supérieur de Lorraine belge. *Bulletin de la Société belge de Géologie*, 104(1–2):77–89.

Godefroit, P. (1999). New traversodontid (Therapsida: Cynodontia) teeth from the Upper Triassic of Habay-la-Vieille (southern Belgium). *Paläontologische Zeitschrift*, 73(3–4):385–394.

Godefroit, P. and Cuny, G. (1997). Archosauriform teeth from the Upper Triassic of Saint-Nicolas-de-Port (northeastern France). *Palaeovertebrata*, 26(1–4):1–34.

Godefroit, P. and Battail, B. (1997). Late Triassic cynodonts from Saint-Nicolas-de-Port (northeastern France). *Geodiversitas*, 19(3):567–631.

Godefroit, P. and Sigogneau-Russell, D. (1999). Kuehneotheriids from Saint-Nicolas-de-Port (Late Triassic of France). *Geologica Belgica*, 2(3–4):181–196.

Godefroit, P., Cuny, G., Delsate, D., and Roche, M. (1998). Late Triassic vertebrates from Syren (Luxembourg). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 210(3):305–343.

Godfrey, S. J. (1989). The postcranial skeletal anatomy of the Carboniferous tetrapod *Greererpeton burkemorani* Romer, 1969. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 323(1213):75–133.

Godfrey, S. J. (1997). Tetrapods (Amphibians and Reptiles). In Shabica, C. and Hay, A., editors, *Richardson's guide to the fossil fauna of Mazon Creek*, pages 256–269. Northeastern Illinois University Press, Chicago.

Godfrey, S. J., Fiorillo, A. R., and Carroll, R. L. (1987). A newly discovered skull of the temnospondyl amphibian *Dendrerpeton acadianum* Owen. *Canadian Journal of Earth Sciences*, 24(4):796–805.

Goedert, J., Lécuyer, C., Amiot, R., Arnaud-Godet, F., Wang, X., Cui, L., Cuny, G., Douay, G., Fourel, F., Panczer, G., Simon, L., Steyer, J.-S., and Zhu, M. (2018). Euryhaline ecology of early tetrapods revealed by stable isotopes. *Nature*, 558(7708):68–72.

Golubev, V. K. (1995). New species of *Melosaurus* (Amphibia, Labyrinthodontia) from the Kazanian of the Kama River drainage area. *Paleontological Journal*, 29(3):107–119.

Golubev, V. K. (1997a). Faunistic complexes: Permian. In Ivakhnenko, M. F., Golubev, V. K., Gubin, Y. M., Kalandadze, N. N., Novikov, I. V., Sennikov, A. G., and Rautian, A. S., editors, *Permian and Triassic tetrapods of Eastern Europe*, pages 48–51. GEOS, Moscow. [In Russian].

Golubev, V. K. (1997b). Subclassis Anthracosauromorpha. In Ivakhnenko, M. F., Golubev, V. K., Gubin, Y. M., Kalandadze, N. N., Novikov, I. V., Sennikov, A. G., and Rautian, A. S., editors, *Permian and Triassic tetrapods of Eastern Europe*, pages 20–22. GEOS, Moscow. [In Russian].

Golubev, V. K. (2000). The faunal assemblages of Permian terrestrial vertebrates from Eastern Europe. *Paleontological Journal*, 34(Suppl. 2):S211–S224.

Golubev, V. K. (2005). Permian tetrapod stratigraphy. In Lucas, S. G. and Zeigler, K. E., editors, *The Nonmarine Permian*, volume 30, pages 95–99. New Mexico Museum of Natural History.

Golubev, V. K. (2015). Dinocephalian stage in the history of the Permian tetrapod fauna of Eastern Europe. *Paleontological Journal*, 49(12):1346–1352.

Goodrich, E. S. (1930). *Studies on the Structure & Development of Vertebrates*. Macmillan and Co., Limited, London. 837 pp.

Gorsky, V. P., Gusseva, E. A., Crasquin-Soleau, S., and Broutin, J. (2003). Stratigraphic data of the Middle – Late Permian on Russian Platform. *Geobios*, 36(5):533–558.

Gottmann-Quesada, A. and Sander, P. (2009). A redescription of the early archosauromorph *Protorosaurus speneri* Meyer, 1832, and its phylogenetic relationships. *Palaeontographica Abteilung A*, 287(4–6):123–220.

Gould, S. J. (1975). On the scaling of tooth size in mammals. *American Zoologist*, 15(2):351–362.

Govender, R., Hancox, P. J., and Yates, A. M. (2008). Re-evaluation of the postcranial skeleton of the Triassic dicynodont *Kannemeyeria simocephalus* form the *Cynognathus* Assemblage Zone (Subzone B) of South Africa. *Palaeontologia africana*, 43:19–37.

Gow, C. E. (1972). The osteology and relationships of the Millerettidae (Reptilia: Cotylosauria). *Journal of Zoology*, 167(2):219–264.

Gow, C. E. (1986). A new skull of *Megazostrodon* (Mammalia, Triconodonta) from the Ellior Formation (Lower Jurassic) of Southern Africa. *Palaeontologia africana*, 26(2):13–23.

Gow, C. E. (1994). New find of *Diarthrognathus* (Therapsida: Cynodontia) after seventy years. *Palaeontologia africana*, 31:51–54.

Gow, C. E. (1999). The Triassic reptile *Palacrodon browni* Broom, synonymy and a new specimen. *Palaeontologia africana*, 35:21–23.

Gow, C. E. (2000). The skull of *Protosuchus haughtoni*, an early Jurassic crocodyliform from southern Africa. *Journal of Vertebrate Paleontology*, 20(1):49–56.

Gower, D. J. (2000). Rauisuchian archosaurs (Reptilia, Diapsida): an overview. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 218(3):447–488.

Gower, D. J. and Sennikov, A. G. (2000). Early archosaurs from Russia. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 140–159. Cambridge University Press, Cambridge.

Gower, D. J. and Schoch, R. R. (2009). Postcranial anatomy of the rauisuchian archosaur *Batrachotomus kupferzellensis*. *Journal of Vertebrate Paleontology*, 29(1):103–122.

Gower, D. J., Hancox, P. J., Botha-Brink, J., Sennikov, A. G., and Butler, R. J. (2014). A new species of *Garjainia* Ochev, 1958 (Diapsida: Archosauriformes: Erythrosuchidae) from the Early Triassic of South Africa. *PLoS ONE*, 9(11):e111154.

Grady, J. M., Enquist, B. J., Dettweiler-Robinson, E., Wright, N. A., and Smith, F. A. (2014). Evidence for mesothermy in dinosaurs. *Science*, 344(6189):1268–1272.

Green, J. L., Schweitzer, M. H., and Lamm, E.-T. (2010). Limb bone histology and growth in *Placerias hesternus* (Therapsida: Anomodontia) from the Upper Triassic of North America. *Palaeontology*, 53(2):347–364.

Griffin, C. T. and Nesbitt, S. J. (2016). Anomalously high variation in postnatal development is ancestral for dinosaurs but lost in birds. *Proceedings of the National Academy of Sciences*, 113(51):14757–14762.

Grigg, G. and Kirshner, D. (2015). *Biology and Evolution of Crocodylians*. Comstock Publishing Associates, Ithaca, United States, First edition. 649 pp.

Grine, F. E., Hahn, B. D., and Gow, C. E. (1978). Aspects of relative growth and variability in *Diademodon* (Reptilia; Therapsida). *South African Journal of Science*, 74(2):50–58.

Grine, F. E., Forster, C. A., Cluver, M. A., and Georgi, J. A. (2006). Cranial Variability, Ontogeny, and Taxonomy of *Lystrosaurus* from the Karoo Basin of South Africa. In Carrano, M. T., Gaudin, T. J., Blob, R. W., and Wible, J. R., editors, *Amniote Paleobiology: Perspectives on the Evolution of Mammals, Birds, and Reptiles*, chapter 14, pages 432–503. University of Chicago Press, Chicago.

Großmann, F. (2007). The taxonomic and phylogenetic position of the Plesiosauroidea from the Lower Jurassic Posidonia shale of south-west Germany. *Palaeontology*, 50(3):545–564.

Gruntmejer, K., Konietzko-Meier, D., and Bodzioch, A. (2016). Cranial bone histology of *Metoposaurus krasiejowensis* (Amphibia, Temnospondyli) from the Late Triassic of Poland. *PeerJ*, 4:e2685.

Gubin, Y. M. (1980). New Permian dissorophids of the Ural Forelands. *Paleontological Journal*, 14(3):88–96.

Gubin, Y. M. (1991). [Permian archegosauroid amphibians of the USSR]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 249:1–141. [In Russian].

Gubin, Y. M. (1997a). Skull morphology of *Archegosaurus decheni* Goldfuss (Amphibia, Temnospondyli) from the Early Permian of Germany. *Alcheringa: An Australasian Journal of Palaeontology*, 21(2):103–121.

Gubin, Y. M. (1997b). Suborder Edopia. In Ivakhnenko, M. F., Golubev, V. K., Gubin, Y. M., Kalandadze, N. N., Novikov, I. V., Sennikov, A. G., and Rautian, A. S., editors, *Permian and Triassic tetrapods of Eastern Europe*, pages 7–9. GEOS, Moscow. [In Russian].

Gubin, Y. M. (1999). A new diplocaulid (Nectridea, Amphibia) from the Early Permian of Kansas (USA). *Paleontological Journal*, 33(6):630–637.

Gubin, Y. M. (2004). A new dvinosaur (Amphibia, Temnospondyli) from the Upper Tatarian of the Middle Volga Region. *Paleontological Journal*, 38(2):190–199.

Güven, S., Day, M., Almond, J. E., Abdala, F., and Rubidge, B. S. (2012). First tapinocephalid dinocephalian from the *Pristerognathus* Assemblage Zone (Karoo Supergroup, South Africa), including new information on *Criocephalosaurus* (Therapsida: Dinocephalia). In *16th Biennial Conference of the Palaeontological Society of Southern Africa*, volume 47 of *Palaeontologia africana*, page 37. Cape Town.

Güven, S., Rubidge, B. S., and Abdala, F. (2013). Cranial morphology and taxonomy of South African Tapinocephalidae (Therapsida: Dinocephalia): the case of *Avenantia* and *Riebeeckosaurus*. *Palaeontologia africana*, 48:24–33.

Haack, S. C. (1986). A thermal model of the sailback pelycosaur. *Paleobiology*, 12(4):450–458.

Haas, G. (1980). Ein Nothosaurier-Schädel aus dem Muschelkalk des Wadi Ramon (Negev, Israel). *Annalen des Naturhistorischen Museums in Wien*, 83:119–125.

Hadfield, J. D. (2010). MCMC methods for multi-response generalized linear mixed models: the MCMCglmm R package. *Journal of Statistical Software*, 33(2):1–22.

Hadfield, J. (2018a). *MCMCglmm Course Notes*. 143 pp.

Hadfield, J. (2018b). *Package 'MCMCglmm': MCMC generalised linear mixed models*, 2.26 edition. 47 pp.

Hahn, G. R. and Wouters, G. (1987). Cynodontier-Zähne aus der Ober-Trias von Gaume (S-Belgien). *Mémoires pour servir à l'explication des cartes géologiques et miniéres de la Belgique*, 24:1–24.

Halliday, T. J. D. and Goswami, A. (2016). The impact of phylogenetic dating method on interpreting trait evolution: a case study of Cretaceous–Palaeogene eutherian body-size evolution. *Biology Letters*, 12(8):20160051.

Hammer, W. R. (1995). New therapsids from the Upper Fremouw Formation (Triassic) of Antarctica. *Journal of Vertebrate Paleontology*, 15(1):105–112.

Hammer, W. R. and Hickerson, W. J. (1994). A crested theropod dinosaur from Antarctica. *Science*, 264(5160):828–830.

Han, F.-L., Barrett, P. M., Butler, R. J., and Xu, X. (2012). Postcranial anatomy of *Jeholosaurus shangyuanensis* (Dinosauria, Ornithischia) from the Lower Cretaceous Yixian Formation of China. *Journal of Vertebrate Paleontology*, 32(6):1370–1395.

Han, G., Mao, F., Bi, S., Wang, Y., and Meng, J. (2017). A Jurassic gliding euharamiyidan mammal with an ear of five auditory bones. *Nature*, 551:451–456.

Hancock, A. and Howse, R. (1870). On *Proterosaurus speneri*, von Meyer, and a new species, *Proterosaurus huxleyi*, from the Marl-Slate of Midderidge, Durham. *Quarterly Journal of the Geological Society of London*, 26(1–2):565–572.

Hancox, P. J., Shishkin, M. A., Rubidge, B. S., and Kitching, J. W. (1995). A threefold subdivision of the *Cynognathus* Assemblage Zone (Beaufort Group, South Africa) and its palaeogeographical implications. *South African Journal of Science*, 91(3):143–144.

Hancox, P. J., Angielczyk, K. D., and Rubidge, B. S. (2013). *Angonisaurus* and *Shansiodon*, dicynodonts (Therapsida, Anomodontia) from subzone C of the *Cynognathus* Assemblage Zone (Middle Triassic) of South Africa. *Journal of Vertebrate Paleontology*, 33(3):655–676.

Hänni, K. (2004). *Die Gattung Ceresiosaurus–Ceresiosaurus calcagnii Peyer and Ceresiosaurus lanzi n. sp. (Lariosauridae, Sauropterygia)*. PhD thesis, ETH Zürich (vdf Hochschulverlag AG). 147 pp.

Hansen, T. F. (1997). Stabilizing selection and the comparative analysis of adaptation. *Evolution*, 51(5):1341–1351.

Haq, B. U. and Schutter, S. R. (2008). A chronology of Paleozoic sea-level changes. *Science*, 322(5898):64–68.

Hardin, G. (1960). The competitive exclusion principle. *Science*, 131(3409):1292–1297.

Haridy, Y., Macdougall, M. J., and Reisz, R. R. (2018). The lower jaw of the Early Permian parareptile *Delorhynchus*, first evidence of multiple denticulate coronoids in a reptile. *Zoological Journal of the Linnean Society*, 184(3):791–803.

Harmon, L. J., Losos, J. B., Jonathan Davies, T., Gillespie, R. G., Gittleman, J. L., Bryan Jennings, W., Kozak, K. H., McPeek, M. A., Moreno-Roark, F., Near, T. J., Purvis, A., Ricklefs, R. E., Schluter, D., Schulte II, J. A., Seehausen, O., Sidlauskas, B. L., Torres-Carvajal, O., Weir, J. T., and Mooers, A. Ø. (2010). Early bursts of body size and shape evolution are rare in comparative data. *Evolution*, 64(8):2385–2396.

Harris, S. K., Lucas, S. G., Berman, D. S., and Henrici, A. C. (2004). Vertebrate fossil assemblage from the Upper Pennsylvanian Red Tanks Member of the Bursum Formation, Lucero Uplift, central New Mexico. In Lucas, S. G. and Zeigler, K. E., editors, *Carboniferous-Permian Transition at Carrizo Arroyo, Central New Mexico*, volume 25, pages 267–284. New Mexico Museum of Natural History.

Harris, S. K., Lucas, S. G., and Spielmann, J. A. (2010). A partial skeleton of *Ophiacodon navajovicus* (Eupelycosauria: Ophiacodontidae) from the Upper Pennsylvanian of Cañon del Cobre, New Mexico. In Lucas, S. G., Schneider, J. W., and Spielmann, J. A., editors, *Carboniferous-Permian* *transition in Cañon del Cobre, northern New Mexico*, volume 49, pages 137–150. New Mexico Museum of Natural History.

Harrison, J. F., Kaiser, A., and VandenBrooks, J. M. (2010). Atmospheric oxygen level and the evolution of insect body size. *Proceedings of the Royal Society of London B: Biological Sciences*, 277(1690):1937–1946.

Hasegawa, Y., Manabe, M., Hirano, H., and Takahashi, F. (1998). A turtle from the Early Jurassic Toyora Group, Yamaguchi, Japan. *Memoirs of the National Science Museum*, 31:67–72.

Haubold, H. (1990). Ein neuer Dinosaurier (Ornithischia, Thyreophora) aus dem unteren Jura des nördlichen Mitteleuropa. *Revue de Paléobiologie, Genève*, 9(1):149–177.

Haughton, S. H. (1918). Investigations in South African fossil reptiles and Amphibia (part 11). 11. Some new carnivorous Therapsida, with notes upon the brain-case in certain species. *Annals of the South African Museum*, 12(2):175–216.

Haughton, S. H. (1924a). A bibliographic list of pre-Stormberg Karroo reptilia, with a table of horizons. *Transactions of the Royal Society of South Africa*, 12(1):51–104.

Haughton, S. H. (1924b). On a new type of thecodont from the Middle Beaufort Beds. *Annals of the Transvaal Museum*, 11(1):93–97.

Haughton, S. H. (1932). On a collection of Karroo vertebrates from Tanganyika Territory. *Quarterly Journal of the Geological Society of London*, 88(1–4):634–671.

Haughton, S. H. (1965). The Rubidge collection of fossil Karro vertebrates. *Palaeontologia africana*, 9:1–17.

Haughton, S. H. and Boonstra, L. D. (1929). Pareiasaurian studies. Part I. An attempt at a classification of the Pareiasauria based on skull features. *Annals of the South African Museum*, 28(1):79–87.

Haughton, S. H. and Brink, A. S. (1954). A bibliographic list of the Reptilia from the Karroo beds of Africa. *Palaeontologia africana*, 2:1–187.

Hauser, N., Cabaleri, N. G., Gallego, O. F., Monferran, M. D., Silva Nieto, D., Armella, C., Matteini, M., Aparicio González, P. A., Pimentel, M. M., Volkheimer, W., and Reimold, W. U. (2017). U-Pb and Lu-Hf zircon geochronology of the Cañadón Asfalto Basin, Chubut, Argentina: implications for the magmatic evolution in central Patagonia. *Journal of South American Earth Sciences*, 78:190–212.

Haworth, A. H. (1825). A binary arrangement of the class Amphibia. *Philosophical Magazine*, 65(325):372–373.

Healy, K., Guillerme, T., Finlay, S., Kane, A., Kelly, S. B. A., McClean, D., Kelly, D. J., Donohue, I., Jackson, A. L., and Cooper, N. (2014). Ecology and mode-of-life explain lifespan variation in birds and mammals. *Proceedings of the Royal Society of London B: Biological Sciences*, 281(1784):20140298.

Heaton, M. J. (1979). Cranial anatomy of primitive captorhinid reptiles from the Late Pennsylvanian and Early Permian, Oklahoma and Texas. *Oklahoma Geological Survey Bulletin*, 127:1–84.

Heckert, A. B. (2004). Late Triassic microvertebrates from the Lower Chinle Group (Otischalkian-Adamanian:Carnian), southwestern U.S.A. In Heckert, A. B., editor, *Late Triassic Microvertebrates*, volume 27, pages 1–170. New Mexico Museum of Natural History.

Heckert, A. B. and Lucas, S. G. (2006). Micro- and small vertebrate biostratigraphy and biochronology of the Upper Triassic Chinle Group, southwestern USA. In Harris, J. D., Lucas, S. G., Spielmann, J. A., Lockley, M. G., Milner, A. R. C., and Kirkland, J. I., editors, *The Triassic-Jurassic Terrestrial Transition*, volume 37, pages 94–104. New Mexico Museum of Natural History.

Heckert, A. B. and Miller-Camp, J. A. (2013). Tooth enamel microstructure of *Revueltosaurus* and *Krzyzanowskisaurus* (Reptilia: Archosauria) from the Upper Triassic Chinle Group, USA: implications for function, growth, and phylogeny. *Palaeontologia Electronica*, 16(1.1A):23 pp.

Heckert, A. B., Lucas, S. G., Kahle, R., and Zeigler, K. (2001). New occurence of *Trilophosaurus* (Reptilia: Archosauromorpha) from the Upper Triassic of West Texas and its biochronological significance. In Lucas, S. G. and Ulmer-Scholle, D., editors, *New Mexico Geological Society Guidebook, 52nd Field Conference, Geology of the Llano Estacado*, pages 115–122. New Mexico Geological Society.

Heckert, A. B., Lucas, S. G., and Hunt, A. P. (2005). Triassic vertebrate fossils in Arizona. In Heckert, A. B. and Lucas, S. G., editors, *Vertebrate Paleontology in Arizona*, volume 29, pages 16–44. New Mexico Museum of Natural History.

Heckert, A. B., Lucas, S. G., Rinehart, L. F., Spielmann, J. A., Hunt, A. P., and Kahle, R. (2006). Revision of the archosauromorph reptile *Trilophosaurus*, with a description of the first skull of *Trilophosaurus jacobsi*, from the Upper Triassic Chinle Group, West Texas, USA. *Palaeontology*, 49(3):621–640.

Heckert, A. B., Lucas, S. G., Rinehart, L. F., and Hunt, A. P. (2008). A new genus and species of sphenodontian from the Ghost Ranch *Coelophysis* quarry (Upper Triassic: Apachean), Rock Point Formation, New Mexico, USA. *Palaeontology*, 51(4):827–845.

Heckert, A. B., Lucas, S. G., and Spielmann, J. A. (2012a). A new species of the enigmatic archosauromorph *Doswellia* from the Upper Triassic Bluewater Creek Formation, New Mexico, USA. *Palaeontology*, 55(6):1333–1348.

Heckert, A. B., Mitchell, J. S., Schneider, V. P., and Olsen, P. E. (2012b). Diverse new microvertebrate assemblage from the Upper Triassic Cumnock Formation, Sanford Subbasin, North Carolina, USA. *Journal of Paleontology*, 86(2):368–390.

Heckert, A. B., Jenkins, H. J., Lucas, S. G., and Hunt, A. P. (2013). Mandibles of juvenile phytosaurs (Archosauria: Crurotarsi) from the Upper Triassic Chinle Group of Texas and New Mexico, USA. In Tanner, L. H., Spielmann, J. A., and Lucas, S. G., editors, *The Triassic System*, volume 61, pages 228–236. New Mexico Museum of Natural History.

Heckert, A. B., Schneider, V. P., Fraser, N. C., and Webb, R. A. (2015). A new aetosaur (Archosauria, Suchia) from the Upper Triassic Pekin Formation, Deep River Basin, North Carolina, U.S.A., and its implications for early aetosaur evolution. *Journal of Vertebrate Paleontology*, 35(1):e881831.

Heckert, A. B., Fraser, N. C., and Schneider, V. P. (2017). A new species of *Coahomasuchus* (Archosauria, Aetosauria) from the Upper Triassic Pekin Formation, Deep River Basin, North Carolina. *Journal of Paleontology*, 91(1):162–178.

Hedman, M. M. (2010). Constraints on clade ages from fossil outgroups. *Paleobiology*, 36(1):16–31.

Heim, N. A., Knope, M. L., Schaal, E. K., Wang, S. C., and Payne, J. L. (2015). Cope's rule in the evolution of marine animals. *Science*, 347(6224):867–870.

Hellrung, H. (2003). *Gerrothorax pustuloglomeratus*, ein Temnospondyle (Amphibia) mit knöcherner Branchialkammer aus dem Unteren Keuper von Kupferzell (Süddeutschland). *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 330:1–130.

Henderson, D. M. and Weishampel, D. B. (2002). Convergent evolution of the maxilla-dental-complex among carnivorous archosaurs. *Senckenbergiana lethaea*, 82(1):77–91.

Hendrickx, C., Hartman, S. A., and Mateus, O. (2015). An overview of non-avian theropod discoveries and classification. *PalArch's Journal of Vertebrate Paleontology*, 12(1):1–73.

Hendrickx, C., Abdala, F., and Choiniere, J. (2016). Postcanine microstructure in *Cricodon metabolus*, a Middle Triassic gomphodont cynodont from south-eastern Africa. *Palaeontology*, 59(6):851–861.

Henrici, A. C., Martens, T., Berman, D. S., and Sumida, S. S. (2011). An ostodolepid 'microsaur' (Lepospondyli) from the Lower Permian Tambach Formation of central Germany. *Journal of Vertebrate Paleontology*, 31(5):997–1004.

Herrera-Flores, J. A., Stubbs, T. L., Elsler, A., and Benton, M. J. (2018). Taxonomic reassessment of *Clevosaurus latidens* Fraser, 1993 (Lepidosauria, Rhynchocephalia) and rhynchocephalian phylogeny based on parsimony and Bayesian inference. *Journal of Paleontology*, 92(4):734–742.

Hewison, R. H. (2007). The skull and mandible of the stereospondyl *Lydekkerina huxleyi*, (Tetrapoda: Temnospondyli) from the Lower Triassic of South Africa, and a reappraisal of the family Lydekkerinidae, its origin, taxonomic relationships and phylogenetic importance. *Journal of Temnospondyl Palaeontology*, 1(1):1–80.

Ho, L. S. T. and Ané, C. (2014). Intrinsic inference difficulties for trait evolution with Ornstein-Uhlenbeck models. *Methods in Ecology and Evolution*, 5(11):1133–1146.

Hoffman, D. K., Heckert, A. B., and Zanno, L. E. (2018). Under the armor: X-ray computed tomographic reconstruction of the internal skeleton of *Coahomasuchus chathamensis* (Archosauria: Aetosauria) from the Upper Triassic of North Carolina, USA, and a phylogenetic analysis of Aetosauria. *PeerJ*, 6:e4368.

Hofmann, R. and Sander, P. M. (2014). The first juvenile specimens of *Plateosaurus engelhardti* from Frick, Switzerland: isolated neural arches and their implications for developmental plasticity in a basal sauropodomorph. *PeerJ*, 2:e458.

Holden, C. (2002). Taxonomic tussle. *Science*, 295(5559):1459.

Holliday, C. M. and Nesbitt, S. J. (2013). Morphology and diversity of the mandibular symphysis of archosauriforms. *Geological Society, London, Special Publications*, 379(1):555–571.

Holmes, R. B. (1989). The skull and axial skeleton of the Lower Permian anthracosauroid amphibian *Archeria crassidisca* Cope. *Palaeontographica Abteilung A*, 207(4–6):161–206.

Holmes, R. B. and Carroll, R. L. (2010). An articulated embolomere skeleton (Amphibia: Anthracosauria) from the Lower Pennsylvanian (Bashkirian) of Nova Scotia. *Canadian Journal of Earth Sciences*, 47(3):209–219.

Holmes, R. B., Carroll, R. L., and Reisz, R. R. (1998). The first articulated skeleton of *Dendrerpeton acadianum* (Temnospondyli, Dendrerpetontidae) from the Lower Pennsylvanian locality of Joggins, Nova Scotia, and a review of its relationships. *Journal of Vertebrate Paleontology*, 18(1):64–79.

Holmes, R. (1984). The Carboniferous amphibian *Proterogyrinus scheelei* Romer, and the early evolution of tetrapods. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 306(1130):431–524.

Holmes, R. and Baird, D. (2011). The smaller embolomerous amphibians (Anthracosauria) from the Middle Pennsylvanian (Desmoinesian) localities at Linton and Five Points coal mines, Ohio. *Breviora*, 523:1–13.

Holmes, R., Berman, D. S., and Anderson, J. S. (2013). A new dissorophid (Temnospondyli, Dissorophoidea) from the Early Permian of New Mexico (United States). *Comptes Rendus Palevol*, 12(7–8):419–435.

Holwerda, F. M., Pol, D., and Rauhut, O. W. M. (2015). Using dental enamel wrinkling to define sauropod tooth morphotypes from the Cañadón Asfalto Formation, Patagonia, Argentina. *PLoS ONE*, 10(2):e0118100.

Holz, M. (2015). Mesozoic paleogeography and paleoclimates – a discussion of the diverse greenhouse and hothouse conditions of an alien world. *Journal of South American Earth Sciences*, 61:91–107.

Hone, D. W. E. and Benton, M. J. (2007). An evaluation of the phylogenetic relationships of the pterosaurs among archosauromorph reptiles. *Journal of Systematic Palaeontology*, 5(4):465–469.

Hone, D. W. E. and Benton, M. J. (2008a). A new genus of rhynchosaur from the Middle Triassic of south-west England. *Palaeontology*, 51(1):95–115.

Hone, D. W. E. and Benton, M. J. (2008b). Contrasting supertree and total-evidence methods: the origin of the pterosaurs. *Zitteliana, Reihe B*, 28:35–60.

Hone, D. W. E., Farke, A. A., and Wedel, M. J. (2016). Ontogeny and the fossil record: what, if anything, is an adult dinosaur? *Biology Letters*, 12(2):20150947.

Hook, R. W. (2000). R. L. Carroll, K. A. Bossy, A. C. Milner, S. M. Andrews, and C. F Wellstead: Handbuch der Paläoherpetologie/Encyclopedia of Paleoherpetology, Part 1, Lepospondyli. *Journal of Vertebrate Paleontology*, 20(1):212–213.

Hook, R. W. and Baird, D. (1986). The Diamond Coal Mine of Linton, Ohio, and its Pennsylvanian-age vertebrates. *Journal of Vertebrate Paleontology*, 6(2):174–190.

Hopkins, S. S. B. (2018). Estimation of Body Size in Fossil Mammals. In Croft, D. A., Su, D. F., and Simpson, S. W., editors, *Methods in Paleoecology: Reconstructing Cenozoic Terrestrial Environments and Ecological Communities*, Vertebrate Paleobiology and Paleoanthropology, pages 7–22. Springer International Publishing, Cham.

Hopson, J. A. (2014). The Traversodontid Cynodont *Mandagomphodon hirschsoni* from the Middle Triassic of the Ruhuhu Valley, Tanzania. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 14, pages 233–253. Springer, Dordrecht.

Hopson, J. A. and Kitching, J. W. (1972). A revised classification of cynodonts (Reptilia; Therapsida). *Palaeontologia africana*, 14:71–85.

Hopson, J. A. and Barghusen, H. (1986). An analysis of therapsid relationships. In Hotton, III, N., MacLean, P. D., Roth, J. J., and Roth, E. C., editors, *The Ecology and Biology of Mammal-like Reptiles*, pages 83–106. Smithsonian Institution Press, Washington.

Hopson, J. A. and Kitching, J. W. (2001). A probainognathian cynodont from South Africa and the phylogeny of nonmammalian cynodonts. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 156(1):5–35.

Hopson, J. A. and Sues, H.-D. (2006). A traversodont cynodont from the Middle Triassic (Ladinian) of Baden-Württemberg (Germany). *Paläontologische Zeitschrift*, 80(2):124–129.

Hopson, J. A. and Sidor, C. A. (2015). A juvenile specimen of the trirachodontid cynodont *Cricodon metabolus* from the Luangwa Basin of Zambia: implications for tooth replacement in gomphodont cynodonts and for trirachodontid systematics. *SVP Program and Abstracts Book*, page 147.

Houssaye, A. (2013). Bone histology of aquatic reptiles: what does it tell us about secondary adaptation to an aquatic life? *Biological Journal of the Linnean Society*, 108(1):3–21.

Hsiou, A. S., De França, M. A. G., and Ferigolo, J. (2015). New data on the *Clevosaurus* (Sphenodontia: Clevosauridae) from the Upper Triassic of Southern Brazil. *PLoS ONE*, 10(9):e0137523.

Hu, S. (1993). A new Theropoda (*Dilophosaurus sinensis* sp. nov.) from Yunnan, China. *Vertebrata PalAsiatica*, 31(1):65–69. [In Chinese with English abstract].

Hungerbühler, A. (2001). The status and phylogenetic relationships of *"Zanclodon" arenaceus*: the earliest known phytosaur? *Paläontologische Zeitschrift*, 75(1):97–112.

Hungerbühler, A., Mueller, B., Chatterjee, S., and Cunningham, D. P. (2012). Cranial anatomy of the Late Triassic phytosaur *Machaeroprosopus*, with the description of a new species from West Texas. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103:269–312.

Hunt, A. P. (1993). Revision of the Metoposauridae (Amphibia: Temnospondyli) and description of a new genus from western North America. *Museum of Northern Arizona Bulletin*, 59:67–97.

Hunt, A. P. and Lucas, S. G. (1993). A new phytosaur (Reptilia: Archosauria) genus from the uppermost Triassic of the western United States and its biochronological significance. In Lucas, S. G. and Morales, M., editors, *The Nonmarine Triassic*, volume 3 of *New Mexico Museum of Natural History Bulletin*, pages 193–196. New Mexico Museum of Natural History.

Hurlburt, G. (1999). Comparison of body mass estimation techniques, using recent reptiles and the pelycosaur *Edaphosaurus boanerges*. *Journal of Vertebrate Paleontology*, 19(2):338–350.

Hurum, J. H., Roberts, A. J., Nakrem, H. A., Stenløkk, J. A., and Mørk, A. (2014). The first recovered ichthyosaur from the Middle Triassic of Edgeøya, Svalbard. *Norwegian Petroleum Directorate Bulletin*, 11:97–110.

Husson, F., Josse, J., Lê, S., and Mazet, J. (2018). *Package 'FactoMineR': multivariate exploratory data analysis and data mining*, 1.41 edition. 97 pp.

Hutchinson, M. N., Skinner, A., and Lee, M. S. Y. (2012). *Tikiguania* and the antiquity of squamate reptiles (lizards and snakes). *Biology Letters*, 8(4):665–669.

Huttenlocker, A. K. (2013). *The paleobiology of South African therocephalian therapsids (Amniota, Synapsida) and the effects of the end-Permian extinction on size, growth, and bone microstructure*. PhD thesis, University of Washington, Washington. 414 pp.

Huttenlocker, A. K. (2014). Body size reductions in nonmammalian eutheriodont therapsids (Synapsida) during the end-Permian mass extinction. *PLoS ONE*, 9(2):e87553.

Huttenlocker, A. K. and Sidor, C. A. (2012). Taxonomic revision of therocephalians (Therapsida: Theriodontia) from the Lower Triassic of Antarctica. *American Museum Novitates*, 3738:1–19.

Huttenlocker, A. K. and Abdala, F. (2015). Revision of the first therocephalian, *Theriognathus* Owen (Therapsida: Whaitsiidae), and implications for cranial ontogeny and allometry in nonmammaliaform eutheriodonts. *Journal of Paleontology*, 89(4):645–664.

Huttenlocker, A. K. and Sidor, C. A. (2016). The first karenitid (Therapsida, Therocephalia) from the upper Permian of Gondwana and the biogeography of Permo-Triassic therocephalians. *Journal of Vertebrate Paleontology*, 36(4):e1111897.

Huttenlocker, A. K. and Smith, R. M. H. (2017). New whaitsioids (Therapsida: Therocephalia) from the Teekloof Formation of South Africa and therocephalian diversity during the end-Guadalupian extinction. *PeerJ*, 5:e3868.

Huttenlocker, A. K., Pardo, J. D., and Small, B. J. (2007). *Plemmyradytes shintoni*, gen. et sp. nov., an Early Permian amphibamid (Temnospondyli: Dissorophoidea) from the Eskridge Formation, Nebraska. *Journal of Vertebrate Paleontology*, 27(2):316–328.

Huttenlocker, A. K., Sidor, C. A., and Smith, R. M. H. (2011a). A new specimen of *Promoschorhynchus* (Therapsida: Therocephalia: Akidnognathidae) from the Lower Triassic of South Africa and its implications for theriodont survivorship across the Permo-Triassic boundary. *Journal of Vertebrate Paleontology*, 31(2):405–421.

Huttenlocker, A. K., Mazierski, D., and Reisz, R. R. (2011b). Comparative osteohistology of hyperelongate neural spines in the Edaphosauridae (Amniota: Synapsida). *Palaeontology*, 54(3):573–590.

Huttenlocker, A. K., Pardo, J. D., Small, B. J., and Anderson, J. S. (2013). Cranial morphology of recumbirostrans (Lepospondyli) from the Permian of Kansas and Nebraska, and early morphological evolution inferred by micro-computed tomography. *Journal of Vertebrate Paleontology*, 33(3):540–552.

Huttenlocker, A. K., Sidor, C. A., and Angielczyk, K. D. (2015). A new eutherocephalian (Therapsida, Therocephalia) from the upper Permian Madumabisa Mudstone Formation (Luangwa Basin) of Zambia. *Journal of Vertebrate Paleontology*, 35(5):e969400.

Huttenlocker, A. K., Henrici, A., John Nelson, W., Elrick, S., Berman, D. S., Schlotterbeck, T., and Sumida, S. S. (2018a). A multitaxic bonebed near the Carboniferous-Permian boundary (Halgaito Formation, Cutler Group) in Valley of the Gods, Utah, USA: vertebrate paleontology and taphonomy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 499:72–92.

Huttenlocker, A. K., Grossnickle, D. M., Kirkland, J. I., Schultz, J. A., and Luo, Z.-X. (2018b). Late-surviving stem mammal links the lowermost Cretaceous of North America and Gondwana. *Nature*, 558(7708):108–112.

Huttenlocker, A. (2009). An investigation into the cladistic relationships and monophyly of therocephalian therapsids (Amniota: Synapsida). *Zoological Journal of the Linnean Society*, 157(4):865–891.

Ibrahim, N., Sereno, P. C., Dal Sasso, C., Maganuco, S., Fabbri, M., Martill, D. M., Zouhri, S., Myhrvold, N., and Iurino, D. A. (2014). Semiaquatic adaptations in a giant predatory dinosaur. *Science*, 345(6204):1613–1616.

Ingavat, R. and Janvier, P. (1981). *Cyclotosaurus* cf. *posthumus* Fraas (Capitosauridae, Stereospondyli) from the Huai Hin Lat Formation (Upper Triassic), Northeastern Thailand. *Geobios*, 14(6):711–725.

Ingram, T. and Mahler, D. (2013). SURFACE: detecting convergent evolution from comparative data by fitting Ornstein-Uhlenbeck models with stepwise Akaike Information Criterion. *Methods in Ecology and Evolution*, 4(5):416–425.

International Commission on Stratigraphy (ICS) (2017). International Chronostratigraphic Chart.

International Commission on Zoological Nomenclature (ICZN) (1999). *International Code of Zoological Nomenclature*. International Trust for Zoological Nomenclature, London, 4th edition.

Irmis, R. B. (2004). First report of *Megapnosaurus* (Theropoda: Coelophysoidea) from China. *PaleoBios*, 24(3):11–18.

Irmis, R. B. (2005a). A review of the vertebrate fauna of the Lower Jurassic Navajo Sandstone in Arizona. In McCord, R. D., editor, *Vertebrate Paleontology of Arizona*, number 11 in Mesa Southwest Museum Bulletin, pages 55–71. Mesa Southwest Museum.

Irmis, R. B. (2005b). The vertebrate fauna of the Upper Triassic Chinle Formation in Northern Arizona. In Nesbitt, S. J., Parker, W. G., and Irmis, R. B., editors, *Guidebook to the Triassic Formations of the Colorado Plateau in northern Arizona: Geology, Paleontology, and History*, number 9 in Mesa Southwest Museum Bulletin, pages 63–88. Mesa Southwest Museum.

Irmis, R. B. (2011). Evaluating hypotheses for the early diversification of dinosaurs. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):397–426.

Irmis, R. B. and Knoll, F. (2008). New ornithischian dinosaur material from the Lower Jurassic Lufeng Formation of China. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 247(1):117–128.

Irmis, R. B. and Whiteside, J. H. (2012). Delayed recovery of non-marine tetrapods after the end-Permian mass extinction tracks global carbon cycle. *Proceedings of the Royal Society B: Biological Sciences*, 279(1732):1310–1318.

Irmis, R. B., Nesbitt, S. J., Padian, K., Smith, N. D., Turner, A. H., Woody, D., and Downs, A. (2007a). A Late Triassic dinosauromorph assemblage from New Mexico and the rise of dinosaurs. *Science*, 317(5836):358–361.

Irmis, R. B., Parker, W. G., Nesbitt, S. J., and Liu, J. (2007b). Early ornithischian dinosaurs: the Triassic record. *Historical Biology*, 19(1):3–22.

Irmis, R. B., Nesbitt, S. J., and Sues, H.-D. (2013a). Early Crocodylomorpha. *Geological Society, London, Special Publications*, 379(1):275–302.

Irmis, R. B., Whiteside, J. H., and Kammerer, C. F. (2013b). Non-biotic controls of observed diversity in the paleontologic record: an example from the Permo-Triassic Karoo Basin of South Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 372:62–77.

Ivakhnenko, M. F. (1979). [Permian and Triassic procolophonians of the Russian Platform]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 164:1–80. [In Russian].

Ivakhnenko, M. F. (1987). [The Permian parareptiles of the USSR]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 223:1–160. [In Russian].

Ivakhnenko, M. F. (1990). Elements of the Early Permian tetrapod faunal asemblages of Eastern Europe. *Paleontological Journal*, 24(2):104–112.

Ivakhnenko, M. F. (1995). Primitive Late Permian dinocephalian-titanosuchids of Eastern Europe. *Paleontological Journal*, 29(3):120–129.

Ivakhnenko, M. F. (1996a). New primitive therapsids from the Permian of Eastern Europe. *Paleontological Journal*, 30(3):337–343.

Ivakhnenko, M. F. (1996b). Primitive anomodonts, venyukoviids, from the Late Permian of Eastern Europe. *Paleontological Journal*, 30(5):575–582.

Ivakhnenko, M. F. (1997a). Classis Parareptilia. In Ivakhnenko, M. F., Golubev, V. K., Gubin, Y. M., Kalandadze, N. N., Novikov, I. V., Sennikov, A. G., and Rautian, A. S., editors, *Permian and Triassic tetrapods of Eastern Europe*, pages 14–20. GEOS, Moscow. [In Russian].

Ivakhnenko, M. F. (1997b). New Late Permian nycteroleterids from Eastern Europe. *Paleontological Journal*, 31(5):552–558.

Ivakhnenko, M. F. (1999). Biarmosuches from the Ocher faunal assemblage of eastern Europe. *Paleontological Journal*, 33(3):289–296.

Ivakhnenko, M. F. (2000). Estemmenosuches and primitive theriodonts from the Late Permian. *Paleontological Journal*, 34(2):189–197.

Ivakhnenko, M. F. (2001). [Tetrapods of the East European Placket - Late Paleozoic natural territorial complex]. *Trudy Paleontologicheskogo Instituta RAN*, 283:1–200. [In Russian].

Ivakhnenko, M. F. (2003). Eotherapsids from the East European Placket (Late Permian). *Paleontological Journal*, 37(Supplement 4):S339–S465.

Ivakhnenko, M. F. (2008a). Cranial morphology and evolution of Permian Dinomorpha (Eotherapsida) of Eastern Europe. *Paleontological Journal*, 42(9):859–995.

Ivakhnenko, M. F. (2008b). [Subclass Parareptilia]. In Ivakhnenko, M. F. and Kurochkin, E. N., editors, *[Fossil vertebrates of Russia and adjacent countries: Fossil Reptiles and Birds. Part 1]*, pages 49–85. GEOS, Moscow. [In Russian].

Ivakhnenko, M. F. (2008c). [Subclass Theromorpha]. In Ivakhnenko, M. F. and Kurochkin, E. N., editors, *[Fossil vertebrates of Russia and adjacent countries: Fossil Reptiles and Birds. Part 1]*, pages 101–183. GEOS, Moscow. [In Russian].

Ivakhnenko, M. F. (2008d). The first whaitsiid (Therocephalia, Theromorpha) from the terminal Permian of eastern Europe. *Paleontological Journal*, 42(4):409–413.

Ivakhnenko, M. F. (2011). Permian and Triassic therocephals (Eutherapsida) of Eastern Europe. *Paleontological Journal*, 45(9):981–1144.

Ivakhnenko, M. F. (2012). Permian Cynodontia (Theromorpha) of Eastern Europe. *Paleontological Journal*, 46(2):199–207.

Ivakhnenko, M. F. (2015). Patterns of changes in theromorph taxa of Permian terrestrial communities of Eastern Europe. *Paleontological Journal*, 49(1):70–78.

Ivakhnenko, M. F., Golubev, V. K., and Kalandadze, N. N. (1997). List of main sites: Upper Permian. In Ivakhnenko, M. F., Golubev, V. K., Gubin, Y. M., Kalandadze, N. N., Novikov, I. V., Sennikov, A. G., and Rautian, A. S., editors, *Permian and Triassic tetrapods of Eastern Europe*, pages 54–79. GEOS, Moscow. [In Russian].

Ivie, M. A., Slipinski, S. A., and Wegrzynowicz, P. (2001). Generic homonyms in the Colydiinae (Coleoptera: Zopheridae). *Insecta Mundi*, 15(1):63–64.

Jacobs, L. L., Winkler, D. A., Newman, K. D., Gomani, E. M., and Deino, A. (2005). Therapsids from the Permian Chiweta Beds and the age of the Karoo Supergroup in Malawi. *Palaeontologia Electronica*, 8(1.28A):1–23.

Jaekel, O. (1904). Über ein neues Reptil aus dem Buntsandstein der Eifel. *Zeitschrift der Deutschen Geologischen Gesellschaft*, 56:90–94.

Jaekel, O. (1909). Über die Klassen der Tetrapoden. *Zoologischer Anzeiger*, 34(7–8):193–212.

Jalil, N.-E. (1997). A new prolacertiform diapsid from the Triassic of North Africa and the interrelationships of the Prolacertiformes. *Journal of Vertebrate Paleontology*, 17(3):506–525.

Jalil, N.-E. and Dutuit, J.-M. (1996). Permian captorhinid reptiles from the Argana Formation, Morocco. *Palaeontology*, 39(4):907–918.

Jansen, M., Reisz, R. R., Kammerer, C. F., and Fröbisch, J. (2013). 3D reconstruction of a basal therapsid skull – combining modern and conventional methods for 3D retro-deformation. In Reitner, J., Yang, Q., Wang, Y., and Reich, M., editors, *Palaeobiology and geobiology of fossil Lagerstätten through Earth history – A joint conference of the "Paläontologische Gesellschaft" and the "Palaeontological Society of China"*, volume Abstract Volume, pages 77–78. Universitätsverlag Göttingen, Göttingen.

Jeannot, A. M., Damiani, R., and Rubidge, B. S. (2006). Cranial anatomy of the Early Triassic stereospondyl *Lydekkerina huxleyi* (Tetrapoda: Temnospondyli) and the taxonomy of South African lydekkerinids. *Journal of Vertebrate Paleontology*, 26(4):822–838.

Jenkins, Jr., F. A., Crompton, A. W., and Downs, W. R. (1983). Mesozoic mammals from Arizona: new evidence on mammalian evolution. *Science*, 222(4629):1233–1235.

Jenkins, Jr., F. A., Shubin, N. H., Amaral, W. W., Gatesy, S. M., Schaff, C. R., Clemmensen, L. B., Downs, W. R., Davidson, A. R., Bonde, N., and Osbæck, F. (1994). Late Triassic continental vertebrates and depositional environments of the Fleming Fjord Formation, Jameson Land, East Greenland. *Meddelelser om Grønland, Geoscience*, 32:3–25.

Jetz, W., Carbone, C., Fulford, J., and Brown, J. H. (2004). The scaling of animal space use. *Science*, 306(5694):266–268.

Jetz, W., Thomas, G. H., Joy, J. B., Hartmann, K., and Mooers, A. O. (2012). The global diversity of birds in space and time. *Nature*, 491(7424):444–448.

Ji, C., Jiang, D.-Y., Motani, R., Hao, W.-C., Sun, Z.-Y., and Cai, T. (2013). A new juvenile specimen of *Guanlingsaurus* (Ichthyosauria, Shastasauridae) from the Upper Triassic of southwestern China. *Journal of Vertebrate Paleontology*, 33(2):340–348.

Ji, C., Jiang, D.-Y., Motani, R., Rieppel, O., Hao, W.-C., and Sun, Z.-Y. (2016). Phylogeny of the Ichthyopterygia incorporating recent discoveries from South China. *Journal of Vertebrate Paleontology*, 36(1):e1025956.

Jiang, D.-Y., Schmitz, L., Hao, W.-C., and Sun, Y.-L. (2006). A new mixosaurid ichthyosaur from the Middle Triassic of China. *Journal of Vertebrate Paleontology*, 26(1):60–69.

Jiang, D.-Y., Motani, R., Huang, J.-D., Tintori, A., Hu, Y.-C., Rieppel, O., Fraser, N. C., Ji, C., Kelley, N. P., Fu, W.-L., and Zhang, R. (2016). A large aberrant stem ichthyosauriform indicating early rise and demise of ichthyosauromorphs in the wake of the end-Permian extinction. *Scientific Reports*, 6:26232.

Jiang, S. and Ji, S.-a. (2014). New specimens of *Stenocybus acidentatus* (Therapsida: Dinocephalia) from the Middle Permian Dashankou Fauna of China. *Acta Geologica Sinica - English Edition*, 88(3):730–737.

Jiang, S., Ji, S.-a., and Mo, J. (2017). First record of bystrowianid chroniosuchians (Amphibia: Anthracosauromorpha) from the Middle Permian of China. *Acta Geologica Sinica (English Edition)*, 91(5):1523–1529.

Jinnah, Z. A. and Rubidge, B. (2007). A double-tusked dicynodont and its biostratigraphic significance. *South African Journal of Science*, 103(1–2):51–53.

Jirah, S. and Rubidge, B. S. (2014). Refined stratigraphy of the Middle Permian Abrahamskraal Formation (Beaufort Group) in the southern Karoo Basin. *Journal of African Earth Sciences*, 100:121–135.

Johnson, M. M., Young, M. T., Steel, L., Foffa, D., Smith, A. S., Hua, S., Havlik, P., Howlett, E. A., and Dyke, G. (2018). Re-description of '*Steneosaurus*' *obtusidens* Andrews, 1909, an unusual macrophagous teleosaurid crocodylomorph from the Middle Jurassic of England. *Zoological Journal of the Linnean Society*, 182(2):385–418.

Jones, M. E. H. (2006). The Early Jurassic clevosaurs from China (Diapsida: Lepidosauria). In Harris, J. D., Lucas, S. G., Spielmann, J. A., Lockley, M. G., Milner, A. R. C., and Kirkland, J. I., editors, *The Triassic-Jurassic Terrestrial Transition*, volume 37, pages 548–562. New Mexico Museum of Natural History.

Jones, M. E. H., Anderson, C. L., Hipsley, C. A., Müller, J., Evans, S. E., and Schoch, R. R. (2013). Integration of molecules and new fossils supports a Triassic origin for Lepidosauria (lizards, snakes, and tuatara). *BMC Evolutionary Biology*, 13:208.

Jones, M. E., O'Higgins, P., Fagan, M. J., Evans, S. E., and Curtis, N. (2012). Shearing mechanics and the influence of a flexible symphysis during oral food processing in *Sphenodon* (Lepidosauria: Rhynchocephalia). *The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology*, 295(7):1075–1091.

Joyce, W. G. (2007). Phylogenetic relationships of Mesozoic turtles. *Bulletin of the Peabody Museum of Natural History*, 48(1):3–102.

Joyce, W. G. (2015). The origin of turtles: A paleontological perspective. *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution*, 324(3):181–193.

Joyce, W. G. (2017). A review of the fossil record of basal Mesozoic turtles. *Bulletin of the Peabody Museum of Natural History*, 58(1):65–113.

Joyce, W., Schoch, R., and Lyson, T. (2013). The girdles of the oldest fossil turtle, *Proterochersis robusta*, and the age of the turtle crown. *BMC Evolutionary Biology*, 13:266.

Jung, J. P. (2018). Redescription and phylogenetic analysis of the materials assigned to the taxon "*Captorhinikos*" *chozaensis*. Master's thesis, California State University San Bernadino, San Bernardino. 79 pp.

Jurcsák, T. (1975). *Tanystropheus biharicus* n. sp. (Reptilia, Squamata), o nouă specie pentru fauna Triasică a României. *Nymphaea*, 3:45–52.

Juul, L. (1994). The phylogeny of basal archosaurs. *Palaeontologia africana*, 31:1–38.

Kammerer, C. F. (2009). *Cranial disparity in the non-mammalian Synapsida*. PhD thesis, University of Chicago, Chicago. 633 pp.

Kammerer, C. F. (2011). Systematics of the Anteosauria (Therapsida: Dinocephalia). *Journal of Systematic Palaeontology*, 9(2):261–304.

Kammerer, C. F. (2014a). A Redescription of *Eriphostoma microdon* Broom, 1911 (Therapsida, Gorgonopsia) from the Tapinocephalus Assemblage Zone of South Africa and a Review of Middle Permian Gorgonopsians. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 11, pages 171–184. Springer, Dordrecht.

Kammerer, C. F. (2014b). Theriodontia: Introduction. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 10, pages 165–169. Springer, Dordrecht.

Kammerer, C. F. (2015). Cranial osteology of *Arctognathus curvimola*, a short-snouted gorgonopsian from the Late Permian of South Africa. *Papers in Palaeontology*, 1(1):41–58.

Kammerer, C. F. (2016a). A new taxon of cynodont from the *Tropidostoma* Assemblage Zone (upper Permian) of South Africa, and the early evolution of Cynodontia. *Papers in Palaeontology*, 2(3):387–397.

Kammerer, C. F. (2016b). Systematics of the Rubidgeinae (Therapsida: Gorgonopsia). *PeerJ*, 4:e1608.

Kammerer, C. F. (2016c). Two unrecognized burnetiamorph specimens from historical Karoo collections. *Palaeontologia africana*, 50:64–75.

Kammerer, C. F. (2017). Anatomy and relationships of the South African gorgonopsian *Arctops* (Therapsida, Theriodontia). *Papers in Palaeontology*, 3(4):583–611.

Kammerer, C. F. (2018). The first skeletal evidence of a dicynodont from the lower Elliot Formation of South Africa. *Palaeontologia africana*, 52:102–128.

Kammerer, C. F. and Sidor, C. A. (2002). Replacement names for the therapsid genera *Criocephalus* Broom 1928 and *Olivieria* Brink 1965. *Palaeontologia africana*, 38:71–72.

Kammerer, C. F. and Angielczyk, K. D. (2009). A proposed higher taxonomy of anomodont therapsids. *Zootaxa*, 2018:1–24.

Kammerer, C. F. and Abdala, F. (2009). Case 3431: *Procynosuchus* Broom, 1937 (Therapsida, Cynodontia): proposed precedence over *Cyrbasiodon* Broom, 1931 and *Parathrinaxodon* Parrington, 1936. *Bulletin of Zoological Nomenclature*, 66(1):64–69.

Kammerer, C. F. and Smith, R. M. (2017). An early geikiid dicynodont from the *Tropidostoma* Assemblage Zone (late Permian) of South Africa. *PeerJ*, 5:e2913.

Kammerer, C. F. and Masyutin, V. (2018a). A new therocephalian (*Gorynychus masyutinae* gen. et sp. nov.) from the Permian Kotelnich locality, Kirov Region, Russia. *PeerJ*, 6:e4933.

Kammerer, C. F. and Masyutin, V. (2018b). Gorgonopsian therapsids (*Nochnitsa* gen. nov. and *Viatkogorgon*) from the Permian Kotelnich locality of Russia. *PeerJ*, 6:e4954.

Kammerer, C. F., Flynn, J. J., Ranivoharimanana, L., and Wyss, A. R. (2010). The first record of a probainognathian (Cynodontia: Chiniquodontidae) from the Triassic of Madagascar. *Journal of Vertebrate Paleontology*, 30(6):1889–1894.

Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J. (2011). A comprehensive taxonomic revision of *Dicynodon* (Therapsida, Anomodontia) and its implications for dicynodont phylogeny, biogeography, and biostratigraphy. *Journal of Vertebrate Paleontology*, 31(6, Supplement):1–158.

Kammerer, C. F., Fröbisch, J., Angielczyk, K. D., and Smith, R. M. (2012). Permian origins of the post-extinction therapsid recovery fauna. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 32(sup2):118–119.

Kammerer, C. F., Fröbisch, J., and Angielczyk, K. D. (2013). On the validity and phylogenetic position of *Eubrachiosaurus browni*, a kannemeyeriiform dicynodont (Anomodontia) from Triassic North America. *PLoS ONE*, 8(5):e64203.

Kammerer, C. F., Smith, R. M. H., Day, M. O., and Rubidge, B. S. (2015a). New information on the morphology and stratigraphic range of the mid-Permian gorgonopsian *Eriphostoma microdon* Broom, 1911. *Papers in Palaeontology*, 1(2):201–221.

Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J. (2015b). Redescription of *Digalodon rubidgei*, an emydopoid dicynodont (Therapsida, Anomodontia) from the Late Permian of South Africa. *Fossil Record*, 18(1):43–55.

Kammerer, C. F., Bandyopadhyay, S., and Ray, S. (2016a). A new taxon of cistecephalid dicynodont from the upper Permian Kundaram Formation of India. *Papers in Palaeontology*, 2(4):569–584.

Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J. (2016b). Redescription of the geikiid *Pelanomodon* (Therapsida, Dicynodontia), with a reconsideration of '*Propelanomodon*'. *Journal of Vertebrate Paleontology*, 36(1):e1030408.

Kammerer, C. F., Butler, R. J., Bandyopadhyay, S., and Stocker, M. R. (2016c). Relationships of the Indian phytosaur *Parasuchus hislopi* Lydekker, 1885. *Papers in Palaeontology*, 2(1):1–23.

Kammerer, C. F., Angielczyk, K. D., and Nesbitt, S. J. (2018). Novel hind limb morphology in a kannemeyeriiform dicynodont from the Manda Beds (Songea Group, Ruhuhu Basin) of Tanzania. *Journal of Vertebrate Paleontology*, 37(6, Supplement):178–188.

Kammerer, C. (2008). A new therocephalian from the *Cistecephalus* Assemblage Zone of South Africa and new information on therocephalian systematics. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 28(sup3):98A–99A.

Kamphausen, D. (1989). Der Schädel von *Eocyclotosaurus woschmidti* Ortlam (Amphibia, Stegocephalia) aus dem Oberen Buntsandstein (Trias) des Schwarzwaldes (SW-Deutschland). *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 149:1–65.

Karl, H.-V., Gröning, E., and Brauckmann, C. (2007). The Mesosauria in the collections of Göttingen and Clausthal: implications for a modified classification. *Clausthaler Geowissenschaften*, 6:63–78.

Karl, H.-V., Arp, G., Siedersbeck, E., and Reitner, J. (2014). A large ichthyosaur vertebra from the lower Kössen Formation (Upper Norian) of the Lahnewiesgraben near Garmisch-Partenkirchen, Germany. In Wiese, F., Reich, M., and Arp, G., editors, *"Spongy, slimy, cosy & more". Commemorative Volume in Celebration of the 60th Birthday of Joachim Reitner*, volume 77 of *Göttingen Contributions to Geosciences*, pages 191–197. Universitätsverlag Göttingen, Göttingen.

Kear, B. P., Poropat, S. F., and Bazzi, M. (2016). Late Triassic capitosaurian remains from Svalbard and the palaeobiogeographical context of Scandinavian Arctic temnospondyls. *Geological Society, London, Special Publications*, 434:113–126.

Keeble, E., Whiteside, D. I., and Benton, M. J. (2018). The terrestrial fauna of the Late Triassic Pant-y-ffynnon Quarry fissures, South Wales, UK and a new species of *Clevosaurus* (Lepidosauria: Rhynchocephalia). *Proceedings of the Geologists' Association*, 129(2):99–119.

Kelley, N. P. and Pyenson, N. D. (2015). Evolutionary innovation and ecology in marine tetrapods from the Triassic to the Anthropocene. *Science*, 348(6232):aaa3716.

Kelley, N. P., Motani, R., Jiang, D.-y., Rieppel, O., and Schmitz, L. (2014). Selective extinction of Triassic marine reptiles during long-term sea-level changes illuminated by seawater strontium isotopes. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 400:9–16.

Kelley, N. P., Motani, R., Embree, P., and Orchard, M. J. (2016). A new Lower Triassic ichthyopterygian assemblage from Fossil Hill, Nevada. *PeerJ*, 4:e1626.

Kellner, A. W. A. (2015). Comments on Triassic pterosaurs with discussion about ontogeny and description of new taxa. *Anais da Academia Brasileira de Ciências*, 87(2):669–689.

Kemp, T. S. (2005). *The Origin & Evolution of Mammals*. Oxford University Press, Oxford. 331 pp.

Kemp, T. S. (2006). The origin and early radiation of the therapsid mammal-like reptiles: a palaeobiological hypothesis. *Journal of Evolutionary Biology*, 19(4):1231–1247.

Kennedy, N. K. (2010). Redescription of the postcranial skeleton of *Limnoscelis paludis* Williston (Diadectomorpha: Limnoscelidae) from the Upper Pennsylvanian of El Cobre Canyon, northern New Mexico. In Lucas, S. G., Schneider, J. W., and Spielmann, J. A., editors, *Carboniferous-Permian transition in Cañon del Cobre, northern New Mexico*, volume 49, pages 211–220. New Mexico Museum of Natural History.

Kent, D. V., Santi Malnis, P., Colombi, C. E., Alcober, O. A., and Martínez, R. N. (2014). Age constraints on the dispersal of dinosaurs in the Late Triassic from magnetochronology of the Los Colorados Formation (Argentina). *Proceedings of the National Academy of Sciences*, 111(22):7958–7963.

Ketchum, H. F. and Barrett, P. M. (2004). New reptile material from the Lower Triassic of Madagascar: implications for the Permian-Triassic extinction event. *Canadian Journal of Earth Sciences*, 41(1):1–8.

Ketchum, H. F. and Benson, R. B. J. (2010). Global interrelationships of Plesiosauria (Reptilia, Sauropterygia) and the pivotal role of taxon sampling in determining the outcome of phylogenetic analyses. *Biological Reviews*, 85(2):361–392.

Keyser, A. W. (1973a). A new Triassic vertebrate fauna from South West Africa. *Palaeontologia africana*, 16:1–15.

Keyser, A. W. (1973b). A re-evaluation of the genus *Tropidostoma* Seeley. *Palaeontologia africana*, 16:25–35.

Keyser, A. W. and Cruickshank, A. R. I. (1979). The origins and classification of Triassic dicynodonts. *Transactions of the Geological Society of South Africa*, 82(1):81–108.

Khabbazian, M., Kriebel, R., Rohe, K., and Ané, C. (2016). Fast and accurate detection of evolutionary shifts in Ornstein-Uhlenbeck models. *Methods in Ecology and Evolution*, 7(7):811–824.

Kielan-Jaworowska, Z., Cifelli, R. L., and Luo, Z.-X. (2004). *Mammals from the Age of Dinosaurs: Origins, Evolution, and Structure*. Columbia University Press, New York. 700 pp.

King, G. M. (1981). The functional anatomy of a Permian dicynodont. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 291(1050):243–322.

King, G. M. (1988). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 17C: Anomodontia*. Verlag Dr. Friedrich Pfeil, München. 174 pp.

King, G. M. and Rubidge, B. S. (1993). A taxonomic revision of small dicynodonts with postcanine teeth. *Zoological Journal of the Linnean Society*, 107(2):131–154.

Kissel, R. A. and Reisz, R. R. (2004). *Ambedus pusillus*, new genus, new species, a small diadectid (Tetrapoda: Diadectomorpha) from the Lower Permian of Ohio, with a consideration of diadectomorph phylogeny. *Annals of Carnegie Museum*, 73(4):197–212.

Kissel, R. A., Dilkes, D. W., and Reisz, R. R. (2002). *Captorhinus magnus*, a new captorhinid (Amniota: Eureptilia) from the Lower Permian of Oklahoma, with new evidence on the homology of the astragalus. *Canadian Journal of Earth Sciences*, 39(9):1363–1372.

Kissel, R. (2010). *Morphology, Phylogeny, and Evolution of Diadectidae (Cotylosauria: Diadectomorpha)*. PhD thesis, Graduate Department of Ecology & Evolutionary Biology, University of Toronto, Toronto, Canada. 185 pp.

Kitching, J. W. and Raath, M. A. (1984). Fossils from the Elliot and Clarens Formations (Karoo sequence) of the Northeastern Cape, Orange Free State and Lesotho, and a suggested biozonation based on tetrapods. *Palaeontologia africana*, 25:111–125.

Kleiber, M. (1947). Body size and metabolic rate. *Physiological Reviews*, 27(4):511–541.

Klein, N. (2012). Postcranial morphology and growth of the pachypleurosaur *Anarosaurus heterodontus* (Sauropterygia) from the Lower Muschelkalk of Winterswijk, The Netherlands. *Paläontologische Zeitschrift*, 86(4):389–408.

Klein, N. and Albers, P. C. (2009). A new species of the sauropsid reptile *Nothosaurus* from the Lower Muschelkalk of the Western Germanic Basin, Winterswijk, the Netherlands. *Acta Palaeontologica Polonica*, 54(4):589–598.

Klein, N. and Hagdorn, H. (2014). Humerus morphology and histology of a new marine reptile (Diapsida) from the Muschelkalk-Keuper-Grenzbonebed (Middle Triassic, Ladinian) of Southwest Germany. *Palaeodiversity*, 7:23–38.

Klein, N., Voeten, D. F., Lankamp, J., Bleeker, R., Sichelschmidt, O. J., Liebrand, M., Nieweg, D. C., and Sander, P. M. (2015). Postcranial material of *Nothosaurus marchicus* from the Lower Muschelkalk (Anisian) of Winterswijk, The Netherlands, with remarks on swimming styles and taphonomy. *Paläontologische Zeitschrift*, 89(4):961–981.

Klein, N., Sander, P. M., Krahl, A., Scheyer, T. M., and Houssaye, A. (2016a). Diverse aquatic adaptations in *Nothosaurus* spp. (Sauropterygia)–inferences from humeral histology and microanatomy. *PLoS ONE*, 11(7):e0158448.

Klein, N., Voeten, D. F. A. E., Haarhuis, A., and Bleeker, R. (2016b). The earliest record of the genus *Lariosaurus* from the early middle Anisian (Middle Triassic) of the Germanic Basin. *Journal of Vertebrate Paleontology*, 36(4):e1163712.

Klembara, J. (1985). A new embolomerous amphibian (Anthracosauria) from the Upper Carboniferous of Florence, Nova Scotia. *Journal of Vertebrate Paleontology*, 5(4):293–302.

Klembara, J. (1997). The cranial anatomy of *Discosauriscus* Kuhn, a seymouriamorph tetrapod from the Lower Permian of the Boskovice Furrow (Czech Republic). *Philosophical Transactions of the Royal Society B: Biological Sciences*, 352(1351):257–302.

Klembara, J. (2005). A new discosauriscid seymouriamorph tetrapod from the Lower Permian of Moravia, Czech Republic. *Acta Palaeontologica Polonica*, 50(1):25–48.

Klembara, J. (2011). The cranial anatomy, ontogeny, and relationships of *Karpinskiosaurus secundus* (Amalitzky) (Seymouriamorpha, Karpinskiosauridae) from the Upper Permian of European Russia. *Zoological Journal of the Linnean Society*, 161(1):184–212.

Klembara, J. and Ruta, M. (2004a). The seymouriamorph tetrapod *Utegenia shpinari* from the ?Upper Carboniferous–Lower Permian of Kazakhstan. Part I: cranial anatomy and ontogeny. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 94(1):45–74.

Klembara, J. and Ruta, M. (2004b). The seymouriamorph tetrapod *Utegenia shpinari* from the ?Upper Carboniferous–Lower Permian of Kazakhstan. Part II: postcranial anatomy and relationships. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 94(1):75–93.

Klembara, J. and Ruta, M. (2005). The seymouriamorph tetrapod *Ariekanerpeton sigalovi* from the Lower Permian of Tadzhikistan. Part I: Cranial anatomy and ontogeny. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 96(1):43–70.

Klembara, J. and Steyer, J. S. (2012). A new species of *Sclerocephalus* (Temnospondyli: Stereospondylomorpha) from the Early Permian of the Boskovice Basin (Czech Republic). *Journal of Paleontology*, 86(2):302–310.

Klembara, J., Clack, J. A., Milner, A. R., and Ruta, M. (2014). Cranial anatomy, ontogeny, and relationships of the Late Carboniferous tetrapod *Gephyrostegus bohemicus* Jaekel, 1902. *Journal of Vertebrate Paleontology*, 34(4):774–792.

Kligman, B., Marsh, A., and Parker, W. (2018). First records of diapsid *Palacrodon* from the Norian, Late Triassic Chinle Formation of Arizona, and their biogeographic implications. *Acta Palaeontologica Polonica*, 63(1):117–127.

Knoll, F. (2005). The tetrapod fauna of the Upper Elliot and Clarens formations in the main Karoo Basin (South Africa and Lesotho). *Bulletin de la Société Géologique de France*, 176(1):81–91.

Knoll, F. and Rohrberg, K. (2012). CT scanning, rapid prototyping and re-examination of a partial skull of a basal crocodylomorph from the Late Triassic of Germany. *Swiss Journal of Geosciences*, 105(1):109–115.

Knoll, F., Padian, K., and de Ricqlès, A. (2010). Ontogenetic change and adult body size of the early ornithischian dinosaur *Lesothosaurus diagnosticus*: Implications for basal ornithischian taxonomy. *Gondwana Research*, 17(1):171–179.

Knutsen, E. M. (2012). A taxonomic revision of the genus *Pliosaurus* (Owen, 1841a) Owen, 1841b. *Norwegian Journal of Geology*, 92(2–3):259–276.

Koch, C. L. (1841). *Die Arachniden*, volume 8. C. H. Zeh'sche Buchhandlung, Nürnberg. 131 pp.

Kogan, I., Schönberger, K., Fischer, J., and Voigt, S. (2009). A nearly complete skeleton of *Saurichthys orientalis* (Pisces, Actinopterygii) from the Madygen Formation (Middle to Late Triassic, Kyrgyzstan, central Asia) – preliminary results. *Freiberger Forschungshefte C*, 532(17):139–152.

Krainer, K., Lucas, S. G., and Strasser, M. (2011). Vertebrate fossils from the northalpine Raibl Beds, western Northern Calcarous Alps, Tyrol (Austria). *Austrian Journal of Earth Sciences*, 104(1):97–106.

Krapovickas, V., Mancuso, A. C., Marsicano, C. A., Domnanovich, N. S., and Schultz, C. L. (2013). Large tetrapod burrows from the Middle Triassic of Argentina: a behavioural adaptation to seasonal semi-arid climate? *Lethaia*, 46(2):154–169.

Krause, A. J., Mills, B. J. W., Zhang, S., Planavsky, N. J., Lenton, T. M., and Poulton, S. W. (2018). Stepwise oxygenation of the Paleozoic atmosphere. *Nature Communications*, 9:4081.

Krebs, B. (1969). *Ctenosauriscus koeneni* (v. Huene), die Pseudosuchia und die Buntsandstein-Reptilien. *Eclogae Geologicae Helvetiae*, 62(2):697–714.

Kruger, A., Rubidge, B. S., Abdala, F., Chindebvu, E. G., and Jacobs, L. L. (2015). *Lende chiweta*, a new therapsid from Malawi, and its influence on burnetiamorph phylogeny and biogeography. *Journal of Vertebrate Paleontology*, 35(6):e1008698.

Kuhn, O. (1939). Beiträge zur Keuperfauna von Halberstadt. *Paläontologische Zeitschrift*, 21(4):258–286.

Kuhn, O. (1969a). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 6: Cotylosauria*. Verlag Dr. Friedrich Pfeil, München. 89 pp.

Kuhn, O. (1969b). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 9: Proganosauria, Bolosauria, Placodontia, Araeoscelidia, Trilophosauria, Weigeltisauria, Millerosauria, Rhynchocephalia, Protorosauria*. Verlag Dr. Friedrich Pfeil, München. 73 pp.

Kuhn, O. (1972). II. Seymourida, usw. In Carroll, R. L., Kuhn, O., and Tatarinov, L. P., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 5B: Batrachosauria (Anthracosauria) Gephyrostegida – Chroniosuchida*, pages 20–69. Verlag Dr. Friedrich Pfeil, München.

Kümmell, S. B. and Frey, E. (2012). Digital arcade in the autopodia of Synapsida: standard position of the digits and dorsoventral excursion angle of digital joints in the rays II–V. *Palaeobiodiversity and Palaeoenvironments*, 92(2):171–196.

Kümmell, S. B. and Frey, E. (2014). Range of movement in ray I of manus and pes and the prehensility of the autopodia in the Early Permian to Late Cretaceous non-anomodont Synapsida. *PLoS ONE*, 9(12):e113911.

Kurkin, A. A. (2017). A new galeopid (Anomodontia, Galeopidae) from the Permian of Eastern Europe. *Paleontological Journal*, 51(3):308–312.

Kurkin, A. (2011). Permian anomodonts: paleobiogeography and distribution of the group. *Paleontological Journal*, 45(4):432–444.

Kurkin, A. (2012). Dicynodontids of Eastern Europe. *Paleontological Journal*, 46(2):187–198.

Kusuhashi, N., Hu, Y., Wang, Y., Hirasawa, S., and Matsuoka, H. (2009). New triconodontids (Mammalia) from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. *Geobios*, 42(6):765–781.

Kutty, T. S. (1972). Permian reptilian fauna from India. *Nature*, 237(5356):462–463.

Kutty, T., Chatterjee, S., Galton, P. M., and Upchurch, P. (2007). Basal sauropodomorphs (Dinosauria: Saurischia) from the Lower Jurassic of India: their anatomy and relationships. *Journal of Paleontology*, 81(6):1218–1240.

Lacerda, M. B., Schultz, C. L., and Bertoni-Machado, C. (2015). First ‘rauisuchian’ archosaur (Pseudosuchia, Loricata) for the Middle Triassic *Santacruzodon* Assemblage Zone (Santa Maria Supersequence), Rio Grande do Sul State, Brazil. *PLoS ONE*, 10(2):e0118563.

Lacerda, M. B., Mastrantonio, B. M., Fortier, D. C., and Schultz, C. L. (2016). New insights on *Prestosuchus chiniquensis* Huene, 1942 (Pseudosuchia, Loricata) based on new specimens from the “Tree Sanga” outcrop, Chiniquá Region, Rio Grande do Sul, Brazil. *PeerJ*, 4:e1622.

Lacerda, M. B., de França, M. A. G., and Schultz, C. L. (2018). A new erpetosuchid (Pseudosuchia, Archosauria) from the Middle–Late Triassic of Southern Brazil. *Zoological Journal of the Linnean Society*, 184(3):804–824.

Landis, M. J. and Schraiber, J. G. (2017). Pulsed evolution shaped modern vertebrate body sizes. *Proceedings of the National Academy of Sciences*, 114(50):13224–13229.

Langer, M. C. (2004). Basal Saurischia. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 25–46. University of California Press, Berkeley, Second edition.

Langer, M. C. (2014). The origins of Dinosauria: much ado about nothing. *Palaeontology*, 57(3):469–478.

Langer, M. C., Ribeiro, A. M., Schultz, C. L., and Ferigolo, J. (2007). The continental tetrapod-bearing Triassic of South Brazil. In Lucas, S. G. and Spielmann, J. A., editors, *The Global Triassic*, volume 41, pages 201–218. New Mexico Museum of Natural History.

Langer, M. C., Ezcurra, M. D., Bittencourt, J. S., and Novas, F. E. (2010). The origin and early evolution of dinosaurs. *Biological Reviews*, 85(1):55–110.

Langer, M. C., Nesbitt, S. J., Bittencourt, J. S., and Irmis, R. B. (2013). Non-dinosaurian Dinosauromorpha. *Geological Society, London, Special Publications*, 379(1):157–186.

Langer, M. C., Rincón, A. D., Ramezani, J., Solórzano, A., and Rauhut, O. W. M. (2014). New dinosaur (Theropoda, stem-Averostra) from the earliest Jurassic of the La Quinta Formation, Venezuelan Andes. *Royal Society Open Science*, 1(2):140184.

Langer, M. C., da Rosa, Á. A. S., and Montefeltro, F. C. (2017a). *Supradapedon* revisited: geological explorations in the Triassic of southern Tanzania. *PeerJ*, 5:e4038.

Langer, M. C., Ezcurra, M. D., Rauhut, O. W. M., Benton, M. J., Knoll, F., McPhee, B. W., Novas, F. E., Pol, D., and Brusatte, S. L. (2017b). Untangling the dinosaur family tree. *Nature*, 551(7678):E1–E3.

Langer, M. C., Ramezani, J., and Da Rosa, Á. A. S. (2018). U-Pb age constraints on dinosaur rise from south Brazil. *Gondwana Research*, 57:133–140.

Langer, M., Boniface, M., Cuny, G., and Barbieri, L. (2000). The phylogenetic position of *Isalorhynchus genovefae*, a Late Triassic rhynchosaur from Madagascar. *Annales de Paléontologie*, 86(2):101–127.

Laurin, M. (1998). The importance of global parsimony and historical bias in understanding tetrapod evolution. Part I. Systematics, middle ear evolution and jaw suspension. *Annales des Sciences Naturelles - Zoologie et Biologie Animale*, 19(1):1–42.

Laurin, M. (2000). Seymouriamorphs. In Heatwole, H. and Carroll, R. L., editors, *Amphibian Biology: Volume 4 - Paleontology*, chapter 6, pages 1064–1080. Surrey Bearry Press, Chipping Norton.

Laurin, M. (2002). Tetrapod phylogeny, amphibian origins, and the definition of the name Tetrapoda. *Systematic Biology*, 51(2):364–369.

Laurin, M. (2004). The evolution of body size, Cope's rule and the origin of amniotes. *Systematic Biology*, 53(4):594–622.

Laurin, M. and Reisz, R. R. (1995). A reevaluation of early amniote phylogeny. *Zoological Journal of the Linnean Society*, 113(2):165–223.

Laurin, M. and Anderson, J. S. (2004). Meaning of the name Tetrapoda in the scientific literature: an exchange. *Systematic Biology*, 53(1):68–80.

Laurin, M. and Soler-Gijón, R. (2006). The oldest known stegocephalian (Sarcopterygii: Temnospondyli) from Spain. *Journal of Vertebrate Paleontology*, 26(2):284–299.

Laurin, M. and de Buffrénil, V. (2016). Microstructural features of the femur in early ophiacodontids: a reappraisal of ancestral habitat use and lifestyle of amniotes. *Comptes Rendus Palevol*, 15(1–2):115–127.

Laurin, M. and Piñeiro, G. H. (2017). A reassessment of the taxonomic position of mesosaurs, and a surprising phylogeny of early amniotes. *Frontiers in Earth Science*, 5:88.

Lautenschlager, S. and Desojo, J. B. (2011). Reassessment of the Middle Triassic rauisuchian archosaurs *Ticinosuchus ferox* and *Stagonosuchus nyassicus*. *Paläontologische Zeitschrift*, 85(4):357–381.

Lautenschlager, S. and Rauhut, O. W. M. (2015). Osteology of *Rauisuchus tiradentes* from the Late Triassic (Carnian) Santa Maria Formation of Brazil, and its implications for rauisuchid anatomy and phylogeny. *Zoological Journal of the Linnean Society*, 173(1):55–91.

Lê, S., Josse, J., and Husson, F. (2008). FactoMineR: an R package for multivariate analysis. *Journal of Statistical Software*, 25(1):1–18.

Leal, L. A., Azevedo, S. A. K., Kellner, A. W. A., and Da Rosa, Á. A. S. (2004). A new early dinosaur (Sauropodomorpha) from the Caturrita Formation (Late Triassic), Paraná Basin, Brazil. *Zootaxa*, 690(1):1–24.

Leardi, J. M., Pol, D., and Clark, J. M. (2017). Detailed anatomy of the braincase of *Macelognathus vagans* Marsh, 1884 (Archosauria, Crocodylomorpha) using high resolution tomography and new insights on basal crocodylomorph phylogeny. *PeerJ*, 5:e2801.

Lebedev, O. A. (2004). A new tetrapod *Jakubsonia livnensis* from the Early Famennian (Devonian) of Russia and palaeoecological remarks on the Late Devonian tetrapod habitats. *Acta Universitatis Latviensis, Series Earth and Environment Sciences*, 679:79–98.

Lebedev, O. A., Sennikov, A. G., Golubev, V. K., Krupina, N. I., Niedzwiedzki, G., and Sulej, T. (2015). The first find of Permian ceratodontids (Dipnoi, Osteichthyes) in Russia. *Paleontological Journal*, 49(10):1112–1124.

LeBlanc, A. R. H., Brar, A. K., May, W. J., and Reisz, R. R. (2015). Multiple tooth-rowed captorhinids from the Early Permian fissure fills of the Bally Mountain Locality of Oklahoma. *Vertebrate Anatomy Morphology Palaeontology*, 1(1):35–49.

Lecuona, A. (2013). *Anatomía y relaciones filogenéticas de Gracilisuchus stipanicicorum y sus implicancias en el origen de Crocodylomorpha*. PhD thesis, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires. 593 pp.

Lecuona, A., Ezcurra, M. D., and Irmis, R. B. (2016). Revision of the early crocodylomorph *Trialestes romeri* (Archosauria, Suchia) from the lower Upper Triassic Ischigualasto Formation of Argentina: one of the oldest-known crocodylomorphs. *Papers in Palaeontology*, 2(4):585–622.

Lee, M. S. Y. (1993). The origin of the turtle body plan: bridging a famous morphological gap. *Science*, 261(5129):1716–1720.

Lee, M. S. Y. (1994). *Evolutionary morphology of pareiasaurs*. PhD thesis, Queen's College, University of Cambridge, Cambridge, United Kingdom. 392 pp.

Lee, M. S. Y. (1995). Historical burden in systematics and the interrelationships of 'parareptiles'. *Biological Reviews*, 70(3):459–547.

Lee, M. S. Y. (1996). Correlated progression and the origin of turtles. *Nature*, 379(6568):812–815.

Lee, M. S. Y. (1997a). A taxonomic revision of pareiasaurian reptiles: implications for Permian terrestrial paleoecology. *Modern Geology*, 21:231–298.

Lee, M. S. Y. (1997b). Pareiasaur phylogeny and the origin of turtles. *Zoological Journal of the Linnean Society*, 120(3):197–280.

Lee, M. S. Y. (2000). The Russian pareiasaurs. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 71–85. Cambridge University Press, Cambridge.

Lee, M. S. Y. (2013). Turtle origins: insights from phylogenetic retrofitting and molecular scaffolds. *Journal of Evolutionary Biology*, 26(12):2729–2738.

Lee, M. S. Y., Cau, A., Naish, D., and Dyke, G. J. (2014). Sustained miniaturization and anatomical innovation in the dinosaurian ancestors of birds. *Science*, 345(6196):562–566.

Legendre, L. J., Guénard, G., Botha-Brink, J., and Cubo, J. (2016). Palaeohistological evidence for ancestral high metabolic rate in archosaurs. *Systematic Biology*, 65(6):989–996.

Lehman, J.-P. (1979). Nouveaux Trématosaures de Madagascar: les stégocéphales malgaches et leur paléoécologie. *Annales de Paléontologie (Vertébrés)*, 65(1):35–53.

Lehman, T. and Chatterjee, S. (2005). Depositional setting and vertebrate biostratigraphy of the Triassic Dockum Group of Texas. *Journal of Earth System Science*, 114(3):325–351.

Lessner, E. J., Stocker, M. R., Smith, N. D., Turner, A. H., Irmis, R. B., and Nesbitt, S. J. (2016). A new rauisuchid (Archosauria, Pseudosuchia) from the Upper Triassic (Norian) of New Mexico increases the diversity and temporal range of the clade. *PeerJ*, 4:e2336.

Lewis, G. E. and Vaughn, P. P. (1965). Early Permian vertebrates from the Cutler Formation of the Placerville area, Colorado. *Geological Survey Professional Paper*, 503-C:1–46.

Li, C. (2003). First record of protorosaurid reptile (order Protorosauria) from the Middle Triassic of China. *Acta Geologica Sinica (English Edition)*, 77(4):419–423.

Li, C., Rieppel, O., and LaBarbera, M. C. (2004). A Triassic aquatic protorosaur with an extremely long neck. *Science*, 305(5692):1931.

Li, C., Wu, X.-c., Cheng, Y.-n., Sato, T., and Wang, L. (2006). An unusual archosaurian from the marine Triassic of China. *Naturwissenschaften*, 93(4):200–206.

Li, C., Rieppel, O., Wu, X.-C., Zhao, L.-J., and Wang, L.-T. (2011a). A new Triassic marine reptile from southwestern China. *Journal of Vertebrate Paleontology*, 31(2):303–312.

Li, C., Wu, X.-C., Zhao, L.-J., Sato, T., and Wang, L.-T. (2012). A new archosaur (Diapsida, Archosauriformes) from the marine Triassic of China. *Journal of Vertebrate Paleontology*, 32(5):1064–1081.

Li, C., Jiang, D.-Y., Cheng, L., Wu, X.-C., and Rieppel, O. (2014). A new species of *Largocephalosaurus* (Diapsida: Saurosphargidae), with implications for the morphological diversity and phylogeny of the group. *Geological Magazine*, 151(1):100–120.

Li, C., Wu, X.-c., Zhao, L.-j., Nesbitt, S. J., Stocker, M. R., and Wang, L.-T. (2016a). A new armored archosauriform (Diapsida: Archosauromorpha) from the marine Middle Triassic of China, with implications for the diverse life styles of archosauriforms prior to the diversification of Archosauria. *The Science of Nature*, 103(11):95.

Li, C., Fraser, N. C., Rieppel, O., Zhao, L.-J., and Wang, L.-T. (2017). A new diapsid from the Middle Triassic of southern China. *Journal of Paleontology*, 91(6):1306–1312.

Li, C., Fraser, N. C., Rieppel, O., and Wu, X.-C. (2018). A Triassic stem turtle with an edentulous beak. *Nature*, 560(7719):476–479.

Li, J.-L. and Cheng, Z.-W. (1999). New anthracosaur and temnospondyl amphibians from Gansu, China–the fifth report on Late Permian Dashankou lower tetrapod fauna. *Vertebrata PalAsiatica*, 37(3):234–247.

Li, J. (2008). Amniota. In Li, J., Wu, X., and Zhang, F., editors, *The Chinese Fossil Reptiles and Their Kin*, pages 27–34. Science Press, Bejing, Second edition.

Li, J. and Sun, A. (2008). Subclass Synapsida. In Li, J., Wu, X., and Zhang, F., editors, *The Chinese Fossil Reptiles and Their Kin*, pages 379–417. Science Press, Bejing, Second edition.

Li, K., Liu, J., Yang, C., and Hu, F. (2011b). Dinosaur assemblages from the Middle Jurassic Shaximiao Formation and Chuanjie Formation in the Sichuan-Yunnan Basin, China. *Volumina Jurassica*, IX:21–42.

Li, X.-W. and Liu, J. (2013). New specimens of pareiasaurs from the Upper Permian Sunjiagou Formation of Liulin, Shanxi and their implications for the taxonomy of Chinese pareiasaurs. *Vertebrata PalAsiatica*, 51(3):199–204.

Li, Z.-G., Jiang, D.-Y., Rieppel, O., Motani, R., Tintori, A., Sun, Z.-Y., and Ji, C. (2016b). A new species of *Xinpusaurus* (Reptilia, Thalattosauria) from the Ladinian (Middle Triassic) of Xingyi, Guizhou, southwestern China. *Journal of Vertebrate Paleontology*, 36(6):e1218340.

Lin, W.-B., Jiang, D.-Y., Rieppel, O., Motani, R., Ji, C., Tintori, A., Sun, Z.-Y., and Zhou, M. (2017). A new specimen of *Lariosaurus xingyiensis* (Reptilia, Sauropterygia) from the Ladinian (Middle Triassic) Zhuganpo Member, Falang Formation, Guizhou, China. *Journal of Vertebrate Paleontology*, 37(2):e1278703.

Liu, J. (2013a). On the taxonomy of *Xinpusaurus* (Reptilia: Thalattosauria). *Vertebrata PalAsiatica*, 51(1):17–23.

Liu, J. (2013b). Osteology, ontogeny, and phylogenetic position of *Sinophoneus yumenensis* (Therapsida, Dinocephalia) from the Middle Permian Dashankou Fauna of China. *Journal of Vertebrate Paleontology*, 33(6):1394–1407.

Liu, J. (2015). New discoveries from the *Sinokannemeyeria-Shansisuchus* Assemblage Zone: 1. Kannemeyeriiformes from Shanxi, China. *Vertebrata PalAsiatica*, 53(1):16–28.

Liu, J. (2016). *Yuanansuchus maopingchangensis* sp. nov., the second capitosauroid temnospondyl from the Middle Triassic Badong Formation of Yuanan, Hubei, China. *PeerJ*, 4:e1903.

Liu, J. and Li, J.-L. (2003). A new material of kannemeyerid from Xinjiang and the restudy of *Parakannemeyeria brevirostris*. *Vertebrata PalAsiatica*, 41(2):147–156.

Liu, J. and Olsen, P. (2010). The phylogenetic relationships of Eucynodontia (Amniota: Synapsida). *Journal of Mammalian Evolution*, 17(3):151–176.

Liu, J. and Abdala, F. (2014). Phylogeny and Taxonomy of the Traversodontidae. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 15, pages 255–279. Springer, Dordrecht.

Liu, J. and Abdala, F. (2015). New discoveries from the *Sinokannemeyeria-Shansisuchus* Assemblage Zone: 2. A new species of *Nothogomphodon* (Therapsida: Therocephalia) from the Ermaying Formation of Shanxi, China. *Vertebrata PalAsiatica*, 53(2):123–132.

Liu, J. and Bever, G. S. (2015). The last diadectomorph sheds light on Late Palaeozoic tetrapod biogeography. *Biology Letters*, 11(5):20150100.

Liu, J. and Abdala, F. (2017a). The tetrapod fauna of the upper Permian Naobaogou Formation of China: 1. *Shiguaignathus wangi* gen. et sp. nov., the first akidnognathid therocephalian from China. *PeerJ*, 5:e4150.

Liu, J. and Abdala, F. (2017b). Therocephalian (Therapsida) and chroniosuchian (Reptiliomorpha) from the Permo-Triassic transitional Guodikeng Formation of the Dalongkou Section, Jimsar, Xinjiang, China. *Vertebrata PalAsiatica*, 55(1):24–40.

Liu, J. and Bever, G. S. (2018). The tetrapod fauna of the upper Permian Naobaogou Formation of China: a new species of *Elginia* (Parareptilia, Pareiasauria). *Papers in Palaeontology*, 4(2):197–209.

Liu, J., Li, J.-L., and Cheng, Z. W. (2002). The *Lystrosaurus* fossils from Xinjiang and their bearing on the terrestrial Permian–Triassic boundary. *Vertebrata PalAsiatica*, 40(4):267–275. [In Chinese with extended English summary].

Liu, J., Soares, M. B., and Reichel, M. (2008). *Massetognathus* (Cynodontia, Traversodontidae) from the Santa Maria Formation of Brazil. *Revista Brasileira de Paleontologia*, 11(1):27–36.

Liu, J., Rubidge, B., and Li, J. (2009). New basal synapsid supports Laurasian origin for therapsids. *Acta Palaeontologica Polonica*, 54(3):393–400.

Liu, J., Rubidge, B., and Li, J. (2010). A new specimen of *Biseridens qilianicus* indicates its phylogenetic position as the most basal anomodont. *Proceedings of the Royal Society B: Biological Sciences*, 277(1679):285–292.

Liu, J., Zhao, L.-J., Li, C., and He, T. (2013a). Osteology of *Concavispina biseridens* (Reptilia, Thalattosauria) from the Xiaowa Formation (Carnian), Guanling, Guizhou, China. *Journal of Paleontology*, 87(2):341–350.

Liu, J., Motani, R., Jiang, D.-Y., Hu, S.-X., Aitchison, J. C., Rieppel, O., Benton, M. J., Zhang, Q.-Y., and Zhou, C.-Y. (2013b). The first specimen of the Middle Triassic *Phalarodon atavus* (Ichthyosauria: Mixosauridae) from South China, showing postcranial anatomy and peri-Tethyan distribution. *Palaeontology*, 56(4):849–866.

Liu, J., Hu, S.-x., Rieppel, O., Jiang, D.-y., Benton, M. J., Kelley, N. P., Aitchison, J. C., Zhou, C.-y., Wen, W., Huang, J.-y., Xie, T., and Lv, T. (2014a). A gigantic nothosaur (Reptilia: Sauropterygia) from the Middle Triassic of SW China and its implication for the Triassic biotic recovery. *Scientific Reports*, 4:7142.

Liu, J., Xu, L., Jia, S.-H., Pu, H.-Y., and Liu, X.-L. (2014b). The Jiyuan tetrapod fauna of the Upper Permian of China–2. stratigraphy, taxonomical review, and correlation. *Vertebrata PalAsiatica*, 52(3):328–339.

Liu, J., Butler, R., Sullivan, C., and Ezcurra, M. (2015a). '*Chasmatosaurus ultimus*,' a putative proterosuchid archosauriform from the Middle Triassic, is an indeterminate crown archosaur. *Journal of Vertebrate Paleontology*, 35(5):e965779.

Liu, J., Organ, C. L., Benton, M. J., Brandley, M. C., and Aitchison, J. C. (2017). Live birth in an archosauromorph reptile. *Nature Communications*, 8:14445.

Liu, X.-Q., Lin, W.-B., Rieppel, O., Sun, Z.-Y., Li, Z.-G., Lu, H., and Jiang, D.-Y. (2015b). A new specimen of *Diandongosaurus acutidentatus* (Sauropterygia) from the Middle Triassic of Yunnan, China. *Vertebrata PalAsiatica*, 53(4):281–290. [In Chinese with English abstract].

Lloyd, G. T. (2012). A refined modelling approach to assess the influence of sampling on palaeobiodiversity curves: new support for declining Cretaceous dinosaur richness. *Biology Letters*, 8(1):123–126.

Lloyd, G. T., Bapst, D. W., Friedman, M., and Davis, K. E. (2016a). Data from: Probabilistic divergence time estimation without branch lengths: dating the origins of dinosaurs, avian flight, and crown birds. Dryad Digital Repository. http://dx.doi.org/10.5061/dryad.p660m.

Lloyd, G. T., Bapst, D. W., Friedman, M., and Davis, K. E. (2016b). Probabilistic divergence time estimation without branch lengths: dating the origins of dinosaurs, avian flight and crown birds. *Biology Letters*, 12(11):20160609.

Lomax, D. R. (2017). A new leptonectid ichthyosaur from the Lower Jurassic (Hettangian) of Nottinghamshire, England, UK, and the taxonomic usefulness of the ichthyosaurian coracoid. *Journal of Systematic Palaeontology*, 15(5):387–401.

Lomax, D. R. and Massare, J. A. (2017). Two new species of *Ichthyosaurus* from the lowermost Jurassic (Hettangian) of Somerset, England. *Papers in Palaeontology*, 3(1):1–20.

Lomax, D. R. and Massare, J. A. (2018). A second specimen of *Protoichthyosaurus applebyi* (Reptilia: Ichthyosauria) and additional information on the genus and species. *Paludicola*, 11(4):164–178.

Lomax, D. R., Massare, J. A., and Mistry, R. T. (2017). The taxonomic utility of forefin morphology in Lower Jurassic ichthyosaurs: *Protoichthyosaurus* and *Ichthyosaurus*. *Journal of Vertebrate Paleontology*, 37(5):e1361433.

Lombard, R. E. and Bolt, J. R. (1995). A new primitive tetrapod, *Whatcheeria deltae*, from the Lower Carboniferous of Iowa. *Palaeontology*, 38(3):471–494.

Long, R. A. and Murry, P. A. (1995). Late Triassic (Carnian and Norian) tetrapods from the southwestern United States. *New Mexico Museum of Natural History and Science Bulletin*, 4:1–254.

Longrich, N. R., Martill, D. M., and Andres, B. (2018). Late Maastrichtian pterosaurs from North Africa and mass extinction of Pterosauria at the Cretaceous-Paleogene boundary. *PLoS Biology*, 16(3):e2001663.

Lozovsky, V. R. (2005). Olson's gap or Olson's bridge, that is the question. In Lucas, S. G. and Zeigler, K. E., editors, *The Nonmarine Permian*, volume 30, pages 179–184. New Mexico Museum of Natural History.

Lü, J., Li, T., Zhong, S., Azuma, Y., Fujita, M., Dong, Z., and Ji, Q. (2007). New yunnanosaurid dinosaur (Dinosauria, Prosauropoda) from the Middle Jurassic Zhanghe Formation of Yuanmou, Yunnan Province of China. *Memoir of the Fukui Prefectural Dinosaur Museum*, 6:1–15.

Lü, J., Kobayashi, Y., Li, T., and Zhong, S. (2010a). A new basal sauropod dinosaur from the Lufeng Basin, Yunnan Province, southwestern China. *Acta Geologica Sinica - English Edition*, 84(6):1336–1342.

Lü, J., Unwin, D. M., Jin, X., Liu, Y., and Ji, Q. (2010b). Evidence for modular evolution in a long-tailed pterosaur with a pterodactyloid skull. *Proceedings of the Royal Society B: Biological Sciences*, 277(1680):383–389.

Lucas, S. G. (1993). Vertebrate biochronology of the Triassic of China. In Lucas, S. G. and Morales, M., editors, *The Nonmarine Triassic*, volume 3, pages 301–306. New Mexico Museum of Natural History.

Lucas, S. G. (1998). The aetosaur *Longosuchus* from the Triassic of Morocco and its biochronological significance. *Comptes Rendus de l'Académie des Sciences - Series IIA - Earth and Planetary Science*, 326(8):589–594.

Lucas, S. G. (2001). A global hiatus in the Middle Permian tetrapod fossil record. *Permophiles*, 38:24–27.

Lucas, S. G. (2004). A global hiatus in the Middle Permian tetrapod fossil record. *Stratigraphy*, 1(1):47–64.

Lucas, S. G. (2006). Global Permian tetrapod biostratigraphy and biochronology. *Geological Society, London, Special Publications*, 265(1):65–93.

Lucas, S. G. (2010). The Triassic timescale based on nonmarine tetrapod biostratigraphy and biochronology. *Geological Society, London, Special Publications*, 334(1):447–500.

Lucas, S. G. (2013a). No gap in the Middle Permian record of terrestrial vertebrates: Comment. *Geology*, 41(9):e293.

Lucas, S. G. (2013b). Vertebrate biostratigraphy and biochronology of the upper Paleozoic Dunkard Group, Pennsylvania–West Virginia–Ohio, USA. *International Journal of Coal Geology*, 119:79–87.

Lucas, S. G. (2017). Permian tetrapod extinction events. *Earth-Science Reviews*, 170:31–60.

Lucas, S. G. (2018). Permian tetrapod biochronology, correlation and evolutionary events. *Geological Society, London, Special Publications*, 450(1):405–444.

Lucas, S. G. and Hunt, A. P. (1993). A dicynodont from the Upper Triassic of New Mexico and its biochronological significance. In Lucas, S. G. and Morales, M., editors, *The Nonmarine Triassic*, volume 3, pages 321–325. New Mexico Museum of Natural History.

Lucas, S. G. and Luo, Z. (1993). *Adelobasileus* from the Upper Triassic of West Texas: the oldest mammal. *Journal of Vertebrate Paleontology*, 13(3):309–334.

Lucas, S. G. and Hunt, A. P. (1994). The chronology and paleobiogeography of mammalian origins. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 20, pages 335–351. Cambridge University Press, Cambridge.

Lucas, S. G. and Wild, R. (1995). A Middle Triassic dicynodont from Germany and the biochronology of Triassic dicynodonts. *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 220:1–16.

Lucas, S. G. and Harris, S. K. (1996). Taxonomic and biochronological significance of specimens of the Triassic dicynodont *Dinodontosaurus* Romer, 1934 in the Tübingen collection. *Paläontologische Zeitschrift*, 70:603–622.

Lucas, S. G. and Heckert, A. B. (2001). Olson's gap: a global hiatus in the record of Middle Permian tetrapods. *Journal of Vertebrate Paleontology*, 21(3, Supplement):75A.

Lucas, S. G. and Tanner, L. H. (2018). The Missing Mass Extinction at the Triassic-Jurassic Boundary. In Tanner, L. H., editor, *The Late Triassic World*, Topics in Geobiology, chapter 15, pages 721–785. Springer, Cham.

Lucas, S. G., Heckert, A. B., Estep, J. W., and Anderson, O. J. (1997). Stratigraphy of the Upper Triassic Chinle Group, Four Corners Region. In Anderson, O., Kues, B. S., and Lucas, S. G., editors, *New Mexico Geological Society 48th Annual Fall Field Conference Guidebook, Mesozoic Geology and Paleontology of the Four Corners Region*, New Mexico Geological Society Guidebook, pages 81–108. New Mexico Geological Society.

Lucas, S. G., Heckert, A. B., and Huber, P. (1998). *Aetosaurus* (Archosauromorpha) from the Upper Triassic of the Newark Supergroup, eastern United States, and its biochronological significance. *Palaeontology*, 41(6):1215–1230.

Lucas, S. G., Heckert, A. B., and Kahle, R. (2002). Postcranial anatomy of *Angistorhinus*, a Late Triassic phytosaur from West Texas. In Heckert, A. B. and Lucas, S. G., editors, *Upper Triassic Stratigraphy and Paleontology*, volume 21, pages 157–164. New Mexico Museum of Natural History.

Lucas, S. G., Harris, S. K., Spielmann, J. A., Berman, D. S., Henrici, A. C., Heckert, A. B., Zeigler, K. E., and Rinehart, L. F. (2005a). Early Permian vertebrate assemblage and its biostratigraphic significance, Arroyo del Agua, Rio Arriba County, New Mexico. In Lucas, S. G., Zeigler, K. E., Lueth, V. W., and Owen, D. E., editors, *New Mexico Geological Society Guidebook, 56th Annual Fall Field Conference, Geology of the Chama Basin*, pages 288–296. New Mexico Geological Society.

Lucas, S. G., Harris, S. K., Spielmann, J. A., Berman, D. S., Henrici, A. C., Heckert, A. B., Zeigler, K. E., and Rinehart, L. F. (2005b). Early Permian vertebrate biostratigraphy at Arroyo del Agua, Rio Arriba County, New Mexico. In Lucas, S. G., Zeigler, K. E., and Spielmann, J. A., editors, *The Permian of Central New Mexico*, volume 31, pages 163–169. New Mexico Museum of Natural History.

Lucas, S. G., Hunt, A. P., and Spielmann, J. A. (2006). *Rioarribasuchus*, a new name for an aetosaur from the Upper Triassic of north-central New Mexico. In Harris, J. D., Lucas, S. G., Spielmann, J. A., Lockley, M. G., Milner, A. R. C., and Kirkland, J. I., editors, *The Triassic-Jurassic Terrestrial Transition*, volume 37, pages 581–582. New Mexico Museum of Natural History.

Lucas, S. G., Spielmann, J. A., and Hunt, A. P. (2013a). A new doswelliid archosauromorph from the Upper Triassic of West Texas. In Tanner, L. H., Spielmann, J. A., and Lucas, S. G., editors, *The Triassic System*, volume 61, pages 382–388. New Mexico Museum of Natural History.

Lucas, S. G., Spielmann, J. A., and Rinehart, L. F. (2013b). Juvenile skull of the phytosaur *Redondasaurus* from the Upper Triassic of New Mexico, and phytosaur ontogeny. In Tanner, L. H., Spielmann, J. A., and Lucas, S. G., editors, *The Triassic System*, volume 61, pages 389–400. New Mexico Museum of Natural History.

Luo, Z.-X. and Martin, T. (2007). Analysis of molar structure and phylogeny of docodont genera. *Bulletin of Carnegie Museum of Natural History*, 39:27–47.

Luo, Z.-X., Kielan-Jaworowska, Z., and Cifelli, R. L. (2002). In quest for a phylogeny of Mesozoic mammals. *Acta Palaeontologica Polonica*, 47(1):1–78.

Luo, Z.-X., Meng, Q.-J., Ji, Q., Liu, D., Zhang, Y.-G., and Neander, A. I. (2015a). Evolutionary development in basal mammaliaforms as revealed by a docodontan. *Science*, 347(6223):760–764.

Luo, Z.-X., Gatesy, S. M., Jenkins, Jr., F. A., Amaral, W. W., and Shubin, N. H. (2015b). Mandibular and dental characteristics of Late Triassic mammaliaform *Haramiyavia* and their ramifications for basal mammal evolution. *Proceedings of the National Academy of Sciences*, 112(51):E7101–E7109.

Luo, Z.-X., Meng, Q.-J., Grossnickle, D. M., Liu, D., Neander, A. I., Zhang, Y.-G., and Ji, Q. (2017). New evidence for mammaliaform ear evolution and feeding adaptation in a Jurassic ecosystem. *Nature*, 548:326–329.

Luo, Z. and Wu, X.-C. (1994). The small tetrapods of the Lower Lufeng Formation, Yunnan, China. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 14, pages 251–270. Cambridge University Press, Cambridge.

Lydekker, R. (1889). On the remains and affinities of five genera of Mesozoic reptiles. *Quarterly Journal of the Geological Society of London*, 45(1–4):41–59.

Ma, L.-T., Jiang, D.-Y., Rieppel, O., Motani, R., and Tintori, A. (2015). A new pistosauroid (Reptilia, Sauropterygia) from the late Ladinian Xingyi marine reptile level, southwestern China. *Journal of Vertebrate Paleontology*, 35(1):e881832.

MacDougall, M. J. and Modesto, S. P. (2011). New information on the skull of the Early Triassic parareptile *Sauropareion anoplus*, with a discussion of tooth attachment and replacement in procolophonids. *Journal of Vertebrate Paleontology*, 31(2):270–278.

MacDougall, M. J. and Reisz, R. (2012). A new parareptile (Parareptilia, Lanthanosuchoidea) from the Early Permian of Oklahoma. *Journal of Vertebrate Paleontology*, 32(5):1018–1026.

MacDougall, M. J. and Reisz, R. R. (2014). The first record of a nyctiphruretid parareptile from the Early Permian of North America, with a discussion of parareptilian temporal fenestration. *Zoological Journal of the Linnean Society*, 172(3):616–630.

MacDougall, M. J., Modesto, S. P., and Botha-Brink, J. (2013). The postcranial skeleton of the Early Triassic parareptile *Sauropareion anoplus*, with a discussion of possible life history. *Acta Palaeontologica Polonica*, 58(4):737–749.

MacDougall, M. J., Modesto, S. P., and Reisz, R. R. (2016). A new reptile from the Richards Spur Locality, Oklahoma, USA, and patterns of Early Permian parareptile diversification. *Journal of Vertebrate Paleontology*, 36(5):e1179641.

MacDougall, M. J., Scott, D., Modesto, S. P., Williams, S. A., and Reisz, R. R. (2017). New material of the reptile *Colobomycter pholeter* (Parareptilia: Lanthanosuchoidea) and the diversity of reptiles during the Early Permian (Cisuralian). *Zoological Journal of the Linnean Society*, 180(3):661–671.

MacDougall, M. J., Modesto, S. P., Brocklehurst, N., Verrière, A., Reisz, R. R., and Fröbisch, J. (2018). Response: A reassessment of the taxonomic position of mesosaurs, and a surprising phylogeny of early amniotes. *Frontiers in Earth Science*, 6:99.

MacIver, M. A., Schmitz, L., Mugan, U., Murphey, T. D., and Mobley, C. D. (2017). Massive increase in visual range preceded the origin of terrestrial vertebrates. *Proceedings of the National Academy of Sciences*, 114(12):E2375–E2384.

MacLaren, J. A., Anderson, P. S. L., Barrett, P. M., and Rayfield, E. J. (2016). Data from: Herbivorous dinosaur jaw disparity and its relationship to extrinsic evolutionary drivers. Dryad Digital Repository. https://doi.org/10.5061/dryad.c78k5.

MacLaren, J. A., Anderson, P. S. L., Barrett, P. M., and Rayfield, E. J. (2017). Herbivorous dinosaur jaw disparity and its relationship to extrinsic evolutionary drivers. *Paleobiology*, 43(1):15–33.

Maddin, H. C. and Anderson, J. S. (2012). Evolution of the amphibian ear with implications for lissamphibian phylogeny: insight gained from the caecilian inner ear. *Fieldiana Life and Earth Sciences*, 5:59–76.

Maddin, H. C., Evans, D. C., and Reisz, R. R. (2006). An Early Permian varanodontine varanopid (Synapsida: Eupelycosauria) from the Richards Spur locality, Oklahoma. *Journal of Vertebrate Paleontology*, 26(4):957–966.

Maddin, H. C., Jenkins, F. A., and Anderson, J. S. (2012). The braincase of *Eocaecilia micropodia* (Lissamphibia, Gymnophiona) and the origin of caecilians. *PLoS ONE*, 7(12):e50743.

Maddin, H. C., Fröbisch, N. B., Evans, D. C., and Milner, A. R. (2013). Reappraisal of the Early Permian amphibamid *Tersomius texensis* and some referred material. *Comptes Rendus Palevol*, 12(7–8):447–461.

Maddison, W. P. and Maddison, D. R. (2018). Mesquite: a modular system for evolutionary analysis. Version 3.51. http://mesquiteproject.org.

Mader, D. (1984). Charakteristische Fossilien des mitteleuropäischen Buntsandsteins. *Naturwissenschaften*, 71(2):69–78.

Maganuco, S., Steyer, J. S., Pasini, G., Boulay, M., Lorrain, S., Bénéteau, A., and Auditore, M. (2009). An exquisite specimen of *Edingerella madagascariensis* (Temnospondyli) from the Lower Triassic of NW Madagascar; cranial anatomy, phylogeny, and restorations. *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, 36(2):1–72.

Maganuco, S., Pasini, G., and Auditore, M. (2014). A revision of the short-faced stereospondyls *Mahavisaurus dentatus* and *Lyrosaurus australis* from the Lower Triassic of Madagascar: cranial anatomy, ontogenetic remarks, palaeoecology and rhytidosteid phylogeny. *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, 39:1–64.

Maisch, M. W. (1998). Kurze Übersicht der Ichthyosaurier des Posidonienschiefer mit Bemerkungen zur Taxonomie der Stenopterygiidae und Temnodontosauridae. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 209(3):401–431.

Maisch, M. W. (2001). Observations on Karoo and Gondwana vertebrates. Part 2: A new skull-reconstruction of *Stahleckeria potens* von Huene, 1935 (Dicynodontia, Middle Triassic) and reconsideration of kannemeyeriiform phylogeny. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 220(1):127–152.

Maisch, M. W. (2002). Observations on Karoo and Gondwana vertebrates. Part 3: Notes on the gorgonopsians from the Upper Permian of Tanzania. *Neues Jahrbuch für Geologie und Paläontologie - Monatshefte*, 2002(4):237–251.

Maisch, M. W. (2008). Revision der Gattung *Stenopterygius* Jaekel, 1904 emend. von Huene, 1922 (Reptilia: Ichthyosauria) aus dem unteren Jura Westeuropas. *Palaeodiversity*, 1:227–271.

Maisch, M. W. (2010). Phylogeny, systematics, and origin of the Ichthyosauria–the state of the art. *Palaeodiversity*, 3:151–214.

Maisch, M. W. (2014a). A well preserved skull of *Cymatosaurus* (Reptilia: Sauropterygia) from the uppermost Buntsandstein (Middle Triassic) of Germany. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 272(2):213–224.

Maisch, M. W. (2014b). On the morphoplogy and taxonomic status of *Xinpusaurus kohi* Jiang et al., 2004 (Diapsida: Thalattosauria) from the Upper Triassic of China. *Palaeodiversity*, 7:47–59.

Maisch, M. W. (2015). A juvenile specimen of *Anshunsaurus huangguoshuensis* Liu, 1999 (Diapsida: Thalattosauria) from the Upper Triassic of China. *Palaeodiversity*, 8:71–87.

Maisch, M. W. (2017). Re-assessment of *Silphoictidoides ruhuhuensis* von Huene, 1950 (Therapsida, Therocephalia) from the Late Permian of Tanzania: one of the most basal baurioids known. *Palaeodiversity*, 10(1):25–39.

Maisch, M. W. and Matzke, A. T. (2000). The Ichthyosauria. *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 298:1–159.

Maisch, M. W. and Matzke, A. T. (2001). Observations on Triassic ichthyosaurs. Part VIII. A redescription of *Phalarodon major* (von Huene, 1916) and the composition and phylogeny of the Mixosauridae. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 220(3):431–447.

Maisch, M. W. and Matzke, A. T. (2002). Observations on Triassic ichthyosaurs. Part IX. The first associated skeletal remains of *Merriamosaurus* n. g. (Ichthyosauria, Lower Triassic) and their bearing on the systematic position of the Omphalosauria. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 226(1):59–94.

Maisch, M. W. and Matzke, A. T. (2003a). Observations on Triassic ichthyosaurs. Part X: The Lower Triassic *Merriamosaurus* from Spitzbergen - additional data on its anatomy and phylogenetic position. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 227(1):93–137.

Maisch, M. W. and Matzke, A. T. (2003b). Observations on Triassic ichthyosaurs. Part XII. A new Early Triassic ichthyosaur genus from Spitzbergen. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 229(3):317–338.

Maisch, M. W. and Matzke, A. T. (2005). Observations on Triassic ichthyosaurs. Part XIV: The Middle Triassic mixosaurid *Phalarodon major* (v. Huene, 1916) from Switzerland and a reconsideration of mixosaurid phylogeny. *Neues Jahrbuch für Geologie und Paläontologie - Monatshefte*, 2005(10):597–613.

Maisch, M. W. and Gebauer, E. V. I. (2005). Reappraisal of *Geikia locusticeps* (Therapsida: Dicynodontia) from the Upper Permian of Tanzania. *Palaeontology*, 48(2):309–324.

Maisch, M. W. and Reisdorf, A. G. (2006). Evidence for the longest stratigraphic range of a post-Triassic ichthyosaur: a *Leptonectes tenuirostris* from the Pliensbachian (Lower Jurassic) of Switzerland. *Geobios*, 39(4):491–505.

Maisch, M. W. and Matzke, A. T. (2014). *Sungeodon kimkraemerae* n. gen. n. sp., the oldest kannemeyeriiform (Therapsida, Dicynodontia) and its implications for the early diversification of large herbivores after the P/T boundary. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 272(1):1–12.

Maisch, M. W., Reisdorf, A. G., Schlatter, R., and Wetzel, A. (2008). A large skull of *Ichthyosaurus* (Reptilia: Ichthyosauria) from the Lower Sinemurian (Lower Jurassic) of Frick (NW Switzerland). *Swiss Journal of Geosciences*, 101(3):617–627.

Maisch, M. W., Matzke, A. T., and Rathgeber, T. (2013). Re-evaluation of the enigmatic archosaur *Dyoplax arenaceus* O. Fraas, 1867 from the Schilfsandstein (Stuttgart Formation, lower Carnian, Upper Triassic) of Stuttgart, Germany. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 267(3):353–362.

Makádi, L., Rabi, M., Csengődi, D., Szentesi, Z., and Ősi, A. (2014). Bakonyi dinoszauruszok és más hazai mezozóos gerincesek a Magyar Természettudományi Múzeum gyűjteményében – az elmúlt évek világhírű felfedezései. *Annales Historico-Naturales Musei Nationalis Hungarici*, 106:71–116.

Manabe, M. and Hasegawa, Y. (1998). A crocodile from the Early Jurassic Toyora Group, Yamaguchi, Japan. *Memoirs of the National Science Museum*, 31:73–77.

Mancuso, A. C., Gaetano, L. C., Leardi, J. M., Abdala, F., and Arcucci, A. B. (2014). The Chañares Formation: a window to a Middle Triassic tetrapod community. *Lethaia*, 47(2):244–265.

Mann, H. B. and Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics*, 18(1):50–60.

Maňourová, M. (1992). *Dawsonerpeton polydens* (Fritsch, 1879) (Amphibia): remarks on morphology and relationship. *Časopis Národního Muzea, Řada přírodovědná*, 159(1–4):95–98.

Marjanović, D. (2010). *Phylogeny of the limbed vertebrates with special consideration of the origin of the modern amphibians*. PhD thesis, Université Pierre et Marie Curie and Universität Wien. 324 pp.

Marjanović, D. and Laurin, M. (2008). A reevaluation of the evidence supporting an unorthodox hypothesis on the origin of extant amphibians. *Contributions to Zoology*, 77(3):149–199.

Marjanović, D. and Laurin, M. (2009). The origin(s) of modern amphibians: a commentary. *Evolutionary Biology*, 36(3):336–338.

Marjanović, D. and Laurin, M. (2013). The origin(s) of extant amphibians: a review with emphasis on the "lepospondyl hypothesis". *Geodiversitas*, 35(1):207–272.

Marjanović, D. and Laurin, M. (2019). Reproducibility in phylogenetics: reevaluation of the largest published morphological data matrix for phylogenetic analysis of Paleozoic limbed vertebrates. *PeerJ*, 6:e5565.

Marquez-Aliaga, A., Klein, N., Reolid, M., Plasencia, P., Villena, J. A., and Martinez-Perez, C. (2019). An enigmatic marine reptile, *Hispaniasaurus cranioelongatus* (gen. et sp. nov.) with nothosauroid affinities from the Ladinian of the Iberian Range (Spain). *Historical Biology*, 31(2):223–233.

Marsh, O. C. (1878). Notice of new fossil reptiles. *American Journal of Science, Series 3*, 15(89):409–411.

Marsicano, C. A., Wilson, J. A., and Smith, R. M. H. (2014). A temnospondyl trackway from the early Mesozoic of Western Gondwana and its implications for basal tetrapod locomotion. *PLoS ONE*, 9(8):e103255.

Marsicano, C. A., Latimer, E., Rubidge, B., and Smith, R. M. H. (2017). The Rhinesuchidae and early history of the Stereospondyli (Amphibia: Temnospondyli) at the end of the Palaeozoic. *Zoological Journal of the Linnean Society*, 181(2):357–384.

Martill, D. M., Vidovic, S. U., Howells, C., and Nudds, J. R. (2016). The oldest Jurassic dinosaur: a basal neotheropod from the Hettangian of Great Britain. *PLoS ONE*, 11(1):e0145713.

Martin, J. E., Fischer, V., Vincent, P., and Suan, G. A. (2012). A longirostrine *Temnodontosaurus* (Ichthyosauria) with comments on Early Jurassic ichthyosaur niche partitioning and disparity. *Palaeontology*, 55(5):995–1005.

Martin, J., Frey, E., and Riess, J. (1986). Soft tissue preservation in ichthyosaurs and a stratigraphic review of the Lower Hettangian of Barrow-Upon-Soar, Leicestershire. *Transactions of the Leicester Literary & Philosophical Society*, 80:58–72.

Martin, T., Marugan-Lobon, J., Vullo, R., Martin-Abad, H., Luo, Z.-X., and Buscalioni, A. D. (2015). A Cretaceous eutriconodont and integument evolution in early mammals. *Nature*, 526(7573):380–384.

Martinelli, A. G. and Rougier, G. W. (2007). On *Chaliminia musteloides* (Eucynodontia: Tritheledontidae) from the Late Triassic of Argentina, and a phylogeny of Ictidosauria. *Journal of Vertebrate Paleontology*, 27(2):442–460.

Martinelli, A. G., Bonaparte, J. F., Schultz, C. L., and Rubert, R. (2005). A new tritheledontid (Therapsida, Eucynodontia) from the Late Triassic of Rio Grande do Sul (Brazil) and its phylogenetic relationships among carnivorous non-mammalian eucynodonts. *Ameghiniana*, 42(1):191–208.

Martinelli, A. G., de la Fuente, M., and Abdala, F. (2009). *Diademodon tetragonus* Seeley, 1894 (Therapsida: Cynodontia) in the Triassic of South America and its biostratigraphic implications. *Journal of Vertebrate Paleontology*, 29(3):852–862.

Martinelli, A. G., Soares, M. B., and Schoch, R. R. (2016a). Owenettids and procolophonids from the lower Keuper shed new light on the diversity of parareptiles in the German Middle Triassic. *Journal of Paleontology*, 90(1):92–101.

Martinelli, A. G., Soares, M. B., and Schwanke, C. (2016b). Two new cynodonts (Therapsida) from the middle-early Late Triassic of Brazil and comments on South American probainognathians. *PLoS ONE*, 11(10):e0162945.

Martinelli, A. G., Eltink, E., Da-Rosa, Á. A. S., and Langer, M. C. (2017a). A new cynodont from the Santa Maria formation, south Brazil, improves Late Triassic probainognathian diversity. *Papers in Palaeontology*, 3(3):401–423.

Martinelli, A. G., Kammerer, C. F., Melo, T. P., Neto, V. D. P., Ribeiro, A. M., Da-Rosa, Á. A. S., Schultz, C. L., and Soares, M. B. (2017b). The African cynodont *Aleodon* (Cynodontia, Probainognathia) in the Triassic of southern Brazil and its biostratigraphic significance. *PLoS ONE*, 12(6):e0177948.

Martinelli, A., Soares, M. B., de Oliveira, T. V., Rodrigues, P. G., and Schultz, C. L. (2017c). The Triassic eucynodont *Candelariodon barberenai* revisited and the early diversity of stem prozostrodontians. *Acta Palaeontologica Polonica*, 62(3):527–542.

Martínez, R. N. (2009). *Adeopapposaurus mognai*, gen. et sp. nov.(Dinosauria: Sauropodomorpha), with comments on adaptations of basal Sauropodomorpha. *Journal of Vertebrate Paleontology*, 29(1):142–164.

Martínez, R. N. and Alcober, O. A. (2009). A basal sauropodomorph (Dinosauria: Saurischia) from the Ischigualasto Formation (Triassic, Carnian) and the early evolution of Sauropodomorpha. *PLoS ONE*, 4:e4397.

Martínez, R. N. and Apaldetti, C. (2017). A Late Norian–Rhaetian coelophysid neotheropod (Dinosauria, Saurischia) from the Quebrada del Barro Formation, northwestern Argentina. *Ameghiniana*, 54(5):488–505.

Martínez, R. N., Sereno, P. C., Alcober, O. A., Colombi, C. E., Renne, P. R., Montañez, I. P., and Currie, B. S. (2011). A basal dinosaur from the dawn of the dinosaur era in southwestern Pangaea. *Science*, 331(6014):206–210.

Martínez, R. N., Apaldetti, C., Alcober, O. A., Colombi, C. E., Sereno, P. C., Fernandez, E., Malnis, P. S., Correa, G. A., and Abelin, D. (2012). Vertebrate succession in the Ischigualasto Formation. *Journal of Vertebrate Paleontology*, 32(sup1):10–30.

Martínez, R. N., Apaldetti, C., Colombi, C. E., Praderio, A., Fernandez, E., Malnis, P. S., Correa, G. A., Abelin, D., and Alcober, O. (2013). A new sphenodontian (Lepidosauria: Rhynchocephalia) from the Late Triassic of Argentina and the early origin of the herbivore opisthodontians. *Proceedings of the Royal Society B: Biological Sciences*, 280(1772):20132057.

Martz, J. W. (2008). *Lithostratigraphy, chemostratigraphy, and vertebrate biostratigraphy of the Dockum Group (Upper Triassic), of southern Garza County, West Texas*. PhD thesis, Texas Tech University, Lubbock. 504 pp.

Martz, J. W. and Parker, W. G. (2017). Revised Formulation of the Late Triassic Land Vertebrate “Faunachrons” of Western North America: Recommendations for Codifying Nascent Systems of Vertebrate Biochronology. In Zeigler, K. E. and Parker, W. G., editors, *Terrestrial Depositional Systems: Deciphering Complexities through Multiple Stratigraphic Methods*, pages 39–125. Elsevier, Amsterdam.

Martz, J. W., Mueller, B., Nesbitt, S. J., Stocker, M. R., Parker, W. G., Atanassov, M., Fraser, N., Weinbaum, J., and Lehane, J. R. (2012). A taxonomic and biostratigraphic re-evaluation of the Post Quarry vertebrate assemblage from the Cooper Canyon Formation (Dockum Group, Upper Triassic) of southern Garza County, western Texas. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):339–364.

Martz, J. W., Irmis, R. B., and Milner, A. R. C. (2014). Lithostratigraphy and biostratigraphy of the Chinle Formation (Upper Triassic) in southern Lisbon Valley, southeastern Utah. In MacLean, J., Biek, R., and Huntoon, J., editors, *Geology of Utah's Far South*, volume 43 of *Utah Geological Association Publication*, pages 397–448. Utah Geological Association.

Martz, J. W., Kirkland, J. I., Milner, A. R. C., Parker, W. G., and Santucci, V. L. (2017). Upper Triassic lithostratigraphy, depositional systems, and vertebrate paleontology across southern Utah. *Geology of the Intermountain West*, 4:99–180.

Marzola, M., Mateus, O., Shubin, N. H., and Clemmensen, L. B. (2017). *Cyclotosaurus naraserluki*, sp. nov., a new Late Triassic cyclotosaurid (Amphibia, Temnospondyli) from the Fleming Fjord Formation of the Jameson Land Basin (East Greenland). *Journal of Vertebrate Paleontology*, 37(2):e1303501.

Marzola, M., Mateus, O., Milàn, J., and Clemmensen, L. B. (2018). A review of Palaeozoic and Mesozoic tetrapods from Greenland. *Bulletin of the Geological Society of Denmark*, 66:21–46.

Massare, J. A. and Callaway, J. M. (1994). *Cymbospondylus* (Ichthyosauria: Shastasauridae) from the Lower Triassic Thaynes Formation of southeastern Idaho. *Journal of Vertebrate Paleontology*, 14(1):139–141.

Massare, J. A. and Lomax, D. R. (2016). A new specimen of *Ichthyosaurus conybeari* (Reptilia, Ichthyosauria) from Watchet, Somerset, England, U.K., and a re-examination of the species. *Journal of Vertebrate Paleontology*, 36(5):e1163264.

Massare, J. A. and Lomax, D. R. (2018). A taxonomic reassessment of *Ichthyosaurus communis* and *I. intermedius* and a revised diagnosis for the genus. *Journal of Systematic Palaeontology*, 16(3):263–277.

Massare, J. A., Lomax, D. R., and Klein, A. (2015). A large forefin of *Ichthyosaurus* from the U. K., and estimates of the size range of the genus. *Paludicola*, 10(2):119–135.

Mastrantonio, B. M. (2010). *Descrição osteológica de materiais cranianos e pós-cranianos de Prestosuchus chiniquensis (Archosauria, Rauisuchia) do Mesotriássico do RS (Biozona de Dinodontosaurus, Formação Santa Maria) e considerações filogenéticas sobre rauissúquios*. PhD thesis, Universidade Federal do Rio Grande do Sul, Porto Alegre. 244 pp.

Mastrantonio, B. M., Schultz, C. L., Desojo, J. B., and Garcia, J. B. (2013). The braincase of *Prestosuchus chiniquensis* (Archosauria: Suchia). *Geological Society, London, Special Publications*, 379(1):425–440.

Matsumoto, R. and Evans, S. E. (2010). Choristoderes and the freshwater assemblages of Laurasia. *Journal of Iberian Geology*, 36(2):253–274.

Maxwell, E. E. (2012). New metrics to differentiate species of *Stenopterygius* (Reptilia: Ichthyosauria) from the Lower Jurassic of southwestern Germany. *Journal of Paleontology*, 86(1):105–115.

Maxwell, E. E. (2018). Redescription of the ‘lost’ holotype of *Suevoleviathan integer* (Bronn, 1844) (Reptilia: Ichthyosauria). *Journal of Vertebrate Paleontology*, 38(2):e1439833.

Maxwell, E. E. and Kear, B. P. (2013). Triassic ichthyopterygian assemblages of the Svalbard archipelago: a reassessment of taxonomy and distribution. *GFF*, 135(1):85–94.

Maxwell, E. E., Fernández, M. S., and Schoch, R. R. (2012). First diagnostic marine reptile remains from the Aalenian (Middle Jurassic): a new ichthyosaur from southwestern Germany. *PLoS ONE*, 7(8):e41692.

Maxwell, S. J., Hopley, P. J., Upchurch, P., and Soligo, C. (2018). Sporadic sampling, not climatic forcing, drives observed early hominin diversity. *Proceedings of the National Academy of Sciences*, 115(19):4891–4896.

May, W. J. and Hall, J. D. (2016). First occurrence of the diplocaulid genus *Diploceraspis* from the Wellington Formation (Lower Permian) of Northern Oklahoma. *Transactions of the Kansas Academy of Science*, 119(2):193–199.

May, W., Huttenlocker, A. K., Pardo, J. D., Benca, J., and Small, B. J. (2011). New Upper Pennsylvanian armored dissorophid records (Temnospondyli, Dissorophoidea) from the U.S. midcontinent and the stratigraphic distributions of dissorophids. *Journal of Vertebrate Paleontology*, 31(4):907–912.

Mazierski, D. M. and Reisz, R. R. (2010). Description of a new specimen of *Ianthasaurus hardestiorum* (Eupelycosauria: Edaphosauridae) and a re-evaluation of edaphosaurid phylogeny. *Canadian Journal of Earth Sciences*, 47(6):901–912.

McGhee, Jr., G. R. (2013). *When the Invasion of Land Failed*. Columbia University Press, New York. 317 pp.

McGowan, C. (1996). Giant ichthyosaurs of the Early Jurassic. *Canadian Journal of Earth Sciences*, 33(7):1011–1021.

McGowan, C. and Motani, R. (1999). A reinterpretation of the Upper Triassic ichthyosaur *Shonisaurus*. *Journal of Vertebrate Paleontology*, 19(1):42–49.

McGowan, C. and Motani, R. (2003). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 8: Ichthyopterygia*. Verlag Dr. Friedrich Pfeil, München. 173 pp.

McHugh, J. B. (2012). *Temnospondyl ontogeny and phylogeny, a window into terrestrial ecosystems during the Permian-Triassic mass extinction*. PhD thesis, University of Iowa. 198 pp.

McHugh, J. B. (2015). Paleohistology of *Micropholis stowi* (Dissorophoidea) and *Lydekkerina huxleyi* (Lydekkerinidae) humeri from the Karoo Basin of South Africa, and implications for bone microstructure evolution in temnospondyl amphibians. *Journal of Vertebrate Paleontology*, 35(1):e902845.

McInroe, B., Astley, H. C., Gong, C., Kawano, S. M., Schiebel, P. E., Rieser, J. M., Choset, H., Blob, R. W., and Goldman, D. I. (2016). Tail use improves performance on soft substrates in models of early vertebrate land locomotors. *Science*, 353(6295):154–158.

McPhee, B. W. and Choiniere, J. N. (2018). The osteology of *Pulanesaura eocollum*: implications for the inclusivity of Sauropoda (Dinosauria). *Zoological Journal of the Linnean Society*, 182(4):830–861.

McPhee, B. W., Yates, A. M., Choiniere, J. N., and Abdala, F. (2014). The complete anatomy and phylogenetic relationships of *Antetonitrus ingenipes* (Sauropodiformes, Dinosauria): implications for the origins of Sauropoda. *Zoological Journal of the Linnean Society*, 171(1):151–205.

McPhee, B. W., Bonnan, M. F., Yates, A. M., Neveling, J., and Choiniere, J. N. (2015). A new basal sauropod from the pre-Toarcian Jurassic of South Africa: evidence of niche-partitioning at the sauropodomorph–sauropod boundary? *Scientific Reports*, 5:13224.

McPhee, B. W., Upchurch, P., Mannion, P. D., Sullivan, C., Butler, R. J., and Barrett, P. M. (2016). A revision of *Sanpasaurus yaoi* Young, 1944 from the Early Jurassic of China, and its relevance to the early evolution of Sauropoda (Dinosauria). *PeerJ*, 4:e2578.

McPhee, B. W., Bordy, E. M., Sciscio, L., and Choiniere, J. N. (2017). The sauropodomorph biostratigraphy of the Elliot Formation of southern Africa: Tracking the evolution of Sauropodomorpha across the Triassic–Jurassic boundary. *Acta Palaeontologica Polonica*, 62(3):441–465.

McPhee, B. W., Benson, R. B. J., Botha-Brink, J., Bordy, E. M., and Choiniere, J. N. (2018). A giant dinosaur from the earliest Jurassic of South Africa and the transition to quadrupedality in early sauropodomorphs. *Current Biology*, 28(19):3143–3151.

Meade, A. and Pagel, M. (2016). *Manual: BayesTraits V3*. University of Reading. 80 pp.

Mehl, M. G. (1915). The Phytosauria of the Trias. *The Journal of Geology*, 23(2):129–165.

Mehl, M. G. (1916). New or little known phytosaurs from Arizona. In Mehl, M. G., Toepelmann, W. C., and Schwartz, G. M., editors, *New or little known reptiles from the Trias of Arizona and New Mexico, with notes from the fossil bearing horizons near Wingate, New Mexico*, Bulletin of the University of Oklahoma, New Series 103, University Studies Series 5, pages 5–28. University of Oklahoma, Norman.

Mehl, M. G. (1922). A new phytosaur from the Trias of Arizona. *The Journal of Geology*, 30(2):144–157.

Melo, T. P., Abdala, F., and Soares, M. B. (2015). The Malagasy cynodont *Menadon besairiei* (Cynodontia; Traversodontidae) in the Middle–Upper Triassic of Brazil. *Journal of Vertebrate Paleontology*, 35(6):e1002562.

Melo, T. P., Martinelli, A. G., and Soares, M. B. (2017). A new gomphodont cynodont (Traversodontidae) from the Middle–Late Triassic Dinodontosaurus Assemblage Zone of the Santa Maria Supersequence, Brazil. *Palaeontology*, 60(4):571–582.

Mendrez, C. H. (1974a). A new specimen of *Promoschorhynchus platyrhinus* Brink 1954 (Moschorhinidae) from the *Daptocephalus*-zone (Upper Permian) of South Africa. *Palaeontologia africana*, 17:69–85.

Mendrez, C. H. (1974b). Etude du crane d'un jeune specimen de *Moschorhinus kitchingi* Broom, 1920 (? *Tigrisuchus simus* Owen, 1876), Therocephalia Pristerosauria Moschorhinidae d'Afrique australe. *Annals of the South African Museum*, 64:71–115.

Mendrez-Carroll, C. H. (1979). Nouvelle étude du crâne du type de *Scaloposaurus constrictus* Owen, 1876, spécimen jeune, Therocephalia, Scaloposauria, Scaloposauridae, de la zone à *Cistecephalus* (Permien supérieur) d'Afrique australe. *Bulletin du Muséum national d'Histoire naturelle, Paris, 4ème série, section C (Sciences de la Terre, Paléontologie, Géologie, Minéralogie)*, 1(3):155–201.

Meng, Q.-J., Ji, Q., Zhang, Y.-G., Liu, D., Grossnickle, D. M., and Luo, Z.-X. (2015). An arboreal docodont from the Jurassic and mammaliaform ecological diversification. *Science*, 347(6223):764–768.

Metzger, K. A., Daniel, W. J., and Ross, C. F. (2005). Comparison of beam theory and finite-element analysis with in vivo bone strain data from the alligator cranium. *The Anatomical Record Part A: Discoveries in Molecular, Cellular, and Evolutionary Biology*, 283A(2):331–348.

Meyer, A. L. S. and Wiens, J. J. (2018). Estimating diversification rates for higher taxa: BAMM can give problematic estimates of rates and rate shifts. *Evolution*, 72(1):39–53.

Milner, A. C. (1980). A review of the Nectridea (Amphibia). In Panchen, A. L., editor, *The Terrestrial Environment and the Origin of Land Vertebrates*, volume 15 of *Systematics Association Special Volume*, chapter 15, pages 377–405. Academic Press, London.

Milner, A. C. (1994). The aïstopod amphibian from the Viséan of East Kirkton, West Lothian, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 84(3–4):363–368.

Milner, A. C. (1996). A juvenile diplocaulid nectridean amphibian from the Lower Permian of Texas and Oklahoma. *Special Papers in Palaeontology*, 52:129–138.

Milner, A. C. and Ruta, M. (2009). A revision of *Scincosaurus* (Tetrapoda, Nectridea) from the Moscovian of Nýřany, Czech Republic, and the phylogeny and interrelationships of nectrideans. *Special Papers in Palaeontology*, 81:71–89.

Milner, A. C. and Barrett, P. M. (2016). Smith Woodward's contribution on fossil tetrapods. *Geological Society, London, Special Publications*, 430:289–309.

Milner, A. C., Milner, A. R., and Walsh, S. A. (2009). A new specimen of *Baphetes* from Nýřany, Czech Republic and the intrinsic relationships of the Baphetidae. *Acta Zoologica*, 90(s1):318–334.

Milner, A. R. (1978). A reappraisal of the early Permian amphibians *Memonomenos dyscriton* and *Cricotillus brachydens*. *Palaeontology*, 21(3):667–686.

Milner, A. R. (1982). Small temnospondyl amphibians from the Middle Pennsylvanian of Illinois. *Palaeontology*, 25(3):635–664.

Milner, A. R. (1989). The relationships of the eryopoid-grade temnospondyl amphibians from the Permian of Europe. *Acta Musei Reginaehradecensis Series A.: Scientiae Naturales*, 22:131–137.

Milner, A. R. (1991). Lydekkerinid temnospondyls - relationships and 'extinction'. In Kielan-Jaworowska, Z., Heintz, N., and Nakrem, H. A., editors, *Fifth Symposium on Mesozoic Terrestrial Ecosystems and Biota. Extended Abstracts*, number 364 in Contributions from the Paleontological Museum, University of Oslo, pages 49–50.

Milner, A. R. (1993). The Paleozoic relatives of lissamphibians. *Herpetological Monographs*, 7:8–27.

Milner, A. R. and Sequeira, S. E. K. (2003). Revision of the amphibian genus *Limnerpeton* (Temnospondyli) from the Upper Carboniferous of the Czech Republic. *Acta Palaeontologica Polonica*, 48(1):123–141.

Milner, A. R. and Sequeira, S. E. K. (2004). *Slaugenhopia texensis* (Amphibia: Temnospondyli) from the Permian of Texas is a primitive tupilakosaurid. *Journal of Vertebrate Paleontology*, 24(2):320–325.

Milner, A. R. and Schoch, R. R. (2013). *Trimerorhachis* (Amphibia: Temnospondyli) from the Lower Permian of Texas and New Mexico: cranial osteology, taxonomy and biostratigraphy. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 270(1):91–128.

Milner, A. R., Gardiner, B. G., Fraser, N. C., and Taylor, M. A. (1990). Vertebrates from the Middle Triassic Otter Sandstone Formation of Devon. *Palaeontology*, 33(4):873–892.

Milner, A. (2007). *Mordex laticeps* and the base of the Trematopidae. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 27(sup3):118A.

Milner, A. and Schoch, R. (2006). *Stegops*, a problematic spiky-head temnospondyl. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 26(sup3):101A.

Mitchell, J. S., Heckert, A. B., and Sues, H.-D. (2010). Grooves to tubes: evolution of the venom delivery system in a Late Triassic "reptile". *Naturwissenschaften*, 97(12):1117–1121.

Mocho, P., Royo-Torres, R., and Ortega, F. (2014). Phylogenetic reassessment of *Lourinhasaurus alenquerensis*, a basal Macronaria (Sauropoda) from the Upper Jurassic of Portugal. *Zoological Journal of the Linnean Society*, 170(4):875–916.

Modesto, S. P. (1996). A basal captorhinid reptile from the Fort Sill fissures, Lower Permian of Oklahoma. *Oklahoma Geology Notes*, 56(1):4–14.

Modesto, S. P. (1998). New information on the skull of the Early Permian reptile *Captorhinus aguti*. *PaleoBios*, 18(2–3):21–35.

Modesto, S. P. (1999). *Colobomycter pholeter* from the Lower Permian of Oklahoma: a parareptile, not a protorothyridid. *Journal of Vertebrate Paleontology*, 19(3):466–472.

Modesto, S. P. and Reisz, R. R. (1990a). A new skeleton of *Ianthasaurus hardestii*, a primitive edaphosaur (Synapsida: Pelycosauria) from the Upper Pennsylvanian of Kansas. *Canadian Journal of Earth Sciences*, 27(6):834–844.

Modesto, S. P. and Rybczynski, N. (2000). The amniote faunas of the Russian Permian: implications for Late Permian terrestrial vertebrate biogeography. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 17–34. Cambridge University Press, Cambridge.

Modesto, S. P. and Damiani, R. J. (2003). Taxonomic status of *Thelegnathus browni* Broom, a procolophonid reptile from the South African Triassic. *Annals of Carnegie Museum*, 72(1):53–64.

Modesto, S. P. and Sues, H.-D. (2004). The skull of the Early Triassic archosauromorph reptile *Prolacerta broomi* and its phylogenetic significance. *Zoological Journal of the Linnean Society*, 140(3):335–351.

Modesto, S. P. and Damiani, R. (2007). The procolophonoid reptile *Sauropareion anoplus* from the lowermost Triassic of South Africa. *Journal of Vertebrate Paleontology*, 27(2):337–349.

Modesto, S. P. and Botha-Brink, J. (2008). Evidence of a second, large archosauriform reptile in the Lower Triassic Katberg Formation of South Africa. *Journal of Vertebrate Paleontology*, 28(3):914–917.

Modesto, S. P., Damiani, R. J., and Sues, H.-D. (2002). A reappraisal of *Coletta seca*, a basal procolophonoid reptile from the Lower Triassic of South Africa. *Palaeontology*, 45(5):883–895.

Modesto, S. P., Damiani, R. J., Neveling, J., and Yates, A. M. (2003). A new Triassic owenettid parareptile and the mother of mass extinctions. *Journal of Vertebrate Paleontology*, 23(3):715–719.

Modesto, S. P., Scott, D. M., Botha-Brink, J., and Reisz, R. R. (2010). A new and unusual procolophonid parareptile from the Lower Triassic Katberg Formation of South Africa. *Journal of Vertebrate Paleontology*, 30(3):715–723.

Modesto, S. P., Lamb, A. J., and Reisz, R. R. (2014). The captorhinid reptile *Captorhinikos valensis* from the lower Permian Vale Formation of Texas, and the evolution of herbivory in eureptiles. *Journal of Vertebrate Paleontology*, 34(2):291–302.

Modesto, S. P., Scott, D. M., MacDougall, M. J., Sues, H.-D., Evans, D. C., and Reisz, R. R. (2015). The oldest parareptile and the early diversification of reptiles. *Proceedings of the Royal Society of London B: Biological Sciences*, 282(1801):20141912.

Modesto, S. P., Scott, D., and Reisz, R. R. (2018). A new small captorhinid reptile from the lower Permian of Oklahoma and resource partitioning among small captorhinids in the Richards Spur fauna. *Papers in Palaeontology*, 4(2):293–307.

Modesto, S. and Reisz, R. R. (1990b). Taxonomic status of *Edaphosaurus raymondi* Case. *Journal of Paleontology*, 64(6):1049–1051.

Modesto, S. and Smith, R. M. H. (2001). A new Late Permian captorhinid reptile: a first record from the South African Karoo. *Journal of Vertebrate Paleontology*, 21(3):405–409.

Moen, D. and Morlon, H. (2014). Why does diversification slow down? *Trends in Ecology & Evolution*, 29(4):190–197.

Molnar, J. L., Pierce, S. E., Bhullar, B.-A. S., Turner, A. H., and Hutchinson, J. R. (2015). Morphological and functional changes in the vertebral column with increasing aquatic adaptation in crocodylomorphs. *Royal Society Open Science*, 2(11):150439.

Montañez, I. P., Tabor, N. J., Niemeier, D., DiMichele, W. A., Frank, T. D., Fielding, C. R., Isbell, J. L., Birgenheier, L. P., and Rygel, M. C. (2007). CO_2-forced climate and vegetation instability during Late Paleozoic deglaciation. *Science*, 315(5808):87–91.

Montefeltro, F. C., Langer, M. C., and Schultz, C. L. (2010). Cranial anatomy of a new genus of hyperodapedontine rhynchosaur (Diapsida, Archosauromorpha) from the Upper Triassic of southern Brazil. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(1):27–52.

Montellano, M., Hopson, J. A., and Clark, J. M. (2008). Late Early Jurassic mammaliaforms from Huizachal Canyon, Tamaulipas, México. *Journal of Vertebrate Paleontology*, 28(4):1130–1143.

Moon, B. C. (2019). A new phylogeny of ichthyosaurs (Reptilia: Diapsida). *Journal of Systematic Palaeontology*, 17(2):129–155.

Moore, B. R., Höhna, S., May, M. R., Rannala, B., and Huelsenbeck, J. P. (2016). Critically evaluating the theory and performance of Bayesian analysis of macroevolutionary mixtures. *Proceedings of the National Academy of Sciences*, 113(34):9569–9574.

Morales, M. and Shishkin, M. A. (2002). A re-assessment of *Parotosuchus africanus* (Broom), a capitosauroid temnospondyl amphibian from the Triassic of South Africa. *Journal of Vertebrate Paleontology*, 22(1):1–11.

Morato, L. (2006). *Dinodontosaurus* (Synapsida, Dicynodontia): reconstituições morfológicas e aspectos biomecânicos. Master's thesis, Universidade Federal do Rio Grande do Sul, Porto Alegre. 158 pp.

Mortimer, M. (2011). Do they even understand the matrix they're coding? The Theropod Database Blog. January 28, http://theropoddatabase.blogspot.co.uk/2011/01/do-they-even-understand-matrix-theyre.html.

Moser, M. (2003). *Plateosaurus engelhardti* Meyer, 1837 (Dinosauria: Sauropodomorpha) aus dem Feuerletten (Mittelkeuper; Obertrias) von Bayern. *Zitteliana, Reihe B*, 24:3–186.

Moser, M. and Schoch, R. (2007). Revision of the type material and nomenclature of *Mastodonsaurus giganteus* (Jaeger) (Temnospondyli) from the Middle Triassic of Germany. *Palaeontology*, 50(5):1245–1266.

Motani, R. (1999). Phylogeny of the Ichthyopterygia. *Journal of Vertebrate Paleontology*, 19(3):473–496.

Motani, R. (2000). Is *Omphalosaurus* ichthyopterygian?–A phylogenetic perspective. *Journal of Vertebrate Paleontology*, 20(2):295–301.

Motani, R. (2009). The evolution of marine reptiles. *Evolution: Education and Outreach*, 2(2):224–235.

Motani, R., Manabe, M., and Dong, Z.-M. (1999). The status of *Himalayasaurus tibetensis* (Ichthyopterygia). *Paludicola*, 2(2):174–181.

Motani, R., Jiang, D.-Y., Chen, G.-B., Tintori, A., Rieppel, O., Ji, C., and Huang, J.-D. (2015a). A basal ichthyosauriform with a short snout from the Lower Triassic of China. *Nature*, 517(7535):485–488.

Motani, R., Chen, X.-h., Jiang, D.-y., Cheng, L., Tintori, A., and Rieppel, O. (2015b). Lunge feeding in early marine reptiles and fast evolution of marine tetrapod feeding guilds. *Scientific Reports*, 5:8900.

Motani, R., Jiang, D.-Y., Tintori, A., Rieppel, O., Chen, G.-B., and You, H. (2015c). Status of *Chaohusaurus chaoxianensis* (Chen, 1985). *Journal of Vertebrate Paleontology*, 35(1):e892011.

Motani, R., Jiang, D.-y., Tintori, A., Ji, C., and Huang, J.-d. (2017). Pre- versus post-mass extinction divergence of Mesozoic marine reptiles dictated by time-scale dependence of evolutionary rates. *Proceedings of the Royal Society B: Biological Sciences*, 284(1854):20170241.

Motulsky, H. and Christopoulos, A. (2003). *Fitting Models to Biological Data using Linear and Nonlinear Regression. A practical guide to curve fitting*. GraphPad Software, San Diego. 351 pp.

Mueller, B. D. (2007). *Koskinonodon* Branson and Mehl, 1929, a replacement name for the preoccupied temnospondyl *Buettneria* Case, 1922. *Journal of Vertebrate Paleontology*, 27(1):225.

Mueller, B. D. and Parker, W. G. (2006). A new species of Trilophosaurus (Diapsida: Archosauromorpha) from the Sonsela Member (Chinle Formation) of Petrified Forest National Park, Arizona. *Museum of Northern Arizona Bulletin*, 62:119–125.

Mueller-Töwe, I. J. (2006). *Anatomy, phylogeny, and palaeoecology of the basal thalattosuchians (Mesoeucrocodylia) from the Liassic of Central Europe*. PhD thesis, Johannes Gutenberg-Universität, Mainz. 369 pp.

Mukherjee, D. and Ray, S. (2014). A new *Hyperodapedon* (Archosauromorpha, Rhynchosauria) from the Upper Triassic of India: implications for rhynchosaur phylogeny. *Palaeontology*, 57(6):1241–1276.

Mukherjee, D., Ray, S., Chandra, S., Pal, S., and Bandyopadhyay, S. (2012). Upper Gondwana succession of the Rewa Basin, India: understanding the interrelationship of lithologic and stratigraphic variables. *Journal of the Geological Society of India*, 79(6):563–575.

Müller, J. (2005a). The anatomy of *Askeptosaurus italicus* from the Middle Triassic of Monte San Giorgio and the interrelationships of thalattosaurs (Reptilia, Diapsida). *Canadian Journal of Earth Sciences*, 42(7):1347–1367.

Müller, J. and Reisz, R. R. (2005). An early captorhinid reptile (Amniota, Eureptilia) from the Upper Carboniferous of Hamilton, Kansas. *Journal of Vertebrate Paleontology*, 25(3):561–568.

Müller, J. and Reisz, R. R. (2006). The phylogeny of early eureptiles: comparing parsimony and Bayesian approaches in the investigation of a basal fossil clade. *Systematic Biology*, 55(3):503–511.

Müller, J. and Danto, M. (2012). The enigmatic reptile *Kadaliosaurus* from the Lower Permian of Germany and the monophyly of araeoscelidian diapsids. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 32(sup2):147–148.

Müller, J., Berman, D. S., Henrici, A. C., Martens, T., and Sumida, S. S. (2006). The basal reptile *Thuringothyris mahlendorffae* (Amniota: Eureptilia) from the Lower Permian of Germany. *Journal of Paleontology*, 80(4):726–739.

Müller, J., Li, J.-L., and Reisz, R. R. (2008). A new bolosaurid parareptile, *Belebey chengi* sp. nov., from the Middle Permian of China and its paleogeographic significance. *Naturwissenschaften*, 95(12):1169–1174.

Müller, J., Scheyer, T. M., Head, J. J., Barrett, P. M., Werneburg, I., Ericson, P. G. P., Pol, D., and Sánchez-Villagra, M. R. (2010). Homeotic effects, somitogenesis and the evolution of vertebral numbers in recent and fossil amniotes. *Proceedings of the National Academy of Sciences*, 107(5):2118–2123.

Müller, M. E. (2005b). Cladogenetic size increase with climate induced punctuation in two clades of Triassic plagiosaurides. In Lindgren, J., Eriksson, M. E., and Calner, M., editors, *Meeting proceedings: Lundadagarna i Historisk Geologi och Paleontologi IX 14–15th of March, 2005*, volume 127 of *GFF*, page 53.

Müller, R. T. and Dias-da-Silva, S. (2017). Taxon sample and character coding deeply impact unstable branches in phylogenetic trees of dinosaurs. *Historical Biology*, pages 1–4.

Müller, R. T., Langer, M. C., Aires, A. S. S., and Dias-da-Silva, S. (2014). New dinosauriform (Ornithodira, Dinosauromorpha) record from the Upper Triassic of Southern Brazil. *Paleontological Research*, 18(2):118–121.

Müller, R. T., Langer, M. C., Cabreira, S. F., and Dias-da-Silva, S. (2016). The femoral anatomy of *Pampadromaeus barberenai* based on a new specimen from the Upper Triassic of Brazil. *Historical Biology*, 28(5):656–665.

Müller, R. T., Langer, M. C., Bronzati, M., Pacheco, C. P., Cabreira, S. F., and Dias-da-Silva, S. (2018a). Early evolution of sauropodomorphs: anatomy and phylogenetic relationships of a remarkably well-preserved dinosaur from the Upper Triassic of southern Brazil. *Zoological Journal of the Linnean Society*, 184(4):1187–1248.

Müller, R. T., Langer, M. C., and Dias-da-Silva, S. (2018b). Ingroup relationships of Lagerpetidae (Avemetatarsalia: Dinosauromorpha): a further phylogenetic investigation on the understanding of dinosaur relatives. *Zootaxa*, 4392(1):149–158.

Müller, R. T., Langer, M. C., Pacheco, C. P., and Dias-da-Silva, S. (2019). The role of ontogeny on character polarization in early dinosaurs: a new specimen from the Late Triassic of southern Brazil and its implications. *Historical Biology*, 31(6):794–805.

Munk, W. and Sues, H.-D. (1993). Gut contents of *Parasaurus* (Pareiasauria) and *Protorosaurus* (Archosauromorpha) from the Kupferschiefer (Upper Permian) of Hessen, Germany. *Paläontologische Zeitschrift*, 67(1–2):169–176.

Muñoz-Muñoz, F. and Perpiñán, D. (2010). Measurement error in morphometric studies: comparison between manual and computerized methods. *Annales Zoologici Fennici*, 47(1):46–56.

Murry, P. A. (1987). New reptiles from the Upper Triassic Chinle Formation of Arizona. *Journal of Paleontology*, 61(4):773–786.

Murry, P. A. and Long, R. A. (1989). Geology and paleontology of the Cinle Formation, Petrified Forest National Park and vicinity, Arizona and a discussion of vertebrate fossils of the southwestern Upper Triassic. In Lucas, S. G. and Hunt, A. P., editors, *Dawn of the Age of Dinosaurs in the American Southwest*, pages 29–64. New Mexico Museum of Natural History, Albuquerque.

Nair, J. P. and Salisbury, S. W. (2012). New anatomical information on *Rhoetosaurus brownei* Longman, 1926, a gravisaurian sauropodomorph dinosaur from the Middle Jurassic of Queensland, Australia. *Journal of Vertebrate Paleontology*, 32(2):369–394.

Naish, D. and Martill, D. M. (2007). Dinosaurs of Great Britain and the role of the Geological Society of London in their discovery: basal Dinosauria and Saurischia. *Journal of the Geological Society*, 164(3):493–510.

Nakajima, Y. and Schoch, R. R. (2011). The first temnospondyl amphibian from Japan. *Journal of Vertebrate Paleontology*, 31(5):1154–1157.

Narkiewicz, K. and Narkiewicz, M. (2015). The age of the oldest tetrapod tracks from Zachełmie, Poland. *Lethaia*, 48(1):10–12.

Nash, D. S. (1975). The morphology and relationships of a crocodilian, *Orthosuchus stormbergi*, from the Upper Triassic of Lesotho. *Annals of the South African Museum*, 67(7):227–329.

Nasterlack, T., Canoville, A., and Chinsamy, A. (2012). New insights into the biology of the Permian genus *Cistecephalus* (Therapsida, Dicynodontia). *Journal of Vertebrate Paleontology*, 32(6):1396–1410.

Nath, T. and Yadagiri, P. (2007). A new mammal-like reptile (Cynodontia) from Upper Triassic Maleri Formation of Pranhita-Godavari Valley, Andhra Pradesh. *Journal of the Geological Society of India*, 69(1):57–60.

Natural History Museum (2014a). Dataset: Collection specimens. Resource: Specimens. Record: http://data.nhm.ac.uk/specimen/4ea21a0c-21ee-4249-9aef-d4ebebfe5b6b. Technical report, Retrieved: 16:13 06 Aug 2015 (GMT).

Natural History Museum (2014b). Dataset: Collection specimens. Resource: Specimens. Record: http://data.nhm.ac.uk/specimen/c7157042-9dc0-400f-9daf-8b6a4926c7c9. Technical report, Retrieved: 16:13 06 Aug 2015 (GMT).

Navarro, C. A., Martin-Silverstone, E., and Stubbs, T. L. (2018). Morphometric assessment of pterosaur jaw disparity. *Royal Society Open Science*, 5(4):172130.

Neenan, J. M., Klein, N., and Scheyer, T. M. (2013). European origin of placodont marine reptiles and the evolution of crushing dentition in Placodontia. *Nature Communications*, 4:1621.

Neenan, J. M., Li, C., Rieppel, O., and Scheyer, T. M. (2015). The cranial anatomy of Chinese placodonts and the phylogeny of Placodontia (Diapsida: Sauropterygia). *Zoological Journal of the Linnean Society*, 175(2):415–428.

Nelson, W. J., Hook, R. W., and Chaney, D. S. (2013). Lithostratigraphy of the Lower Permian (Leonardian) Clear Fork Formation of north-central Texas. In Lucas, S. G., DiMichele, W. A., Barrick, J. E., Schneider, J. W., and Spielmann, J. A., editors, *Carboniferous-Permian transition in central New Mexico*, volume 60, pages 286–311. New Mexico Museum of Natural History.

Nesbitt, S. J. (2005). Osteology of the Middle Triassic pseudosuchian archosaur *Arizonasaurus babbitti*. *Historical Biology*, 17(1–4):19–47.

Nesbitt, S. J. (2009). *The early evolution of archosaurs: relationships and the origin of major clades*. PhD thesis, Columbia University, New York. 656 pp.

Nesbitt, S. J. (2011). The early evolution of archosaurs: relationships and the origin of major clades. *Bulletin of the American Museum of Natural History*, 352:1–292.

Nesbitt, S. J. and Butler, R. J. (2013). Redescription of the archosaur *Parringtonia gracilis* from the Middle Triassic Manda beds of Tanzania, and the antiquity of Erpetosuchidae. *Geological Magazine*, 150(2):225–238.

Nesbitt, S. J. and Ezcurra, M. D. (2015). The early fossil record of dinosaurs in North America: a new neotheropod from the base of the Upper Triassic Dockum Group of Texas. *Acta Palaeontologica Polonica*, 60(3):513–526.

Nesbitt, S. J., Irmis, R. B., and Parker, W. G. (2007). A critical re-evaluation of the Late Triassic dinosaur taxa of North America. *Journal of Systematic Palaeontology*, 5(2):209–243.

Nesbitt, S. J., Smith, N. D., Irmis, R. B., Turner, A. H., Downs, A., and Norell, M. A. (2009a). A complete skeleton of a Late Triassic saurischian and the early evolution of dinosaurs. *Science*, 326(5959):1530–1533.

Nesbitt, S. J., Stocker, M. R., Small, B. J., and Downs, A. (2009b). The osteology and relationships of *Vancleavea campi* (Reptilia: Archosauriformes). *Zoological Journal of the Linnean Society*, 157(4):814–864.

Nesbitt, S. J., Liu, J., and Li, C. (2011). A sail-backed suchian from the Heshanggou Formation (Early Triassic: Olenekian) of China. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):271–284.

Nesbitt, S. J., Turner, A. H., and Weinbaum, J. C. (2012). A survey of skeletal elements in the orbit of Pseudosuchia and the origin of the crocodylian palpebral. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):365–381.

Nesbitt, S. J., Butler, R. J., and Gower, D. J. (2013a). A new archosauriform (Reptilia: Diapsida) from the Manda Beds (Middle Triassic) of southwestern Tanzania. *PLoS ONE*, 8(9):e72753.

Nesbitt, S. J., Desojo, J. B., and Irmis, R. B. (2013b). Anatomy, phylogeny and palaeobiology of early archosaurs and their kin. *Geological Society, London, Special Publications*, 379(1):1–7.

Nesbitt, S. J., Brusatte, S. L., Desojo, J. B., Liparini, A., De França, M. A. G., Weinbaum, J. C., and Gower, D. J. (2013c). Rauisuchia. *Geological Society, London, Special Publications*, 379(1):241–274.

Nesbitt, S. J., Barrett, P. M., Werning, S., Sidor, C. A., and Charig, A. J. (2013d). The oldest dinosaur? A Middle Triassic dinosauriform from Tanzania. *Biology Letters*, 9(1):20120949.

Nesbitt, S. J., Sidor, C. A., Angielczyk, K. D., Smith, R. M. H., and Tsuji, L. A. (2014). A new archosaur from the Manda beds (Anisian, Middle Triassic) of southern Tanzania and its implications for character state optimizations at Archosauria and Pseudosuchia. *Journal of Vertebrate Paleontology*, 34(6):1357–1382.

Nesbitt, S. J., Flynn, J. J., Pritchard, A. C., Parrish, J. M., Ranivoharimanana, L., and Wyss, A. R. (2015). Postcranial osteology of *Azendohsaurus madagaskarensis* (?Middle to Upper Triassic, Isalo Group, Madagascar) and its systematic position among stem archosaur reptiles. *Bulletin of the American Museum of Natural History*, 398:1–126.

Nesbitt, S. J., Butler, R. J., Ezcurra, M. D., Barrett, P. M., Stocker, M. R., Angielczyk, K. D., Smith, R. M. H., Sidor, C. A., Niedźwiedzki, G., Sennikov, A. G., and Charig, A. J. (2017). The earliest bird-line archosaurs and the assembly of the dinosaur body plan. *Nature*, 544(7651):484–487.

Nesbitt, S. (2007). The anatomy of *Effigia okeeffeae* (Archosauria, Suchia), theropod-like convergence, and the distribution of related taxa. *Bulletin of the American Museum of Natural History*, 302:1–84.

Nesbitt, S. and Desojo, J. B. (2017). The osteology and phylogenetic position of *Luperosuchus fractus* (Archosauria: Loricata) from the latest Middle Triassic or earliest Late Triassic of Argentina. *Ameghiniana*, 54(3):261–282.

Neubert, K. and Brunner, E. (2007). A studentized permutation test for the non-parametric Behrens–Fisher problem. *Computational Statistics & Data Analysis*, 51(10):5192–5204.

Neuhäuser, M. (2010). A nonparametric two-sample comparison for skewed data with unequal variances. *Journal of Clinical Epidemiology*, 63(6):691–693.

Neuhäuser, M. and Ruxton, G. D. (2009). Distribution-free two-sample comparisons in the case of heterogeneous variances. *Behavioral Ecology and Sociobiology*, 63(4):617–623.

Nicholls, E. L., Brinkman, D. B., and Wu, X.-C. (1998). A new archosaur from the Upper Triassic Pardonet Formation of British Columbia. *Canadian Journal of Earth Sciences*, 35(10):1134–1142.

Nicholls, E. L., Brinkman, D. B., and Callaway, J. M. (1999). New material of *Phalarodon* (Reptilia: Ichthyosauria) from the Triassic of British Columbia and its bearing on the interrelationships of mixosaurs. *Palaeontographica Abteilung A*, 252(1–3):1–22.

Nichols, K. M. and Silberling, N. J. (1977). Stratigraphy and depositional history of the Star Peak Group (Triassic), northwestern Nevada. *Geological Society of America Special Papers*, 178:1–74.

Nicolas, M. and Rubidge, B. S. (2010). Changes in Permo-Triassic terrestrial tetrapod ecological representation in the Beaufort Group (Karoo Supergroup) of South Africa. *Lethaia*, 43(1):45–59.

Niedźwiedzki, G., Szrek, P., Narkiewicz, K., Narkiewicz, M., and Ahlberg, P. E. (2010). Tetrapod trackways from the early Middle Devonian period of Poland. *Nature*, 463(7277):43–48.

Niedźwiedzki, G., Sulej, T., and Dzik, J. (2012). A large predatory archosaur from the Late Triassic of Poland. *Acta Palaeontologica Polonica*, 57(2):267–276.

Niedźwiedzki, G., Bajdek, P., Owocki, K., and Kear, B. P. (2016). An Early Triassic polar predator ecosystem revealed by vertebrate coprolites from the Bulgo Sandstone (Sydney Basin) of southeastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 464:5–15.

Niedźwiedzki, G., Bajdek, P., Qvarnström, M., Sulej, T., Sennikov, A. G., and Golubev, V. K. (2016). Reduction of vertebrate coprolite diversity associated with the end-Permian extinction event in Vyazniki region, European Russia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 450:77–90.

Niedźwiedzki, G., Sennikov, A., and Brusatte, S. L. (2016). The osteology and systematic position of *Dongusuchus efremovi* Sennikov, 1988 from the Anisian (Middle Triassic) of Russia. *Historical Biology*, 28(4):550–570.

Nield, C. M., Damiani, R., and Warren, A. (2006). A short-snouted trematosauroid (Tetrapoda, Temnospondyli) from the Early Triassic of Australia: the oldest known trematosaurine. *Alcheringa: An Australasian Journal of Palaeontology*, 30(2):263–271.

Nordén, K. K., Duffin, C. J., and Benton, M. J. (2015). A marine vertebrate fauna from the Late Triassic of Somerset, and a review of British placodonts. *Proceedings of the Geologists' Association*, 126(4–5):564–581.

Norman, D. B., Witmer, L. M., and Weishampel, D. B. (2004). Basal Ornithischia. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 325–334. University of California Press, Berkeley, Second edition.

Norman, D. B., Butler, R. J., and Maidment, S. C. R. (2007). Reconsidering the status and affinities of the ornithischian dinosaur *Tatisaurus oehleri* Simmons, 1965. *Zoological Journal of the Linnean Society*, 150(4):865–874.

Norman, D. B., Crompton, A. W., Butler, R. J., Porro, L. B., and Charig, A. J. (2011). The Lower Jurassic ornithischian dinosaur *Heterodontosaurus tucki* Crompton & Charig, 1962: cranial anatomy, functional morphology, taxonomy, and relationships. *Zoological Journal of the Linnean Society*, 163(1):182–276.

Nosotti, S. (2007). *Tanystropheus longobardicus* (Reptilia, Protorosauria): re-interpretations of the anatomy based on new specimens from the Middle Triassic of Besano (Lombardy, northern Italy). *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, 35(3):1–88.

Novas, F. E. (1994). New information on the systematics and postcranial skeleton of *Herrerasaurus ischigualastensis* (Theropoda: Herrerasauridae) from the Ischigualasto Formation (Upper Triassic) of Argentina. *Journal of Vertebrate Paleontology*, 13(4):400–423.

Novas, F. E., Ezcurra, M. D., Chatterjee, S., and Kutty, T. S. (2011). New dinosaur species from the Upper Triassic Upper Maleri and Lower Dharmaram formations of Central India. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):333–349.

Novas, F. E., Agnolin, F. L., and Ezcurra, M. D. (2015). Taxonomy of basal dinosauriforms: evidence provided by a new specimen from the Triassic Chañares Formation, NW Argentina.

In *Libro de resúmenes del V Congreso Latinoamericano de Paleontología de Vertebrados*, page 50. Colonia del Sacramento, Uruguay.

Novikov, I. V. (1986). A new species of *Parotosuchus* (Amphibia: Labyrinthodontia) from the Triassic deposits of the Vychegda River Basin. *Paleontological Journal*, 20(3):126–128.

Novikov, I. V. (1990). New Early Triassic labyrinthodonts from the Middle Timan'. *Paleontological Journal*, 24(1):48–60.

Novikov, I. V. (1993). On the major stages of Early Triassic faunal development in Eastern Europe. In Lucas, S. G. and Morales, M., editors, *The Nonmarine Triassic*, volume 3, pages 369–370. New Mexico Museum of Natural History.

Novikov, I. V. (1994). Continental Triassic biostratigraphy of the Timan-North Urals region using tetrapod fauna. *Trudy Paleontologicheskogo Instituta RAN*, 261:1–139. [In Russian].

Novikov, I. V. (2007). New data on trematosauroid labyrinthodonts of Eastern Europe: 1. Genus *Inflectosaurus* Shishkin, 1960. *Paleontological Journal*, 41(2):167–174.

Novikov, I. V. (2010). New data on trematosauroid labyrinthodonts of Eastern Europe: 2. *Trematosaurus galae* sp. nov.: cranial morphology. *Paleontological Journal*, 44(4):457–467.

Novikov, I. V. (2012a). New data on trematosauroid labyrinthodonts of Eastern Europe: 3. *Qantas samarensis* gen. et sp. nov. *Paleontological Journal*, 46(2):177–186.

Novikov, I. V. (2012b). New data on trematosauroid labyrinthodonts of Eastern Europe: 4. Genus *Benthosuchus* Efremov, 1937. *Paleontological Journal*, 46(4):400–411.

Novikov, I. V. (2016). New temnospondyl amphibians from the basal Triassic of Obshchii Syrt Highland, Eastern Europe. *Paleontological Journal*, 50(3):297–310.

Novikov, I. V., Shishkin, M. A., and Golubev, V. K. (2000). Permian and Triassic anthracosaurs from Eastern Europe. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 60–70. Cambridge University Press, Cambridge.

Novozhilov, N. I. (1948). [On the remains of an unknown vertebrate in the Permian deposits of the southern shore of the Khatanga Bay]. *Doklady Akademii Nauk SSSR*, 59(4):743–746. [In Russian].

Ogg, J. G., Ogg, G. M., and Gradstein, F. M. (2016). *A Concise Geologic Time Scale 2016*. Elsevier, Amsterdam. 234 pp.

O'Hara, R. B. and Kotze, D. J. (2010). Do not log-transform count data. *Methods in Ecology and Evolution*, 1(2):118–122.

Olivier, C., Houssaye, A., Jalil, N.-E., and Cubo, J. (2017). First palaeohistological inference of resting metabolic rate in an extinct synapsid, *Moghreberia nmachouensis* (Therapsida: Anomodontia). *Biological Journal of the Linnean Society*, 121(2):409–419.

Olori, J. C. (2013). Morphometric analysis of skeletal growth in the lepospondyls *Microbrachis pelikani* and *Hyloplesion longicostatum* (Tetrapoda, Lepospondyli). *Journal of Vertebrate Paleontology*, 33(6):1300–1320.

Olori, J. C. (2015). Skeletal morphogenesis of *Microbrachis* and *Hyloplesion* (Tetrapoda: Lepospondyli), and implications for the developmental patterns of extinct, early tetrapods. *PLoS ONE*, 10(6):e0128333.

Olroyd, S. L. and Sidor, C. A. (2017). A review of the Guadalupian (middle Permian) global tetrapod fossil record. *Earth-Science Reviews*, 171:583–597.

Olroyd, S. L., Sidor, C. A., and Angielczyk, K. D. (2017). New materials of the enigmatic dicynodont *Abajudon kaayai* (Therapsida, Anomodontia) from the lower Madumabisa Mudstone Formation, middle Permian of Zambia. *Journal of Vertebrate Paleontology*, 37(6):e1403442.

Olsen, P. E. and Flynn, J. J. (1989). Field guide to the vertebrate paleontology of Late Triassic rocks in the southwestern Newark Basin (Newark Supergroup, New Jersey and Pennsylvania). *The Mosasaur*, 4:1–43.

Olsen, P. E., Sues, H.-D., and Norell, M. A. (2000). First record of *Erpetosuchus* (Reptilia: Archosauria) from the Late Triassic of North America. *Journal of Vertebrate Paleontology*, 20(4):633–636.

Olshevsky, G. (1991). *A Revision of the Parainfraclass Archosauria Cope, 1869, Excluding the Advanced Crocodylia - Mesozoic Meanderings 2*. George Olshevsky, San Diego. 196 pp.

Olson, E. C. (1947). The family Diadectidae and its bearing on the classification of reptiles. *Fieldiana: Geology*, 11(1):1–53.

Olson, E. C. (1952). Fauna of the Upper Vale and Choza: 6. *Diplocaulus*. *Fieldiana: Geology*, 10(14):147–166.

Olson, E. C. (1957). Catalogue of localities of Permian and Triassic terrestrial vertebrates of the territories of the U.S.S.R. *The Journal of Geology*, 65(2):196–226.

Olson, E. C. (1958). Fauna of the Vale and Choza: 14. Summary, review, and integration of the geology and the faunas. *Fieldiana: Geology*, 10(32):397–448.

Olson, E. C. (1962). Late Permian terrestrial vertebrates, U.S.A. and U.S.S.R. *Transactions of the American Philosophical Society, New Series*, 52(2):1–224.

Olson, E. C. (1967). Early Permian vertebrates of Oklahoma. *Oklahoma Geological Survey Circular*, 74:1–111.

Olson, E. C. (1968). The family Caseidae. *Fieldiana: Geology*, 17(3):225–349.

Olson, E. C. (1970). New and little known genera and species of vertebrates from the Lower Permian of Oklahoma. *Fieldiana: Geology*, 18(3):359–434.

Olson, E. C. (1972a). *Diplocaulus parvus* n. sp. (Amphibia: Nectridea) from the Chickasha Formation (Permian: Guadalupian) of Oklahoma. *Journal of Paleontology*, 46(5):656–659.

Olson, E. C. (1972b). *Fayella chickashaensis*, the Dissorophoidea and the Permian terrestrial radiations. *Journal of Paleontology*, 46(1):104–114.

Olson, E. C. (1979). *Seymouria grandis* n. sp.(Batrachosauria: Amphibia) from the Middle Clear Fork (Permian) of Oklahoma and Texas. *Journal of Paleontology*, 53(3):720–728.

Olson, E. C. (1980). The North American Seymouriidae. In Jacobs, L. L., editor, *Aspects of Vertebrate History*, pages 137–152. Museum of Northern Arizona Press, Flagstaff.

Olson, E. C. and Mead, J. G. (1982). The Vale Formation (Lower Permian): its vertebrates and paleoecology. *Texas Memorial Museum Bulletin*, 29:1–46.

Olson, E. C. and Chudinov, P. (1992). Upper Permian terrestrial vertebrates of the USA and Russia: 1991. *International Geology Review*, 34(11):1143–1160.

O'Meara, R. N. and Asher, R. J. (2016). The evolution of growth patterns in mammalian versus nonmammalian cynodonts. *Paleobiology*, 42(3):439–464.

Opluštil, S., Schmitz, M., Kachlík, V., and Štamberg, S. (2016). Re-assessment of lithostratigraphy, biostratigraphy, and volcanic activity of the Late Paleozoic Intra-Sudetic, Krkonoše-Piedmont and Mnichovo Hradiště Basins (Czech Republic) based on new U-Pb CA-ID-TIMS ages. *Bulletin of Geosciences*, 91(2):399–432.

Opluštil, S., Jirásek, J., Schmitz, M., and Matýsek, D. (2017). Biotic changes around the radioisotopically constrained Carboniferous-Permian boundary in the Boskovice Basin (Czech Republic). *Bulletin of Geosciences*, 92(1):95–122.

Orr, W. N. (1986). A Norian (Late Triassic) ichthyosaur from the Martin Bridge Limestone, Wallowa Mountains, Oregon. In Vallier, T. L. and Brooks, H. C., editors, *Geology of the Blue Mountains Region of Oregon, Idaho, and Washington*, number 1435 in U. S. Geological Survey Professional Paper, pages 41–47. United States Government Printing Office, Washington.

Osborn, H. F. (1886). A new mammal from the American Triassic. *Science*, 8(201):540.

Ősi, A. (2011). Feeding-related characters in basal pterosaurs: implications for jaw mechanism, dental function and diet. *Lethaia*, 44(2):136–152.

Ősi, A. (2014). The evolution of jaw mechanism and dental function in heterodont crocodyliforms. *Historical Biology*, 26(3):279–414.

Ősi, A., Botfalvai, G., Prondvai, E., Hajdu, Z., Czirják, G., Szentesi, Z., Pozsgai, E., Götz, A., Makádi, L., Csengődi, D., and Sebe, K. (2013). First report of Triassic vertebrate assemblages from the Villány Hills (Southern Hungary). *Central European Geology*, 56(4):297–335.

Ősi, A., Young, M. T., Galácz, A., and Rabi, M. (2018). A new large-bodied thalattosuchian crocodyliform from the Lower Jurassic (Toarcian) of Hungary, with further evidence of the mosaic acquisition of marine adaptations in Metriorhynchoidea. *PeerJ*, 6:e4668.

Otero, A. and Reguero, M. (2013). Dinosaurs (Reptilia, Archosauria) at Museo de La Plata, Argentina: annotated catalogue of the type material and Antarctic specimens. *Palaeontologia Electronica*, 16(1.3T):24 pp.

Otero, A. and Pol, D. (2013). Postcranial anatomy and phylogenetic relationships of *Mussaurus patagonicus* (Dinosauria, Sauropodomorpha). *Journal of Vertebrate Paleontology*, 33(5):1138–1168.

Otero, A., Krupandan, E., Pol, D., Chinsamy, A., and Choiniere, J. (2015). A new basal sauropodiform from South Africa and the phylogenetic relationships of basal sauropodomorphs. *Zoological Journal of the Linnean Society*, 174(3):589–634.

Otoo, B. K. A., Clack, J. A., Smithson, T. R., Bennett, C. E., Kearsey, T. I., and Coates, M. I. (2019). A fish and tetrapod fauna from Romer's Gap preserved in Scottish Tournaisian floodplain deposits. *Palaeontology*, 62(2):225–253.

Ottone, E. G., Monti, M., Marsicano, C. A., de la Fuente, M. S., Naipauer, M., Armstrong, R., and Mancuso, A. C. (2014). A new Late Triassic age for the Puesto Viejo Group (San Rafael depocenter, Argentina): SHRIMP U–Pb zircon dating and biostratigraphic correlations across southern Gondwana. *Journal of South American Earth Sciences*, 56:186–199.

Owen, R. (1859). *On the Classification and Geographical Distribution of the Mammalia Being the Lecture on Sir Robert Reade's Foundation, Delivered before the University of Cambridge, in the Senate- House, May 10, 1859. To Which is Added an Appendix "On the Gorilla," and "On the Extinction and Transmutation of Species."*. John W. Parker and Son, London. 103 pp.

Owen, R. (1876). *Descriptive and illustrated catalogue of the Fossil Reptilia of South Africa in the collection of the British Museum*. British Museum (Natural History), London, United Kingdom. 88 pp.

Owen (1860). On some reptilian fossils from South Africa. *Quarterly Journal of the Geological Society of London*, 16(1–2):49–63.

Pacheco, C. P., Eltink, E., Müller, R. T., and Dias-da-Silva, S. (2017). A new Permian temnospondyl with Russian affinities from South America, the new family Konzhukoviidae, and the phylogenetic status of Archegosauroidea. *Journal of Systematic Palaeontology*, 15(3):241–256.

Pacheco, C. P., Martinelli, A. G., Pavanatto, A. E. B., Soares, M. B., and Dias-da-Silva, S. (2018). *Prozostrodon brasiliensis*, a probainognathian cynodont from the Late Triassic of Brazil: second record and improvements on its dental anatomy. *Historical Biology*, 30(4):475–485.

Padian, K. (1983). Osteology and functional morphology of *Dimorphodon macronyx* (Buckland) (Pterosauria: Rhamphorhynchoidea) based on new material in the Yale Peabody Museum. *Postilla*, 189:1–44.

Padian, K. (2008a). The Early Jurassic pterosaur *Campylognathoides* Strand, 1928. *Special Papers in Palaeontology*, 80:65–107.

Padian, K. (2008b). The Early Jurassic pterosaur *Dorygnathus banthensis* (Theodori, 1830). *Special Papers in Palaeontology*, 80:1–64.

Padian, K. (2013). The problem of dinosaur origins: integrating three approaches to the rise of Dinosauria. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103:423–442.

Padian, K. (2018). Measuring and comparing extinction events: reconsidering diversity crises and concepts. *Integrative and Comparative Biology*, 58(6):1191–1203.

Pagel, M. (1997). Inferring evolutionary processes from phylogenies. *Zoologica Scripta*, 26(4):331–348.

Pagel, M. (1999). Inferring the historical patterns of biological evolution. *Nature*, 401(6756):877–884.

Palmeirim, J. M. (1998). Analysis of skull measurements and measurers: can we use data obtained by various observers? *Journal of Mammalogy*, 79(3):1021–1028.

Panchen, A. L. (1970). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 5A: Batrachosauria (Anthracosauria)*. Verlag Dr. Friedrich Pfeil, München. 83 pp.

Panchen, A. L. (1975). A new genus and species of anthracosaur amphibian from the Lower Carboniferous of Scotland and the status of *Pholidogaster pisciformis* Huxley. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 269(900):581–637.

Panchen, A. L. (1977). On *Anthracosaurus russelli* Huxley (Amphibia: Labyrinthodontia) and the Family Anthracosauridae. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 279(968):447–512.

Panciroli, E., Walsh, S., Fraser, N. C., Brusatte, S. L., and Corfe, I. (2017). A reassessment of the postcanine dentition and systematics of the tritylodontid *Stereognathus* (Cynodontia, Tritylodontidae, Mammaliamorpha), from the Middle Jurassic of the United Kingdom. *Journal of Vertebrate Paleontology*, 37(5):e1351448.

Pankakoski, E., Väisänen, R. A., and Nurmi, K. (1987). Variability of muskrat skulls: measurement error, environmental modification and size allometry. *Systematic Biology*, 36(1):35–51.

Paradis, E. and Schliep, K. (2019). ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. *Bioinformatics*, 35(3):526–528.

Paradis, E., Claude, J., and Strimmer, K. (2004). APE: analyses of phylogenetics and evolution in R language. *Bioinformatics*, 20(2):289–290.

Pardo, J. D. (2014). Morphology, ontogeny, and phylogenetic relationships of the Permo-Carboniferous tetrapod *Brachydectes newberryi* from the Council Grove Group, Nebraska, USA. Master's thesis, University of Calgary, Calgary. 226 pp.

Pardo, J. D. and Anderson, J. S. (2016). Cranial morphology of the Carboniferous-Permian tetrapod *Brachydectes newberry* (Lepospondyli, Lysorophia): new data from μCT. *PLoS ONE*, 11(8):e0161823.

Pardo, J. D., Szostakiwskyj, M., Ahlberg, P. E., and Anderson, J. S. (2017a). Hidden morphological diversity among early tetrapods. *Nature*, 546:642–645.

Pardo, J. D., Small, B. J., and Huttenlocker, A. K. (2017b). Stem caecilian from the Triassic of Colorado sheds light on the origins of Lissamphibia. *Proceedings of the National Academy of Sciences*, 114(27):E5389–E5395.

Parham, J. F., Donoghue, P. C. J., Bell, C. J., Calway, T. D., Head, J. J., Holroyd, P. A., Inoue, J. G., Irmis, R. B., Joyce, W. G., Ksepka, D. T., Patané, J. S. L., Smith, N. D., Tarver, J. E., van Tuinen, M., Yang, Z., Angielczyk, K. D., Greenwood, J. M., Hipsley, C. A., Jacobs, L., Makovicky, P. J., Múller, J., Smith, K. T., Theodor, J. M., Warnock, R. C. M., and Benton, M. J. (2012). Best practices for justifying fossil calibrations. *Systematic Biology*, 61(2):346–359.

Parker, W. G. (2006). The stratigraphic distribution of major fossil localities in Petrified Forest National Park, Arizona. *Museum of Northern Arizona Bulletin*, 62:46–61.

Parker, W. G. (2007). Reassessment of the aetosaur '*Desmatosuchus*' *chamaensis* with a reanalysis of the phylogeny of the Aetosauria (Archosauria: Pseudosuchia). *Journal of Systematic Palaeontology*, 5(1):41–68.

Parker, W. G. (2008). Description of new material of the aetosaur *Desmatosuchus spurensis* (Archosauria: Suchia) from the Chinle Formation of Arizona and a revision of the genus *Desmatosuchus*. *PaleoBios*, 28(1):1–40.

Parker, W. G. (2012). Redescription and taxonomic status of specimens of *Episcoposaurus* and *Typothorax*, the earliest known aetosaurs (Archosauria: Suchia) from the Upper Triassic of western North America, and the problem of proxy “holotypes”. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):313–338.

Parker, W. G. (2014). *Taxonomy and phylogeny of the Aetosauria (Archosauria: Pseudosuchia) including a new species from the Upper Triassic of Arizona*. PhD thesis, University of Texas, Austin. 437 pp.

Parker, W. G. (2016). Revised phylogenetic analysis of the Aetosauria (Archosauria: Pseudosuchia); assessing the effects of incongruent morphological character sets. *PeerJ*, 4:e1583.

Parker, W. G. and Irmis, R. B. (2006). A new species of the Late Triassic phytosaur *Pseudopalatus* (Archosauria: Pseudosuchia) from Petrified Forest National Park, Arizona. *Museum of Northern Arizona Bulletin*, 62:126–143.

Parker, W. G. and Martz, J. W. (2010). Using positional homology in aetosaur (Archosauria: Pseudosuchia) osteoderms to evaluate the taxonomic status of *Lucasuchus hunti*. *Journal of Vertebrate Paleontology*, 30(4):1100–1108.

Parker, W. G. and Martz, J. W. (2011). The Late Triassic (Norian) Adamanian–Revueltian tetrapod faunal transition in the Chinle Formation of Petrified Forest National Park, Arizona. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):231–260.

Parker, W. G. and Nesbitt, S. J. (2013). Cranial remains of *Poposaurus gracilis* (Pseudosuchia: Poposauroidea) from the Upper Triassic, the distribution of the taxon, and its implications for poposauroid evolution. *Geological Society, London, Special Publications*, 379(1):503–523.

Parker, W. G., Hungerbühler, A., and Martz, J. W. (2012). The taxonomic status of the phytosaurs (Archosauriformes) *Machaeroprosopus* and *Pseudopalatus* from the Late Triassic of the western United States. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):265–268.

Parmar, V., Prasad, G. V. R., and Kumar, D. (2013). The first multituberculate mammal from India. *Naturwissenschaften*, 100(6):515–523.

Parrish, J. M. (1992). Phylogeny of the Erythrosuchidae (Reptilia: Archosauriformes). *Journal of Vertebrate Paleontology*, 12(1):93–102.

Parry, L. A., Baron, M. G., and Vinther, J. (2017). Multiple optimality criteria support Ornithoscelida. *Royal Society Open Science*, 4(10):170833.

Paton, R. L. (1974). Lower Permian pelycosaurs from the English midlands. *Palaeontology*, 17(3):541–552.

Paton, R. L., Smithson, T. R., and Clack, J. A. (1999). An amniote-like skeleton from the Early Carboniferous of Scotland. *Nature*, 398(6727):508–513.

Pavanatto, A. E. B., Pretto, F. A., Kerber, L., Müller, R. T., Da-Rosa, Á. A. S., and Dias-da-Silva, S. (2018). A new Upper Triassic cynodont-bearing fossiliferous site from southern Brazil, with taphonomic remarks and description of a new traversodontid taxon. *Journal of South American Earth Sciences*, 88:179–196.

Pawley, K. (2006). *The postcranial skeleton of temnospondyls (Tetrapoda: Temnospondyli)*. PhD thesis, La Trobe University, Melbourne. 442 pp.

Payne, J. L. and Clapham, M. E. (2012). End-Permian mass extinction in the oceans: an ancient analog for the twenty-first century? *Annual Reviews of Earth and Planetary Sciences*, 40(1):89–111.

Payne, J. L., Bush, A. M., Heim, N. A., Knope, M. L., and McCauley, D. J. (2016). Ecological selectivity of the emerging mass extinction in the oceans. *Science*, 353(6305):1284–1286.

Pearson, M. R., Benson, R. B., Upchurch, P., Fröbisch, J., and Kammerer, C. F. (2013). Reconstructing the diversity of early terrestrial herbivorous tetrapods. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 372:42–49.

Pelletier, V. (2014). Postcranial Description and Reconstruction of the Varanodontine Varanopid *Aerosaurus wellesi* (Synapsida: Eupelycosauria). In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 4, pages 53–68. Springer, Dordrecht.

Pennell, M. W. and Harmon, L. J. (2013). An integrative view of phylogenetic comparative methods: connections to population genetics, community ecology, and paleobiology. *Annals of the New York Academy of Sciences*, 1289(1):90–105.

Perea, D., Soto, M., Sterli, J., Mesa, V., Toriño, P., Roland, G., and Silva, J. D. (2014). *Tacuarembemys kusterae*, gen. et sp. nov., a new Late Jurassic–?earliest Cretaceous continental turtle from western Gondwana. *Journal of Vertebrate Paleontology*, 34(6):1329–1341.

Pérez-Ben, C. M., Schoch, R. R., and Báez, A. M. (2018). Miniaturization and morphological evolution in Paleozoic relatives of living amphibians: a quantitative approach. *Paleobiology*, 44(1):58–75.

Pérez-García, A. and Codrea, V. (2018). New insights on the anatomy and systematics of *Kallokibotion* Nopcsa, 1923, the enigmatic uppermost Cretaceous basal turtle (stem Testudines) from Transylvania. *Zoological Journal of the Linnean Society*, 182(2):419–443.

Perner, T. (2018). A new interesting archosaur from the Ladinian (Middle Triassic) of the Dolomites (Northern Italy) - Preliminary report. In Perner, T. and Wachtler, M., editors, *Some new and exciting Triassic Archosauria from the Dolomites (Northern Italy)*, pages 1–8. DOLOMYTHOS-Museum and Oregon Institute of Geological Research, Innichen.

Persons, IV, W. S. and Currie, P. J. (2016). An approach to scoring cursorial limb proportions in carnivorous dinosaurs and an attempt to account for allometry. *Scientific Reports*, 6:19828.

Persons, IV, W. S., Currie, P. J., and Erickson, G. M. (2019). An older and exceptionally large adult specimen of *Tyrannosaurus rex*. *Anatomical Record*, pages 1–17.

Peters, D. (2000). A reexamination of four prolacertiforms with implications for pterosaur phylogenesis. *Rivista Italiana di Paleontologia e Stratigrafia*, 106(3):293–336.

Peters, R. H. (1983). *The Ecological Implications of Body Size*. Cambridge University Press, Cambridge. 329 pp.

Peyer, K. and Allain, R. (2010). A reconstruction of *Tazoudasaurus naimi* (Dinosauria, Sauropoda) from the late Early Jurassic of Morocco. *Historical Biology*, 22(1-3):134–141.

Peyre de Fabrègues, C. and Allain, R. (2016). New material and revision of *Melanorosaurus thabanensis*, a basal sauropodomorph from the Upper Triassic of Lesotho. *PeerJ*, 4:e1639.

Peyre de Fabrègues, C., Allain, R., and Barriel, V. (2015). Root causes of phylogenetic incongruence observed within basal sauropodomorph interrelationships. *Zoological Journal of the Linnean Society*, 175(3):569–586.

Phillips, J. (1871). *Geology of Oxford and the Valley of the Thames*. Oxford University Press, Oxford. 523 pp.

Pianka, E. R. (1970). On r- and K-Selection. *The American Naturalist*, 104(940):592–597.

Pierce, S. E. and Benton, M. J. (2006). *Pelagosaurus typus* (Mesoeucrocodylia: Thalattosuchia) from the Upper Lias (Toarcian, Lower Jurassic) Of Somerset, England. *Journal of Vertebrate Paleontology*, 26(3):621–635.

Pierce, S. E., Clack, J. A., and Hutchinson, J. R. (2012). Three-dimensional limb joint mobility in the early tetrapod *Ichthyostega*. *Nature*, 486(7404):523–526.

Piñeiro, G., Ramos, A., and Marsicano, C. (2012). A rhinesuchid-like temnospondyl from the Permo-Triassic of Uruguay. *Comptes Rendus Palevol*, 11(1):65–78.

Pinheiro, F. L., França, M. A. G., Lacerda, M. B., Butler, R. J., and Schultz, C. L. (2016). An exceptional fossil skull from South America and the origins of the archosauriform radiation. *Scientific Reports*, 6:22817.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., EISPACK authors, Heisterkamp, S., Willigen, B. V., and R-core (2018). *Package 'nlme': linear and nonlinear mixed effects models*, 3.1-137 edition. 336 pp.

Plummer, M., Best, N., Cowles, K., and Vines, K. (2006). CODA: Convergence diagnosis and output analysis for MCMC. *R News*, 6(1):7–11.

Pol, D. and Powell, J. E. (2007). Skull anatomy of *Mussaurus patagonicus* (Dinosauria: Sauropodomorpha) from the Late Triassic of Patagonia. *Historical Biology*, 19(1):125–144.

Pol, D., Rauhut, O., and Carballido, J. (2009). Skull anatomy of a newbasal eusauropod from the Middle Jurassic of Patagonia. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 29(sup1):165A.

Pol, D., Rauhut, O. W. M., and Becerra, M. (2011). A Middle Jurassic heterodontosaurid dinosaur from Patagonia and the evolution of heterodontosaurids. *Naturwissenschaften*, 98(5):369–379.

Pol, D., Rauhut, O. W. M., Lecuona, A., Leardi, J. M., Xu, X., and Clark, J. M. (2013). A new fossil from the Jurassic of Patagonia reveals the early basicranial evolution and the origins of Crocodyliformes. *Biological Reviews*, 88(4):862–872.

Polley, B. P. and Reisz, R. R. (2011). A new Lower Permian trematopid (Temnospondyli: Dissorophoidea) from Richards Spur, Oklahoma. *Zoological Journal of the Linnean Society*, 161(4):789–815.

Porro, L. B., Holliday, C. M., Anapol, F., Ontiveros, L. C., Ontiveros, L. T., and Ross, C. F. (2011a). Free body analysis, beam mechanics, and finite element modeling of the mandible of *Alligator mississippiensis*. *Journal of Morphology*, 272(8):910–937.

Porro, L. B., Butler, R. J., Barrett, P. M., Moore-Fay, S., and Abel, R. L. (2011b). New heterodontosaurid specimens from the Lower Jurassic of southern Africa and the early ornithischian dinosaur radiation. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101(3–4):351–366.

Prasad, G. V. R. and Manhas, B. K. (1997). A new symmetrodont mammalfrom the Lower Jurassic Kota Formation, Pranhita-Godavari Valley, India. *Geobios*, 30(4):563–572.

Prasad, G. V. R. and Manhas, B. K. (2001). First docodont mammals of Laurasian affinity from India. *Current Science*, 81(9):1235–1238.

Prasad, G. V. R. and Manhas, B. K. (2002). Triconodont mammals from the Jurassic Kota Formation of India. *Geodiversitas*, 24(2):445–464.

Prasad, G. V. R. and Manhas, B. K. (2007). A new docodont mammal from the Jurassic Kota Formation of India. *Palaeontologia Electronica*, 10(2.7A):11 pp.

Pretto, F. A., Langer, M. C., and Schultz, C. L. (2019). A new dinosaur (Saurischia: Sauropodomorpha) from the Late Triassic of Brazil provides insights on the evolution of sauropodomorph body plan. *Zoological Journal of the Linnean Society*, 185(2):388–416.

Prieto-Márquez, A. and Norell, M. A. (2011). Redescription of a nearly complete skull of *Plateosaurus* (Dinosauria: Sauropodomorpha) from the Late Triassic of Trossingen (Germany). *American Museum Novitates*, 3727:1–58.

Pritchard, A. C. and Nesbitt, S. J. (2017). A bird-like skull in a Triassic diapsid reptile increases heterogeneity of the morphological and phylogenetic radiation of Diapsida. *Royal Society Open Science*, 4(10):170499.

Pritchard, A. C., Turner, A. H., Nesbitt, S. J., Irmis, R. B., and Smith, N. D. (2015). Late Triassic tanystropheids (Reptilia, Archosauromorpha) from northern New Mexico (Petrified Forest Member, Chinle Formation) and the biogeography, functional morphology, and evolution of Tanystropheidae. *Journal of Vertebrate Paleontology*, 35(2):e911186.

Pritchard, A. C., Gauthier, J. A., Hanson, M., Bever, G. S., and Bhullar, B.-A. S. (2018). A tiny Triassic saurian from Connecticut and the early evolution of the diapsid feeding apparatus. *Nature Communications*, 9:1213.

Pritchard, A., Turner, A., Irmis, R., Nesbitt, S., and Smith, N. (2016). Extreme modification of the tetrapod forelimb in a Triassic diapsid reptile. *Current Biology*, 26(20):2779–2786.

Puttick, M. N. (2018). Mixed evidence for early bursts of morphological evolution in extant clades. *Journal of Evolutionary Biology*, 31(4):502–515.

Puttick, M. N., Thomas, G. H., and Benton, M. J. (2014). High rates of evolution preceded the origin of birds. *Evolution*, 68(5):1497–1510.

Puttick, M. N., Kriwet, J., Wen, W., Hu, S., Thomas, G. H., and Benton, M. J. (2017a). Body length of bony fishes was not a selective factor during the biggest mass extinction of all time. *Palaeontology*, 60(5):727–741.

Puttick, M. N., O'Reilly, J. E., Tanner, A. R., Fleming, J. F., Clark, J., Holloway, L., Lozano-Fernandez, J., Parry, L. A., Tarver, J. E., Pisani, D., and Donoghue, P. C. J. (2017b). Uncertain-tree: discriminating among competing approaches to the phylogenetic analysis of phenotype data. *Proceedings of the Royal Society B: Biological Sciences*, 284(1846):20162290.

Pyron, R. A. (2011). Divergence time estimation using fossils as terminal taxa and the origins of Lissamphibia. *Systematic Biology*, 60(4):466–481.

R Core Team (2018). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Raath, M. A. (1969). A new coelurosaurian dinosaur from the Forest Sandstone of Rhodesia. *Arnoldia (Rhodesia)*, 4(28):1–25.

Rabosky, D. L. (2014). Automatic detection of key innovations, rate shifts, and diversity-dependence on phylogenetic trees. *PLoS ONE*, 9(2):e89543.

Rabosky, D. L. (2015). No substitute for real data: a cautionary note on the use of phylogenies from birth-death polytomy resolvers for downstream comparative analyses. *Evolution*, 69(12):3207–3216.

Rabosky, D. L. (2018). BAMM at the court of false equivalency: a response to Meyer and Wiens. *Evolution*, 72(10):2246–2256.

Rabosky, D. L. and Hurlbert, A. H. (2015). Species richness at continental scales is dominated by ecological limits. *The American Naturalist*, 185(5):572–583.

Rabosky, D. L., Santini, F., Eastman, J., Smith, S. A., Sidlauskas, B., Chang, J., and Alfaro, M. E. (2013). Rates of speciation and morphological evolution are correlated across the largest vertebrate radiation. *Nature Communications*, 4:1958.

Rabosky, D. L., Grundler, M., Anderson, C., Title, P., Shi, J. J., Brown, J. W., Huang, H., and Larson, J. G. (2014). BAMMtools: an R package for the analysis of evolutionary dynamics on phylogenetic trees. *Methods in Ecology and Evolution*, 5(7):701–707.

Rabosky, D. L., Mitchell, J. S., and Chang, J. (2017). Is BAMM flawed? Theoretical and practical concerns in the analysis of multi-rate diversification models. *Systematic Biology*, 66(4):477–498.

Rabosky, D. L., Chang, J., Title, P. O., Cowman, P. F., Sallan, L., Friedman, M., Kaschner, K., Garilao, C., Near, T. J., Coll, M., and Alfaro, M. E. (2018). An inverse latitudinal gradient in speciation rate for marine fishes. *Nature*, 559(7714):392–395.

Racey, A. and Goodall, J. G. S. (2009). Palynology and stratigraphy of the Mesozoic Khorat Group red bed sequences from Thailand. *Geological Society, London, Special Publications*, 315(1):69–83.

Racey, A., Love, M. A., Canham, A. C., Goodall, J. G. S., Polachan, S., and Jones, P. D. (1996). Stratigraphy and reservoir potential of the Mesozoic Khorat Group, NE Thailand: part 1: stratigraphy and sedimentary evolution. *Journal of Petroleum Geology*, 19(1):5–40.

Raftery, A. E. (1996). Hypothesis testing and model selection. In Gilks, W. R., Richardson, S., and Spiegelhalter, D. J., editors, *Markov Chain Monte Carlo in Practice*, chapter 10, pages 163–187. Springer, Dordrecht.

Ramsay, J. B. and Wilga, C. D. (2007). Morphology and mechanics of the teeth and jaws of white-spotted bamboo sharks (*Chiloscyllium plagiosum*). *Journal of Morphology*, 268(8):664–682.

Rasmussen, C., Huttenlocker, A. K., and Irmis, R. (2016). A new species of *Eryops* from the Lower Permian Cedar Mesa Sandstone (Cutler Group) of southeastern Utah and its implications for the phylogeny and biogeography of eryopids. *SVP Program and Abstracts Book*, page 211.

Rath, S. (2003). *Die Erforschungsgeschichte der Eifel-Geologie*. PhD thesis, Rheinisch-Westfälische Technische Hochschule Aachen, Aachen. 239 pp.

Raugust, T. (2014). *Descrição osteológica e análise filogenética de um novo material de Rauisuchia (Archosauria, Crurotarsi) da formação Santa Maria, Triássico Médio Sul-Rio-Grandense, Brasil*. PhD thesis, Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Porto Alegre. 383 pp.

Rauhut, O. W. M. (2003a). Revision of *Amygdalodon patagonicus* Cabrera, 1947 (Dinosauria, Sauropoda). *Fossil Record*, 6(1):173–181.

Rauhut, O. W. M. (2003b). The interrelationships and evolution of basal theropod dinosaurs. *Special Papers in Palaeontology*, 69:1–213.

Raup, D. M. (1972). Taxonomic diversity during the Phanerozoic. *Science*, 177(4054):1065–1071.

Raup, D. M. (1979). Biases in the fossil record of species and genera. *Bulletin of Carnegie Museum of Natural History*, 13:85–91.

Raup, D. M. and Sepkoski, J. J. (1982). Mass extinctions in the marine fossil record. *Science*, 215(4539):1501–1503.

Ray, S. (2001). Small Permian dicynodonts from India. *Paleontological Research*, 5(3):177–191.

Ray, S. (2005). *Lystrosaurus* (Therapsida, Dicynodontia) from India: taxonomy, relative growth and cranial dimorphism. *Journal of Systematic Palaeontology*, 3(2):203–221.

Ray, S. (2015). A new Late Triassic traversodontid cynodont (Therapsida, Eucynodontia) from India. *Journal of Vertebrate Paleontology*, 35(3):e930472.

Ray, S. and Bandyopadhyay, S. (2003). Late Permian vertebrate community of the Pranhita-Godavari Valley, India. *Journal of Asian Earth Sciences*, 21(6):643–654.

Reig, O. A. (1963). La presencia de dinosaurios saurisquios en los “Estratos de Ischigualasto” (Mesotriásico Superior) de las provincias de San Juan y La Rioja (República Argentina). *Ameghiniana*, 3(1):3–20.

Reiss, S. and Mallison, H. (2014). Motion range of the manus of *Plateosaurus engelhardti* von Meyer, 1837. *Palaeontologia Electronica*, 17(1.12A):19 pp.

Reisz, R. R. (1980). A protorothyridid captorhinomorph reptile from the Lower Permian of Oklahoma. *Life Sciences Contributions, Royal Ontario Museum*, 121:1–16.

Reisz, R. R. (1986). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 17A: Pelycosauria*. Verlag Dr. Friedrich Pfeil, München. 102 pp.

Reisz, R. R. (2014). “Pelycosaur”-Grade Synapsids: Introduction. In Kammerer, C. F., Angielczyk, K. D., and Fröbisch, J., editors, *Early Evolutionary History of the Synapsida*, Vertebrate Paleobiology and Paleoanthropology, chapter 1, pages 3–5. Springer, Dordrecht.

Reisz, R. R. and Berman, D. S. (1986). *Ianthasaurus hardestii* n. sp., a primitive edaphosaur (Reptilia, Pelycosauria) from the Upper Pennsylvanian Rock Lake Shale near Garnett, Kansas. *Canadian Journal of Earth Sciences*, 23(1):77–91.

Reisz, R. R. and Modesto, S. P. (1996). *Archerpeton anthracos* from the Joggins Formation of Nova Scotia: a microsaur, not a reptile. *Canadian Journal of Earth Sciences*, 33(5):703–709.

Reisz, R. R. and Laurin, M. (2001). The reptile *Macroleter*: First vertebrate evidence for correlation of Upper Permian continental strata of North America and Russia. *Geological Society of America Bulletin*, 113(9):1229–1233.

Reisz, R. R. and Scott, D. (2002). *Owenetta kitchingorum*, sp. nov., a small parareptile (Procolophonia: Owenettidae) from the Lower Triassic of South Africa. *Journal of Vertebrate Paleontology*, 22(2):244–256.

Reisz, R. R. and Müller, J. (2004). Molecular timescales and the fossil record: a paleontological perspective. *Trends in Genetics*, 20(5):237–241.

Reisz, R. R. and Fröbisch, J. (2014). The oldest caseid synapsid from the Late Pennsylvanian of Kansas, and the evolution of herbivory in terrestrial vertebrates. *PLoS ONE*, 9(4):e94518.

Reisz, R. R., Berman, D. S., and Scott, D. (1984). The anatomy and relationships of the Lower Permian Reptile *Araeoscelis*. *Journal of Vertebrate Paleontology*, 4(1):57–67.

Reisz, R. R., Berman, D. S., and Scott, D. (1992). The cranial anatomy and relationships of *Secodontosaurus*, an unusual mammal-like reptile (Synapsida: Sphenacodontidae) from the early Permian of Texas. *Zoological Journal of the Linnean Society*, 104(2):127–184.

Reisz, R. R., Wilson, H., and Scott, D. (1997). Varanopseid synapsid skeletal elements from Richards Spur, a Lower Permian fissure fill near Fort Sill, Oklahoma. *Oklahoma Geology Notes*, 57(5):160–170.

Reisz, R. R., Modesto, S. P., and Scott, D. (2000). *Acanthotoposaurus bremneri* and the origin of the Triassic archosauromorph reptile fauna of South Africa. *South African Journal of Science*, 96(8):443–445.

Reisz, R. R., Barkas, V., and Scott, D. (2002). A new early Permian bolosaurid reptile from the Richards Spur Dolese Brothers Quarry, near Fort Sill, Oklahoma. *Journal of Vertebrate Paleontology*, 22(1):23–28.

Reisz, R. R., Laurin, M., and Marjanović, D. (2010). *Apsisaurus witteri* from the Lower Permian of Texas: yet another small varanopid synapsid, not a diapsid. *Journal of Vertebrate Paleontology*, 30(5):1628–1631.

Reisz, R. R., Liu, J., Li, J.-L., and Müller, J. (2011a). A new captorhinid reptile, *Gansurhinus qingtoushanensis*, gen. et sp. nov., from the Permian of China. *Naturwissenschaften*, 98(5):435–441.

Reisz, R. R., Modesto, S. P., and Scott, D. M. (2011b). A new Early Permian reptile and its significance in early diapsid evolution. *Proceedings of the Royal Society of London B: Biological Sciences*, 278(1725):3731–3737.

Reisz, R. R., Scott, D. M., Pynn, B. R., and Modesto, S. P. (2011c). Osteomyelitis in a Paleozoic reptile: ancient evidence for bacterial infection and its evolutionary significance. *Naturwissenschaften*, 98(6):551–555.

Reisz, R. R., MacDougall, M. J., and Modesto, S. P. (2014). A new species of the parareptile genus *Delorhynchus*, based on articulated skeletal remains from Richards Spur, Lower Permian of Oklahoma. *Journal of Vertebrate Paleontology*, 34(5):1033–1043.

Reisz, R. R., LeBlanc, A. R. H., Sidor, C. A., Scott, D., and May, W. (2015). A new captorhinid reptile from the Lower Permian of Oklahoma showing remarkable dental and mandibular convergence with microsaurian tetrapods. *The Science of Nature*, 102(9–10):50.

Reisz, R. R., Haridy, Y., and Müller, J. (2016). *Euconcordia* nom. nov., a replacement name for the captorhinid eureptile *Concordia* Müller and Reisz, 2005 (non Kingsley, 1880), with new data on its dentition. *Vertebrate Anatomy Morphology Palaeontology*, 3:1–6.

Remes, K. and Rauhut, O. W. M. (2005). The oldest Indian dinosaur *Alwalkeria maleriensis* Chatterjee revised: a chimera including remains of a basal saurischian. In Kellner, A. W. A., Henriques, D. D. R., and Rodrigues, T., editors, *II Congresso Latino-Americano de Paleontologia* *de Vertebrados, Boletim de Resumos*, page 218, Rio de Janeiro. Museu Nacional/Universidade Federal do Rio de Janeiro.

Remes, K., Ortega, F., Fierro, I., Joger, U., Kosma, R., Marín Ferrer, J. M., for the Project PALDES, for the Niger Project SNHM, Ide, O. A., and Maga, A. (2009). A new basal sauropod dinosaur from the Middle Jurassic of Niger and the early evolution of Sauropoda. *PLoS ONE*, 4(9):e6924.

Renaut, A. J. (2000). *A re-evaluation of the cranial morphology and taxonomy of the Triassic dicynodont genus Kannemeyeria*. PhD thesis, University of Witwatersrand, Johannesburg. 197 pp.

Renaut, A. J. and Hancox, P. J. (2001). Cranial description and taxonomic re-evaluation of *Kannemeyeria argentinensis* (Therapsida, Dicynodontia). *Palaeontologia africana*, 37:81–91.

Renaut, A. J., Damiani, R. J., Yates, A. M., and Hancox, P. J. (2003). A taxonomic note concerning a dicynodont (Synapsida: Anomodontia) from the Middle Triassic of East Africa. *Palaeontologia africana*, 39:93–94.

Renesto, S. (1995). A sphenodontid from the Norian (Late Triassic) of Lombardy (Northern Italy): a preliminary note. *Modern Geology*, 20:149–158.

Renesto, S. (2000). Bird-like head on a chameleon body: new specimens of the enigmatic diapsid reptile *Megalancosaurus* from the Late Triassic of Northern Italy. *Rivista Italiana di Paleontologia e Stratigrafia*, 106(2):157–180.

Renesto, S. (2005). A possible find of *Endennasaurus* (Reptilia Thalattosauria), with a comparison between *Endennasaurus* and *Pachystropheus*. *Neues Jahrbuch für Geologie und Paläontologie - Monatshefte*, 2005(2):118–128.

Renesto, S. and Binelli, G. (2006). *Vallesaurus cenensis* Wild, 1991, a drepanosaurid (Reptilia, Diapsida) from the Late Triassic of Northern Italy. *Rivista Italiana di Paleontologia e Stratigrafia*, 112(1):77–94.

Renesto, S. and Dalla Vecchia, F. M. (2007). A revision of *Langobardisaurus rossii* Bizzarini and Muscio, 1995 from the Late Triassic of Friuli (Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 113(2):191–201.

Renesto, S. and Dalla Vecchia, F. M. (2018). Late Triassic Marine Reptiles. In Tanner, L. H., editor, *The Late Triassic World*, Topics in Geobiology, chapter 8, pages 263–313. Springer, Cham.

Renesto, S., Spielmann, J. A., Lucas, S. G., and Spagnoli, G. T. (2010). The taxonomy and paleobiology of the Late Triassic (Carnian-Norian: Adamanian-Apachean) drepanosaurs (Diapsida:

Archosauromorpha: Drepanosauromorpha). *New Mexico Museum of Natural History and Science Bulletin*, 46:1–81.

Renesto, S., Binelli, G., and Hagdorn, H. (2014). A new pachypleurosaur from the Middle Triassic Besano Formation of Northern Italy. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 271(2):151–168.

Retallack, G. J., Metzger, C. A., Greaver, T., Jahren, A. H., Smith, R. M., and Sheldon, N. D. (2006). Middle-Late Permian mass extinction on land. *Geological Society of America Bulletin*, 118(11–12):1398–1411.

Revell, L. J. (2012). phytools: an R package for phylogenetic comparative biology (and other things). *Methods in Ecology and Evolution*, 3(2):217–223.

Rey, K., Amiot, R., Fourel, F., Abdala, F., Fluteau, F., Jalil, N.-E., Liu, J., Rubidge, B. S., Smith, R. M. H., Steyer, J. S., Viglietti, P. A., Wang, X., and Lécuyer, C. (2017). Oxygen isotopes suggest elevated thermometabolism within multiple Permo-Triassic therapsid clades. *eLife*, 6:e28589.

Rey, K., Day, M. O., Amiot, R., Goedert, J., Lécuyer, C., Sealy, J., and Rubidge, B. S. (2018). Stable isotope record implicates aridification without warming during the late Capitanian mass extinction. *Gondwana Research*, 59:1–8.

Reynoso, V.-H. (1996). *Early Cretaceous lepidosaurs (Reptilia: Diapsida) from Central México and the phylogeny of lepidosauromorphs*. PhD thesis, McGill University, Montreal, Canada. 297 pp.

Reynoso, V. H. and Cruz, J. A. (2014). 4. Mesozoic Lepidosauromorphs of Mexico: A Review and Discussion of Taxonomic Assignments. In Rivera-Sylva, H. E., Carpenter, K., and Frey, E., editors, *Dinosars and Other Reptiles from the Mesozoic of Mexico*, Life of the Past, pages 44–78. Indiana University Press, Bloomington, USA.

Richards, C., Sidor, C., O'Keefe, R., Steyer, J. S., and Tabor, N. (2007). The mandible of *Moradisaurus grandis* (Reptilia: Captorhinidae) and its implications for herbivory in Moradisaurines. *Journal of Vertebrate Paleontology*, 27(Suppl. to 3):134A.

Rieppel, O. (1989). The hind limb of *Macrocnemus bassanii* (Nopcsa) (Reptilia, Diapsida): development and functional anatomy. *Journal of Vertebrate Paleontology*, 9(4):373–387.

Rieppel, O. (1997a). Introduction - Part II: Sauropterygia. In Callaway, J. M. and Nicholls, E. L., editors, *Ancient Marine Reptiles*, pages 107–119. Academic Press, San Diego.

Rieppel, O. (1997b). Revision of the sauropterygian reptile genus *Cymatosaurus* v. Fritsch, 1894, and the relationships of *Germanosaurus* Nopcsa, 1928, from the Middle Triassic of Europe. *Fieldiana: Geology, New Series*, 36:1–38.

Rieppel, O. (1998). The status of the sauropterygian reptile genera *Ceresiosaurus*, *Lariosaurus*, and *Silvestrosaurus* from the Middle Triassic of Europe. *Fieldiana: Geology, New Series*, 38:1–46.

Rieppel, O. (1999). Phylogeny and paleobiogeography of Triassic Sauropterygia: problems solved and unresolved. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 153(1–4):1–15.

Rieppel, O. (2000). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 12A: Sauropterygia I. Placodontia, Pachypleurosauria, Nothosauria, Pistosauria*. Verlag Dr. Friedrich Pfeil, München. 73 pp.

Rieppel, O. (2001). The cranial anatomy of *Placochelys placodonta* Jaekel, 1902, and a review of the Cyamodontoidea (Reptilia, Placodonta). *Fieldiana: Geology, New Series*, 45:1–104.

Rieppel, O. (2002). The dermal armor of the cyamodontoid placodonts (Reptilia, Sauropterygia): morphology and systematic value. *Fieldiana: Geology, New Series*, 46:1–41.

Rieppel, O. and Kebang, L. (1995). Pachypleurosaurs (Reptilia: Sauropterygia) from the Lower Muschelkalk, and a review of the Pachypleurosauroidea. *Fieldiana: Geology, New Series*, 32:1–44.

Rieppel, O. and Wild, R. (1996). A revision of the genus *Nothosaurus* (Reptilia: Sauropterygia) from the Germanic Triassic, with comments on the status of *Conchiosaurus clavatus*. *Fieldiana: Geology, New Series*, 34:1–82.

Rieppel, O. and Hagdorn, H. (1997). Paleobiogeography of Middle Triassic Sauropterygia in central and western Europe. In Callaway, J. M. and Nicholls, E. L., editors, *Ancient Marine Reptiles*, chapter 5, pages 121–144. Academic Press, San Diego.

Rieppel, O. and Werneburg, R. (1998). A new species of the sauropterygian *Cymatosaurus* from the Lower Muschelkalk of Thuringia, Germany. *Palaeontology*, 41(4):575–589.

Rieppel, O. and Hagdorn, H. (1998). Fossil reptiles from the Spanish Muschelkalk (Mont-ral and Alcover), province Tarragona). *Historical Biology*, 13(1):77–97.

Rieppel, O. and Dalla Vecchia, F. M. (2001). Marine Reptiles from the Triassic of the Tre Venezie Area, Northeastern Italy. *Fieldiana: Geology, New Series*, 44:1–25.

Rieppel, O. and Jun, L. (2006). On *Xinpusaurus* (Reptilia: Thalattosauria). *Journal of Vertebrate Paleontology*, 26(1):200–204.

Rieppel, O., Mazin, J.-M., and Tchernov, E. (1999). Sauropterygia from the Middle Triassic of Maktesh Ramon, Negev, Isral. *Fieldiana: Geology, New Series*, 40:1–85.

Rieppel, O., Liu, J., and Bucher, H. (2000). The first record of a thalattosaur reptile from the Late Triassic of southern China (Guizhou Province, PR China). *Journal of Vertebrate Paleontology*, 20(3):507–514.

Rieppel, O., Jiang, D.-Y., Fraser, N. C., Hao, W.-C., Motani, R., Sun, Y.-L., and Sun, Z.-Y. (2010). *Tanystropheus* cf. *T. longobardicus* from the early Late Triassic of Guizhou Province, southwestern China. *Journal of Vertebrate Paleontology*, 30(4):1082–1089.

Rinehart, L. F., Lucas, S. G., and Schoch, R. R. (2015). *Eocyclotosaurus appetolatus*, a new cyclotosaurid amphibian from the Middle Triassic (Perovkan) Moenkopi Formation of New Mexico, U.S.A. *Journal of Vertebrate Paleontology*, 35(3):e929140.

Ristevski, J., Young, M. T., de Andrade, M. B., and Hastings, A. K. (2018). A new species of *Anteophthalmosuchus* (Crocodylomorpha, Goniopholididae) from the Lower Cretaceous of the Isle of Wight, United Kingdom, and a review of the genus. *Cretaceous Research*, 84:340–383.

Roberto-da-Silva, L., Desojo, J. B., Cabreira, S. F., Aires, A. S. S., Müller, R. T., Pacheco, C., and Dias-da-Silva, S. (2014). A new aetosaur from the Upper Triassic of the Santa Maria Formation, southern Brazil. *Zootaxa*, 3764(3):240–278.

Robinson, P. L. (1957). An unusual sauropsid dentition. *Journal of the Linnean Society of London, Zoology*, 43(291):283–293.

Romano, M. and Nicosia, U. (2014). *Alierasaurus ronchii*, gen. et sp. nov., a caseid from the Permian of Sardinia, Italy. *Journal of Vertebrate Paleontology*, 34(4):900–913.

Romano, M. and Nicosia, U. (2015). Cladistic analysis of Caseidae (Caseasauria, Synapsida): using the gap-weighting method to include taxa based on incomplete specimens. *Palaeontology*, 58(6):1109–1130.

Romano, M., Ronchi, A., Maganuco, S., and Nicosia, U. (2017). New material of *Alierasaurus ronchii* (Synapsida, Caseidae) from the Permian of Sardinia (Italy), and its phylogenetic affinities. *Palaeontologia Electronica*, 20.2.26A:1–27.

Romer, A. S. (1928). Vertebrate faunal horizons in the Texas Permo-Carboniferous red beds. *University of Texas Bulletin*, 2801:67–108.

Romer, A. S. (1945). The late Carboniferous vertebrate fauna of Kounova (Bohemia) compared with that of the Texas redbeds. *American Journal of Science*, 243(8):417–442.

Romer, A. S. (1947). Review of the Labyrinthodontia. *Bulletin of the Museum of Comparative Zoölogy at Harvard College*, 99(1):1–368.

Romer, A. S. (1952). Late Pennsylvanian and early Permian vertebrates of the Pittsburgh-West Virginia region. *Annals of Carnegie Museum*, 33:47–112.

Romer, A. S. (1956a). *Osteology of the Reptiles*. The University of Chicago Press, Chicago. 772 pp.

Romer, A. S. (1956b). The early evolution of land vertebrates. *Proceedings of the American Philosophical Society*, 100(3):157–167.

Romer, A. S. (1967). The Chañares (Argentina) Triassic reptile fauna. III. Two new gomphodonts, *Massetognathus pascuali* and *M. teruggii*. *Breviora*, 264:1–25.

Romer, A. S. (1972). The Chañares (Argentina) Triassic reptile fauna. XIII. An early ornithosuchid pseudosuchian, *Gracilisuchus stipanicicorum*, gen. et sp. nov. *Breviora*, 389. 1–24.

Romer, A. S. and Price, L. W. (1940). Review of the Pelycosauria. *Geological Society of America Special Papers*, 28:1–534.

Ronchi, A., Sacchi, E., Romano, M., and Nicosia, U. (2011). A huge caseid pelycosaur from northwestern Sardinia and its bearing on european Permian stratigraphy and palaeobiogeography. *Acta Palaeontologica Polonica*, 56(4):723–738.

Roopnarine, P. D. and Angielczyk, K. D. (2015a). Community stability and selective extinction during Earth's greatest mass extinction. *bioRxiv*. http://dx.doi.org/10.1101/014688.

Roopnarine, P. D. and Angielczyk, K. D. (2015b). Community stability and selective extinction during the Permian-Triassic mass extinction. *Science*, 350(6256):90–93.

Rossmann, T. (2000). Studien an Mesosauriern (Amniota inc. sed.: Mesosauridae): 2. Neue Erkenntnisse zur Anatomie, mit Berücksichtigung der Taxonomie von *Mesosaurus pleurogaster* (Seeley). *Senckenbergiana lethaea*, 80(1):13–28.

Rossmann, T. and Maisch, M. W. (1999). Das Mesosaurier-Material in der Bayerischen Staatssammlung für Paläontologie und Historische Geologie: Übersicht und neue Erkenntnisse. *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie*, 39:69–83.

Rougier, G. W., Novacek, M. J., McKenna, M. C., and Wible, J. R. (2001). Gobiconodonts from the Early Cretaceous of Oshih (Ashile), Mongolia. *American Museum Novitates*, 3348:1–30.

Rougier, G. W., Isaji, S., and Manabe, M. (2007). An Early Cretaceous mammal from the Kuwajima Formation (Tetori Group), Japan, and a reassessment of triconodont phylogeny. *Annals of Carnegie Museum*, 76(2):73–115.

Rowe, T. B., Sues, H.-D., and Reisz, R. R. (2011). Dispersal and diversity in the earliest North American sauropodomorph dinosaurs, with a description of a new taxon. *Proceedings of the Royal Society B: Biological Sciences*, 278(1708):1044–1053.

Rowe, T. (1988). Definition, diagnosis, and origin of Mammalia. *Journal of Vertebrate Paleontology*, 8(3):241–264.

Rozhdestvenskii, A. K. (1965). [Growth changes in asian dinosaurs and some problems of their taxonomy]. *Paleontologicheskii Zhurnal*, 1965(3):95–109. [Russian original translated by Dale A. Russell. Obtained courtesy of the Polyglot Paleontologist website (http://www.paleoglot.org).].

Rubidge, B. S. (1991). A new primitive dinocephalian mammal-like reptile from the Permian of southern Africa. *Palaeontology*, 34(3):547–559.

Rubidge, B. S. (1994). *Australosyodon*, the first primitive anteosaurid dinocephalian from the Upper Permian of Gondwana. *Palaeontology*, 37(3):579–594.

Rubidge, B. S. (2005). 27th Du Toit Memorial Lecture: Re-uniting lost continents - fossil reptiles from the ancient Karoo and their wanderlust. *South African Journal of Geology*, 108(1):135–172.

Rubidge, B. S. and van den Heever, J. A. (1997). Morphology and systematic position of the dinocephalian *Styracocephalus* platyrhynchus. *Lethaia*, 30(2):157–168.

Rubidge, B. S. and Sidor, C. A. (2001). Evolutionary patterns among Permo-Triassic therapsids. *Annual Review of Ecology and Systematics*, 32(1):449–480.

Rubidge, B. and Angielczyk, K. (2009). Stratigraphic ranges of *Tapinocephalus* Assemblage Zone dicynodonts: implications for middle Permian continental biostratigraphy. *Palaeontologia africana*, 44:134–135.

Ruta, M. (2009). Patterns of morphological evolution in major groups of Paleozoic Temnospondyli (Amphibia: Tetrapoda). *Special Papers in Palaeontology*, 81:91–120.

Ruta, M. (2011). Phylogenetic signal and character compatibility in the appendicular skeleton of early tetrapods. *Special Papers in Palaeontology*, 86:31–43.

Ruta, M. and Coates, M. I. (2003). Bones, molecules, and crown-tetrapod origins. In Donoghue, P. C. J. and P., S. M., editors, *Telling the Evolutionary Time: Molecular Clocks and the Fossil Record*, chapter 11, pages 224–262. Taylor & Francis, London.

Ruta, M. and Bolt, J. R. (2006). A reassessment of the temnospondyl amphibian *Perryella olsoni* from the Lower Permian of Oklahoma. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 97:113–165.

Ruta, M. and Clack, J. A. (2006). A review of *Silvanerpeton miripedes*, a stem amniote from the Lower Carboniferous of East Kirkton, West Lothian, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 97(1):31–63.

Ruta, M. and Coates, M. I. (2007). Dates, nodes and character conflict: addressing the lissamphibian origin problem. *Journal of Systematic Palaeontology*, 5:69–122.

Ruta, M. and Benton, M. J. (2008). Calibrated diversity, tree topology and the mother of mass extinctions: the lesson of temnospondyls. *Palaeontology*, 51(6):1261–1288.

Ruta, M. and Bolt, J. R. (2008). The brachyopoid *Hadrokkosaurus bradyi* from the early Middle Triassic of Arizona, and a phylogenetic analysis of lower jaw characters in temnospondyl amphibians. *Acta Palaeontologica Polonica*, 53(4):579–592.

Ruta, M., Jeffery, J. E., and Coates, M. I. (2003a). A supertree of early tetrapods. *Proceedings of the Royal Society B: Biological Sciences*, 270(1532):2507–2516.

Ruta, M., Coates, M. I., and Quicke, D. L. J. (2003b). Early tetrapod relationships revisited. *Biological Reviews*, 78(2):251–345.

Ruta, M., Wagner, P. J., and Coates, M. I. (2006). Evolutionary patterns in early tetrapods. I. Rapid initial diversification followed by decrease in rates of character change. *Proceedings of the Royal Society B: Biological Sciences*, 273(1598):2107–2111.

Ruta, M., Pisani, D., Lloyd, G. T., and Benton, M. J. (2007). A supertree of Temnospondyli: cladogenetic patterns in the most species-rich group of early tetrapods. *Proceedings of the Royal Society of London B: Biological Sciences*, 274(1629):3087–3095.

Ruta, M., Cisneros, J. C., Liebrecht, T., Tsuji, L. A., and Müller, J. (2011). Amniotes through major biological crises: faunal turnover among parareptiles and the end-Permian mass extinction. *Palaeontology*, 54(5):1117–1137.

Ruta, M., Botha-Brink, J., Mitchell, S. A., and Benton, M. J. (2013). The radiation of cynodonts and the ground plan of mammalian morphological diversity. *Proceedings of the Royal Society of London B: Biological Sciences*, 280(1769):20131865.

Sachs, S. and Kear, B. P. (2018). A rare new Pliensbachian plesiosaurian from the Amaltheenton Formation of Bielefeld in northwestern Germany. *Alcheringa: An Australasian Journal of Palaeontology*, 42(4):487–500.

Sachs, S., Hornung, J. J., Lierl, H.-J., and Kear, B. P. (2016). Plesiosaurian fossils from Baltic glacial erratics: evidence of Early Jurassic marine amniotes from the southwestern margin of Fennoscandia. *Geological Society, London, Special Publications*, 434:149–163.

Sahney, S. and Benton, M. J. (2008). Recovery from the most profound mass extinction of all time. *Proceedings of the Royal Society of London B: Biological Sciences*, 275(1636):759–765.

Sahney, S., Benton, M. J., and Falcon-Lang, H. J. (2010). Rainforest collapse triggered Carboniferous tetrapod diversification in Euramerica. *Geology*, 38(12):1079–1082.

Säilä, L. K. (2005). A new species of the sphenodontian reptile *Clevosaurus* from the Lower Jurassic of South Wales. *Palaeontology*, 48(4):817–831.

Säilä, L. K. (2008). The osteology and affinities of *Anomoiodon liliensterni*, a procolophonid reptile from the Lower Triassic Bundsandstein of Germany. *Journal of Vertebrate Paleontology*, 28(4):1199–1205.

Säilä, L. K. (2009). Alpha taxonomy of the Russian Permian procolophonoid reptiles. *Acta Palaeontologica Polonica*, 54(4):599–608.

Säilä, L. K. (2010). Osteology of *Leptopleuron lacertinum* Owen, a procolophonoid parareptile from the Upper Triassic of Scotland, with remarks on ontogeny, ecology and affinities. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 101:1–25.

Sakamoto, M. (2010). Jaw biomechanics and the evolution of biting performance in theropod dinosaurs. *Proceedings of the Royal Society of London B: Biological Sciences*, 277(1698):3327–3333.

Sakamoto, M. and Ruta, M. (2012). Convergence and divergence in the evolution of cat skulls: temporal and spatial patterns of morphological diversity. *PLoS ONE*, 7(7):e39752.

Sakamoto, M. and Venditti, C. (2018). Phylogenetic non-independence in rates of trait evolution. *Biology Letters*, 14(10):20180502.

Sakamoto, M., Benton, M. J., and Venditti, C. (2016). Dinosaurs in decline tens of millions of years before their final extinction. *Proceedings of the National Academy of Sciences*, 113(18):5036–5040.

Sakamoto, M., Venditti, C., and Benton, M. J. (2017). 'Residual diversity estimates' do not correct for sampling bias in palaeodiversity data. *Methods in Ecology and Evolution*, 8(4):453–459.

Salgado, L., Canudo, J. I., Garrido, A. C., Moreno-Azanza, M., Martínez, L. C. A., Coria, R. A., and Gasca, J. M. (2017). A new primitive neornithischian dinosaur from the Jurassic of Patagonia with gut contents. *Scientific Reports*, 7:42778.

Sallan, L. C. and Coates, M. I. (2010). End-Devonian extinction and a bottleneck in the early evolution of modern jawed vertebrates. *Proceedings of the National Academy of Sciences*, 107(22):10131–10135.

Sallan, L. and Galimberti, A. K. (2015). Body-size reduction in vertebrates following the end-Devonian mass extinction. *Science*, 350(6262):812–815.

Sallan, L., Friedman, M., Sansom, R. S., Bird, C. M., and Sansom, I. J. (2018). The nearshore cradle of early vertebrate diversification. *Science*, 362(6413):460–464.

Saller, F., Renesto, S., and Dalla Vecchia, F. M. (2013). First record of *Langobardisaurus* (Diapsida, Protorosauria) from the Norian (Late Triassic) of Austria, and a revision of the genus. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 268(1):83–95.

San Mauro, D. (2010). A multilocus timescale for the origin of extant amphibians. *Molecular Phylogenetics and Evolution*, 56(2):554–561.

San Mauro, D., Gower, D. J., Müller, H., Loader, S. P., Zardoya, R., Nussbaum, R. A., and Wilkinson, M. (2014). Life-history evolution and mitogenomic phylogeny of caecilian amphibians. *Molecular Phylogenetics and Evolution*, 73:177–189.

Sanchez, S., Tafforeau, P., Clack, J. A., and Ahlberg, P. E. (2016). Life history of the stem tetrapod *Acanthostega* revealed by synchrotron microtomography. *Nature*, 537:408–411.

Sander, P. M. (1989). Early Permian depositional environments and pond bonebeds in central archer County, Texas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 69:1–21.

Sander, P. M. (1992). The Norian *Plateosaurus* bonebeds of central Europe and their taphonomy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 93(3–4):255–299.

Sander, P. M. (2000). Prismless enamel in amniotes: terminology, function, and evolution. In Teaford, M. F., Smith, M. M., and Ferguson, M. W. J., editors, *Development, Function and Evolution of Teeth*, chapter 7, pages 92–106. Cambridge University Press, Cambridge.

Sander, P. M. and Mazin, J. M. (1993). The paleobiogeography of Middle Triassic ichthyosaurs: the five major faunas. In Mazin, J. M. and Pinna, G., editors, *Evolution, ecology and biogeography of the Triassic Reptiles - Acts of the Workshop organized by Museo Civico di Storia Naturale di Milano, Milano 19–21 giugno 1991*, volume 2, pages 145–152. Paleontologia Lombarda, Nuova serie: Società Italiana di Scienze Naturali e Museo Civico di Storia Naturale di Milano, Milano.

Sander, P. M. and Faber, C. (1998). New finds of *Omphalosaurus* and a review of Triassic ichthyosaur paleobiogeography. *Paläontologische Zeitschrift*, 72(1–2):149–162.

Sander, P. M. and Faber, C. (2003). The Triassic marine reptile *Omphalosaurus*: osteology, jaw anatomy, and evidence for ichthyosaurian affinities. *Journal of Vertebrate Paleontology*, 23(4):799–816.

Sander, P. M., Rieppel, O. C., and Bucher, H. (1994). New marine vertebrate fauna from the Middle Triassic of Nevada. *Journal of Paleontology*, 68(3):676–680.

Sander, P. M., Chen, X., Cheng, L., and Wang, X. (2011). Short-snouted toothless ichthyosaur from China suggests Late Triassic diversification of suction feeding ichthyosaurs. *PLoS ONE*, 6(5):e19480.

Sander, P., Klein, N., Albers, P. C., Bickelmann, C., and Winkelhorst, H. (2014). Postcranial morphology of a basal Pistosauroidea (Sauropterygia) from the Lower Muschelkalk of Winterswijk, The Netherlands. *Paläontologische Zeitschrift*, 88(1):55–71.

Sarıgül, V., Agnolín, F., and Chatterjee, S. (2018). Description of a multitaxic bone assemblage from the Upper Triassic Post Quarry of Texas (Dockum group), including a new small basal dinosauriform taxon. *Historia Natural, Tercera Serie*, 8(1):5–24.

Sato, T., Zhao, L.-J., Wu, X.-C., and Li, C. (2014a). A new specimen of the Triassic pistosauroid *Yunguisaurus*, with implications for the origin of Plesiosauria (Reptilia, Sauropterygia). *Palaeontology*, 57(1):55–76.

Sato, T., Cheng, Y.-N., Wu, X.-C., and Shan, H.-Y. (2014b). *Diandongosaurus acutidentatus* Shang, Wu & Li, 2011 (Diapsida: Sauropterygia) and the relationships of Chinese eosauropterygians. *Geological Magazine*, 151(1):121–133.

Satsangi, P. P. (1964). A note on *Chasmatosaurus* from the Panchet Series of Raniganj Coalfield, India. *Current Science*, 33(21):651–652.

Savage, R. J. G. (1971). Tritylodontid incertae sedis. *Proceedings of the Bristol Naturalists' Society*, 32(1):80–83.

Savage, R. J. G. and Waldman, M. (1966). *Oligokyphus* from Holwell Quarry, Somerset. *Proceedings of the Bristol Naturalists' Society*, 31(2):185–192.

Säve-Söderbergh, G. (1935). On the dermal bones of the head in labyrinthodont stegocephalians and primitive Reptilia with special reference to Eotriassic stegocephalians from East Greenland. *Meddelelser om Grønland*, 98(3):1–211.

Schachat, S. R., Labandeira, C. C., Saltzman, M. R., Cramer, B. D., Payne, J. L., and Boyce, C. K. (2018). Phanerozoic pO_2 and the early evolution of terrestrial animals. *Proceedings of the Royal Society B: Biological Sciences*, 285(1871):20172631.

Schaumberg, G., Unwin, D. M., and Brandt, S. (2007). New information on the anatomy of the Late Permian gliding reptile *Coelurosauravus*. *Paläontologische Zeitschrift*, 81(2):160–173.

Scheyer, T. M. and Sues, H.-D. (2017). Expanded dorsal ribs in the Late Triassic pseudosuchian reptile *Euscolosuchus olseni*. *Journal of Vertebrate Paleontology*, 37(1):e1248768.

Scheyer, T. M., Desojo, J. B., and Cerda, I. A. (2014a). Bone histology of phytosaur, aetosaur, and other archosauriform osteoderms (Eureptilia, Archosauromorpha). *The Anatomical Record*, 297(2):240–260.

Scheyer, T. M., Romano, C., Jenks, J., and Bucher, H. (2014b). Early Triassic marine biotic recovery: the predators' perspective. *PLoS ONE*, 9(3):e88987.

Scheyer, T. M., Neenan, J. M., Bodogan, T., Furrer, H., Obrist, C., and Plamondon, M. (2017). A new, exceptionally preserved juvenile specimen of *Eusaurosphargis dalsassoi* (Diapsida) and implications for Mesozoic marine diapsid phylogeny. *Scientific Reports*, 7:4406.

Schmidt-Nielsen, K. (1984). *Scaling: Why is animal size so important?* Cambridge University Press, Cambridge. 241 pp.

Schmitz, L. (2005). The taxonomic status of *Mixosaurus nordenskioeldii* (Ichthyosauria). *Journal of Vertebrate Paleontology*, 25(4):983–985.

Schmitz, L., Sander, P. M., Storrs, G. W., and Rieppel, O. (2004). New Mixosauridae (Ichthyosauria) from the Middle Triassic of the Augusta Mountains (Nevada, USA) and their implications for mixosaur taxonomy. *Palaeontographica Abteilung A*, 270(4–6):133–162.

Schneider, C. A., Rasband, W. S., and Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, 9(7):671–675.

Schneider, J. W. and Werneburg, R. (2012). Biostratigraphie des Rotliegend mit Insekten und Amphibien. In Lützner, H. and Kowalczyk, G., editors, *Deutsche Stratigraphische Kommission: Stratigraphie von Deutschland X. Rotliegend. Teil I: Innervariscische Becken*, number 61 in Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, chapter 5.3, pages 110–142. Schweizerbart Science Publishers, Hannover.

Schoch, R. R. (2000a). The origin and intrarelationships of Triassic capitosaurid amphibians. *Palaeontology*, 43(4):705–727.

Schoch, R. R. (2000b). The status and osteology of two new cyclotosaurid amphibians from the Upper Moenkopi Formation of Arizona (Amphibia: Temnospondyli; Middle Triassic). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 216(3):387–411.

Schoch, R. R. (2006). A complete trematosaurid amphibian from the Middle Triassic of Germany. *Journal of Vertebrate Paleontology*, 26(1):29–43.

Schoch, R. R. (2007). Osteology of the small archosaur *Aetosaurus* from the Upper Triassic of Germany. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 246(1):1–35.

Schoch, R. R. (2008a). A new stereospondyl from the German Middle Triassic, and the origin of the Metoposauridae. *Zoological Journal of the Linnean Society*, 152(1):79–113.

Schoch, R. R. (2008b). The Capitosauria (Amphibia): characters, phylogeny and stratigraphy. *Palaeodiversity*, 1:189–226.

Schoch, R. R. (2011a). A procolophonid-like tetrapod from the German Middle Triassic. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 259(2):251–255.

Schoch, R. R. (2011b). A trematosauroid temnospondyl from the Middle Triassic of Jordan. *Fossil Record*, 14(2):119–127.

Schoch, R. R. (2011c). How diverse is the temnospondyl fauna in the Lower Triassic of southern Germany? *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 261(1):49–60.

Schoch, R. R. (2011d). New archosauriform remains from the German Lower Keuper. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 260(1):87–100.

Schoch, R. R. (2012). Character distribution and phylogeny of the dissorophid temnospondyls. *Fossil Record*, 15(2):121–137.

Schoch, R. R. (2013). The evolution of major temnospondyl clades: an inclusive phylogenetic analysis. *Journal of Systematic Palaeontology*, 11(6):673–705.

Schoch, R. R. (2014a). *Amphibian Evolution: The Life of Early Land Vertebrates*. Topics in Paleobiology. John Wiley & Sons, Ltd, Chichester. 264 pp.

Schoch, R. R. (2014b). First evidence of the branchiosaurid temnospondyl *Leptorophus* in the Early Permian of the Saar-Nahe Basin (SW Germany). *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 272(2):225–236.

Schoch, R. R. (2015a). Amphibien und Chroniosuchier des Lettenkeupers. In Hagdorn, H., Schoch, R., and Schweigert, G., editors, *Der Lettenkeuper - Ein Fenster in die Zeit vor den Dinosauriern*, volume Special Issue of *Palaeodiversity*, chapter 9, pages 203–230. Staatliches Museum für Naturkunde Stuttgart, Stuttgart.

Schoch, R. R. (2015b). Reptilien des Lettenkeupers. In Hagdorn, H., Schoch, R., and Schweigert, G., editors, *Der Lettenkeuper - Ein Fenster in die Zeit vor den Dinosauriern*, volume Special Issue of *Palaeodiversity*, chapter 10, pages 231–264. Staatliches Museum für Naturkunde Stuttgart, Stuttgart.

Schoch, R. R. (2018a). Osteology of the temnospondyl *Neldasaurus* and the evolution of basal dvinosaurians. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 287(1):1–16.

Schoch, R. R. (2018b). The temnospondyl *Parotosuchus nasutus* (v. Meyer, 1858) from the Early Triassic Middle Buntsandstein of Germany. *Palaeodiversity*, 11(1):107–126.

Schoch, R. R. (2019). The putative lissamphibian stem-group: phylogeny and evolution of the dissorophoid temnospondyls. *Journal of Paleontology*, 93(1):137–156.

Schoch, R. R. and Milner, A. R. (2000). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 3B: Stereospondyli*. Verlag Dr. Friedrich Pfeil, München. 203 pp.

Schoch, R. R. and Rubidge, B. S. (2005). The amphibamid *Micropholis* from the *Lystrosaurus* Assemblage Zone of South Africa. *Journal of Vertebrate Paleontology*, 25(3):502–522.

Schoch, R. R. and Milner, A. R. (2008). The intrarelationships and evolutionary history of the temnospondyl family Branchiosauridae. *Journal of Systematic Palaeontology*, 6(4):409–431.

Schoch, R. R. and Witzmann, F. (2009a). Osteology and relationships of the temnospondyl genus *Sclerocephalus*. *Zoological Journal of the Linnean Society*, 157(1):135–168.

Schoch, R. R. and Witzmann, F. (2009b). The temnospondyl *Glanochthon* from the Lower Permian Meisenheim Formation of Germany. *Special Papers in Palaeontology*, 81:121–136.

Schoch, R. R. and Sues, H.-D. (2013). A new dissorophid temnospondyl from the Lower Permian of north-central Texas. *Comptes Rendus Palevol*, 12(7–8):437–445.

Schoch, R. R. and Sues, H.-D. (2014). A new archosauriform reptile from the Middle Triassic (Ladinian) of Germany. *Journal of Systematic Palaeontology*, 12(1):113–131.

Schoch, R. R. and Milner, A. R. (2014). *Handbook of Paleoherpetology Part 3A2: Temnospondyli I*. Verlag Dr. Friedrich Pfeil, München. 150 pp.

Schoch, R. R. and Sues, H.-D. (2015). A Middle Triassic stem-turtle and the evolution of the turtle body plan. *Nature*, 523(7562):584–587.

Schoch, R. R. and Desojo, J. B. (2016). Cranial anatomy of the aetosaur *Paratypothorax andressorum* Long & Ballew, 1985, from the Upper Triassic of Germany and its bearing on aetosaur phylogeny. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 279(1):73–95.

Schoch, R. R. and Sues, H.-D. (2018a). A new lepidosauromorph reptile from the Middle Triassic (Ladinian) of Germany and its phylogenetic relationships. *Journal of Vertebrate Paleontology*, 38(2):e1444619.

Schoch, R. R. and Witzmann, F. (2018). Morphology of the Late Carboniferous temnospondyl *Limnogyrinus elegans*, and the evolutionary history of the Micromelerpetidae. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 289(3):293–310.

Schoch, R. R. and Sues, H.-D. (2018b). Osteology of the Middle Triassic stem-turtle *Pappochelys rosinae* and the early evolution of the turtle skeleton. *Journal of Systematic Palaeontology*, 16(11):927–965.

Schoch, R. R., Voigt, S., and Buchwitz, M. (2010). A chroniosuchid from the Triassic of Kyrgyzstan and analysis of chroniosuchian relationships. *Zoological Journal of the Linnean Society*, 160(3):515–530.

Schoch, R. R., Milner, A. R., and Witzmann, F. (2014). Skull morphology and phylogenetic relationships of a new Middle Triassic plagiosaurid temnospondyl from Germany, and the evolution of plagiosaurid eyes. *Palaeontology*, 57(5):1045–1058.

Schultz, C. L., Langer, M. C., and Montefeltro, F. C. (2016). A new rhynchosaur from south Brazil (Santa Maria Formation) and rhynchosaur diversity patterns across the Middle-Late Triassic boundary. *Paläontologische Zeitschrift*, 90(3):593–609.

Schultze, H.-P. (2013). The paleoenvironment at the transition from piscine to tetrapod sarcopterygians. In Lucas, S. G., DiMichele, W. A., Barrick, J. E., Schneider, J. W., and Spielmann, J. A., editors, *The Carboniferous-Permian Transition*, volume 60, pages 373–397. New Mexico Museum of Natural History.

Schultze, H.-P. and Foreman, B. (1981). A new gymnarthrid microsaur from the Lower Permian of Kansas with a review of the tuditanomorph microsaurs (Amphibia). *Occasional Papers of the Museum of Natural History, The University of Kansas*, 91:1–25.

Sciscio, L., de Kock, M., Bordy, E., and Knoll, F. (2017). Magnetostratigraphy across the Triassic-Jurassic boundary in the main Karoo Basin. *Gondwana Research*, 51:177–192.

Seeley, H. G. (1898). On *Oudenodon* (*Aulacocephalus*) *pithecops* from the *Dicynodon* Beds of East London, Cape Colony. *Geological Magazine*, 5(3):107–110.

Sekiya, T. (2010). A new prosauropod dinosaur from Lower Jurassic in Lufeng of Yunnan. *Global Geology*, 29(1):6–15. [In Chinese with extended English abstract].

Sekiya, T. and Dong, Z. (2010). A new juvenile specimen of *Lufengosaurus huenei* Young, 1941 (Dinosauria: Prosauropoda) from the Lower Jurassic Lower Lufeng Formation of Yunnan, Southwest China. *Acta Geologica Sinica - English Edition*, 84(1):11–21.

Sekiya, T., Jin, X., Zheng, W., Shibata, M., and Azuma, Y. (2014). A new juvenile specimen of *Yunnanosaurus robustus* (Dinosauria: Sauropodomorpha) from Early to Middle Jurassic of Chuxiong Autonomous Prefecture, Yunnan Province, China. *Historical Biology*, 26(2):252–277.

Sen, K. (2003). *Pamelaria dolichotrachela*, a new prolacertid reptile from the Middle Triassic of India. *Journal of Asian Earth Sciences*, 21(6):663–681. Geology of the Pranhita-Godavari Valley , India.

Sengupta, D. P. (2002). Indian metoposaurid amphibians revised. *Paleontological Research*, 6(1):41–65.

Sengupta, D. P. (2003). Triassic temnospondyls of the Pranhita–Godavari basin, India. *Journal of Asian Earth Sciences*, 21(6):655–662.

Sengupta, S., Sengupta, D. P., and Bandyopadhyay, S. (2016). Stratigraphy of the Upper Gondwana Formations around Sohagpur, Western Part of the Satpura Gondwana Basin, Central India. *Journal of the Geological Society of India*, 87(5):503–519.

Sengupta, S., Ezcurra, M. D., and Bandyopadhyay, S. (2017). A new horned and long-necked herbivorous stem-archosaur from the Middle Triassic of India. *Scientific Reports*, 7:8366.

Sennikov, A. G. (1988). The role of the oldest thecodonts in the vertebrate assemblages of Eastern Europe. *Paleontological Journal*, 22(4):74–82.

Sennikov, A. G. (2001). Discovery of a primitive sauropterygian from the Lower Triassic of the Donskaya Luka (Don Basin) and the range of Triassic marine reptiles in Russia. *Paleontological Journal*, 35(3):301–309.

Sennikov, A. G. (2005). A new specialized prolacertilian (Reptilia: Archosauromorpha) from the Lower Triassic of the Orenburg Region. *Paleontological Journal*, 39(2):199–209.

Sennikov, A. G. (2008). [Subclass Lepidosauromorpha]. In Ivakhnenko, M. F. and Kurochkin, E. N., editors, *[Fossil vertebrates of Russia and adjacent countries: Fossil Reptiles and Birds. Part 1]*, pages 263–265. GEOS, Moscow. [In Russian].

Sennikov, A. G. (2011). New tanystropheids (Reptilia: Archosauromorpha) from the Triassic of Europe. *Paleontological Journal*, 45(1):90–104.

Sennikov, A. G. (2012). The first ctenosauriscid (Reptilia: Archosauromorpha) from the Lower Triassic Of Eastern Europe. *Paleontological Journal*, 46(5):499–511.

Sennikov, A. G. (2015). New data on the herpetofauna of the Early Triassic Donskaya Luka locality, Volgograd Region. *Paleontological Journal*, 49(11):1161–1173.

Senter, P. (2004). Phylogeny of Drepanosauridae (Reptilia: Diapsida). *Journal of Systematic Palaeontology*, 2(3):257–268.

Sereno, P. C. (1991). *Lesothosaurus*, “fabrosaurids,” and the early evolution of Ornithischia. *Journal of Vertebrate Paleontology*, 11(2):168–197.

Sereno, P. C. (2007). Basal Sauropodomorpha: historical and recent phylogenetic hypotheses, with comments on *Ammosaurus major* (Marsh, 1889). *Special Papers in Palaeontology*, 77:261–289.

Sereno, P. C. (2012). Taxonomy, morphology, masticatory function and phylogeny of heterodontosaurid dinosaurs. *ZooKeys*, 226:1–225.

Sereno, P. C. and Wild, R. (1992). *Procompsognathus*: theropod, “thecodont” or both? *Journal of Vertebrate Paleontology*, 12(4):435–458.

Sereno, P. C. and Arcucci, A. B. (1994). Dinosaurian precursors from the Middle Triassic of Argentina: *Marasuchus lilloensis*, gen. nov. *Journal of Vertebrate Paleontology*, 14(1):53–73.

Sereno, P. C. and Novas, F. E. (1994). The skull and neck of the basal theropod *Herrerasaurus ischigualastensis*. *Journal of Vertebrate Paleontology*, 13(4):451–476.

Sereno, P. C., Martínez, R. N., and Alcober, O. A. (2012). Osteology of *Eoraptor lunensis* (Dinosauria, Sauropodomorpha). *Journal of Vertebrate Paleontology*, 32(sup1):83–179.

Shang, Q.-H. and Li, C. (2015). A new small-sized eosauropterygian (Diapsida: Sauropterygia) from the Middle Triassic of Luoping, Yunnan, southwestern China. *Vertebrata PalAsiatica*, 53(4):265–280. [In Chinese with English abstract].

Shang, Q.-H., Li, C., and Wu, X.-C. (2017). New information on *Dianmeisaurus gracilis* Shang & Li, 2015. *Vertebrata PalAsiatica*, 55(2):145–161.

Shapiro, M. D. and Jenkins, Jr., F. A. (2001). A cynodont from the Upper Triassic of East Greenland: tooth replacement and double-rootedness. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 156(1):49–58.

Shcherbakov, D. E. (2008). Madygen, Triassic Lagerstätte number one, before and after Sharov. *Alavesia*, 2:113–124.

Shelton, C. D., Sander, P. M., Stein, K., and Winkelhorst, H. (2013). Long bone histology indicates sympatric species of *Dimetrodon* (Lower Permian, Sphenacodontidae). *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 103(3–4):217–236.

Shen, X.-X., Liang, D., Wen, J.-Z., and Zhang, P. (2011). Multiple genome alignments facilitate development of NPCL markers: a case study of tetrapod phylogeny focusing on the position of turtles. *Molecular Biology and Evolution*, 28(12):3237–3252.

Shishkin, M. A. (1960). [On the Yarengiidae, a new family of Triassic labyrinthodonts]. *Paleontologicheskii Zhurnal*, 1960(1):97–106. [In Russian].

Shishkin, M. A. (1967). Plagiosaurs from the Triassic of the USSR. *Paleontological Journal*, 1(1):86–92.

Shishkin, M. A. (1980). The Luzocephalidae, a new Triassic labyrinthodont family. *Paleontological Journal*, 14(1):88–101.

Shishkin, M. A. (1987). [The evolution of the oldest amphibians]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 225:1–142. [In Russian].

Shishkin, M. A. (2005). The patterns of evolution of Early Triassic herpetofauna in Europe and Gondwana: comparison and implications. In Ananjeva, N. and Tsinenko, O., editors, *Herpetologica Petropolitana. Proceedings of the 12th Ordinary General Meeting of the Societas Europaea Herpetologica, August 12 – 16, 2003, St. Petersburg, Russian Journal of Herpetology*, volume 12, pages 301–303. SEH.

Shishkin, M. A. (2010). On some phantom in the taxonomy of the Gondwanan Triassic amphibians. In Mostovski, M. B. and Ovechkina, M. N., editors, *Proceedings of the 16th Conference of the Palaeontological Society of Southern Africa (Howick, August 5–8, 2010)*, pages 96–100. Natal Museum, Pietermaritzburg.

Shishkin, M. A. and Lozovsky, V. R. (1981). A labyrinthodont from the Triassic deposits in the south of the Soviet Pacific Maritime Province. *Doklady Akademii Nauk SSSR, Earth Science Sections*, 246(1–6):196–199.

Shishkin, M. A. and Welman, J. (1994). A new find of *Trematosuchus* (Amphibia, Temnospondyli) from the *Cynognathus* Zone of South Africa. *Palaeontologia africana*, 31:39–49.

Shishkin, M. A. and Sulej, T. (2009). The Early Triassic temnospondyls of the Czatkowice 1 tetrapod assemblage. *Palaeontologia Polonica*, 65(3):31–77.

Shishkin, M. A. and Novikov, I. V. (2017). Early stages of recovery of the east European tetrapod fauna after the end-Permian crisis. *Paleontological Journal*, 51(6):612–622.

Shishkin, M. A., Rubidge, B. S., and Kitching, J. W. (1996). A new lydekkerinid (Amphibia, Temnospondyli) from the Lower Triassic of South Africa: implications for evolution of the early capitosauroid cranial pattern. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 351(1347):1635–1659.

Shishkin, M. A., Novikov, I. V., and Gubin, Y. M. (2000). Permian and Triassic temnospondyls from Russia. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 35–59. Cambridge University Press, Cambridge.

Shishkin, M. A., Rubidge, B. S., Hancox, J., and Welman, J. (2004). Re-evaluation of *Kestrosaurus* Haughton, a capitosaurid temnospondyl amphibian from the Upper Beaufort Group of South Africa. *Russian Journal of Herpetology*, 11(2):121–138.

Shishkin, M. A., Sennikov, A. G., Novikov, I. V., and Ilyina, N. V. (2006). Differentiation of tetrapod communities and some aspects of biotic events in the Early Triassic of Eastern Europe. *Paleontological Journal*, 40(1):1–10.

Shishkin, M. A., Novikov, I. V., and Fortuny, J. (2014). New bystrowianid chroniosuchians (Amphibia, Anthracosauromorpha) from the Triassic of Russia and diversification of Bystrowianidae. *Paleontological Journal*, 48(5):512–522.

Shubin, N. H., Crompton, A. W., Sues, H.-D., and Olsen, P. E. (1991). New fossil evidence on the sister-group of mammals and early Mesozoic faunal distributions. *Science*, 251(4997):1063–1065.

Shubin, N. H., Olsen, P. E., and Sues, H.-D. (1994). Early Jurassic small tetrapods from the McCoy Brook Formation of Nova Scotia, Canada. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 13, pages 242–250. Cambridge University Press, Cambridge.

Sidor, C. A. (2001). Simplification as a trend in synapsid cranial evolution. *Evolution*, 55(7):1419–1442.

Sidor, C. A. (2003). Evolutionary trends and the origin of the mammalian lower jaw. *Paleobiology*, 29(4):605–640.

Sidor, C. A. (2015). The first biarmosuchian from the upper Madumabisa Mudstone Formation (Luangwa Basin) of Zambia. *Palaeontologia africana*, 49:1–7.

Sidor, C. A. and Hopson, J. A. (1995). The taxonomic status of the Upper Permian eotheriodont therapsids of the San Angelo Formation (Guadalupian), Texas. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 15(sup3):53A.

Sidor, C. A. and Hopson, J. A. (1998). Ghost lineages and “mammalness”: assessing the temporal pattern of character acquisition in the Synapsida. *Paleobiology*, 24(2):254–273.

Sidor, C. A. and Welman, J. (2003). A second specimen of *Lemurosaurus pricei* (Therapsida: Burnetiamorpha). *Journal of Vertebrate Paleontology*, 23(3):631–642.

Sidor, C. A. and Smith, R. M. H. (2004). A new galesaurid (Therapsida: Cynodontia) from the Lower Triassic of South Africa. *Palaeontology*, 47(3):535–556.

Sidor, C. A. and Hancox, P. J. (2006). *Elliotherium kersteni*, a new tritheledontid from the Lower Elliot Formation (Upper Triassic) of South Africa. *Journal of Paleontology*, 80(2):333–342.

Sidor, C. A. and Rubidge, B. S. (2006). *Herpetoskylax hopsoni*, a New Biarmosuchian (Therapsida: Biarmosuchia) from the Beaufort Group of Southern Africa. In Carrano, M. T., Gaudin, T. J., Blob, R. W., and Wible, J. R., editors, *Amniote Paleobiology: Perspectives on the Evolution of Mammals, Birds, and Reptiles*, chapter 4, pages 76–113. University of Chicago Press, Chicago.

Sidor, C. A. and Smith, R. M. H. (2007). A second burnetiamorph therapsid from the Permian Teekloof Formation of South Africa and its associated fauna. *Journal of Vertebrate Paleontology*, 27(2):420–430.

Sidor, C. A. and Hopson, J. A. (2018). *Cricodon metabolus* (Cynodontia: Gomphodontia) from the Triassic Ntawere Formation of northeastern Zambia: patterns of tooth replacement and a systematic review of the Trirachodontidae. *Journal of Vertebrate Paleontology*, 37(6, Supplement):39–64.

Sidor, C. A., Steyer, J. S., and Damiani, R. (2007). *Parotosuchus* (Temnospondyli: Mastodonsauridae) from the Triassic of Antarctica. *Journal of Vertebrate Paleontology*, 27(1):232–235.

Sidor, C. A., Damiani, R., and Hammer, W. R. (2008). A new Triassic temnospondyl from Antarctica and a review of Fremouw Formation biostratigraphy. *Journal of Vertebrate Paleontology*, 28(3):656–663.

Sidor, C. A., Angielczyk, K. D., Weide, D. M., Smith, R. M., Nesbitt, S. J., and Tsuji, L. A. (2010). Tetrapod fauna of the lowermost Usili Formation (Songea Group, Ruhuhu Basin) of southern Tanzania, with a new burnetiid record. *Journal of Vertebrate Paleontology*, 30(3):696–703.

Sidor, C. A., Vilhena, D. A., Angielczyk, K. D., Huttenlocker, A. K., Nesbitt, S. J., Peecook, B. R., Steyer, J. S., Smith, R. M. H., and Tsuji, L. A. (2013). Provincialization of terrestrial faunas following the end-Permian mass extinction. *Proceedings of the National Academy of Sciences*, 110(20):8129–8133.

Sidor, C. A., Steyer, J. S., and Hammer, W. R. (2014a). A new capitosauroid temnospondyl from the Middle Triassic upper Fremouw Formation of Antarctica. *Journal of Vertebrate Paleontology*, 34(3):539–548.

Sidor, C. A., Smith, R. M. H., Huttenlocker, A. K., and Peecook, B. R. (2014b). New Middle Triassic tetrapods from the upper Fremouw Formation of Antarctica and their depositional setting. *Journal of Vertebrate Paleontology*, 34(4):793–801.

Sigogneau, D. (1970). *Révision systématique des Gorgonopsiens sud-africains*. Cahiers de Paléontologie. Centre National de la Recherche Scientifique, Paris. 417 pp.

Sigogneau-Russell, D. (1989). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 17B/I: Theriodontia I. Phthinosuchia, Biarmosuchia, Eotitanosuchia, Gorgonopsia*. Verlag Dr. Friedrich Pfeil, München. 127 pp.

Sigogneau-Russell, D. and Hahn, G. (1994). Late Triassic microvertebrates from central Europe. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 10, pages 197–213. Cambridge University Press, Cambridge.

Sigurdsen, T. and Green, D. M. (2011). The origin of modern amphibians: a re-evaluation. *Zoological Journal of the Linnean Society*, 162(2):457–469.

Sigurdsen, T., Huttenlocker, A. K., Modesto, S. P., Rowe, T. B., and Damiani, R. (2012). Reassessment of the morphology and paleobiology of the therocephalian *Tetracynodon darti* (Therapsida), and the phylogenetic relationships of Baurioidea. *Journal of Vertebrate Paleontology*, 32(5):1113–1134.

Silvestro, D., Kostikova, A., Litsios, G., Pearman, P. B., and Salamin, N. (2015). Measurement errors should always be incorporated in phylogenetic comparative analysis. *Methods in Ecology and Evolution*, 6(3):340–346.

Simões, T. R., Caldwell, M. W., Tałanda, M., Bernardi, M., Palci, A., Vernygora, O., Bernardini, F., Mancini, L., and Nydam, R. L. (2018). The origin of squamates revealed by a Middle Triassic lizard from the Italian Alps. *Nature*, 557(7707):706–709.

Simpson, E. O. (1998). The phylogeny and biostratigraphic utility of parasuchids from the Dockum Group of West Texas. Master's thesis, Texas Tech University, Lubbock. 137 pp.

Simpson, G. G. (1944). *Tempo and Mode in Evolution*. Columbia University Press, New York. 237 pp. Reprint Edition, 1984.

Simpson, G. G. (1953). *The Major Features of Evolution*. Columbia University Press, New York. 434 pp.

Skawiński, T., Ziegler, M., Czepiński, Ł., Szermański, M., Tałanda, M., Surmik, D., and Niedźwiedzki, G. (2017). A re-evaluation of the historical 'dinosaur' remains from the Middle-Upper Triassic of Poland. *Historical Biology*, 29(4):442–472.

Small, B. J. (1997). A new procolophonid from the Upper Triassic of Texas, with a description of tooth replacement and implantation. *Journal of Vertebrate Paleontology*, 17(4):674–678.

Small, B. J. (2002). Cranial anatomy of *Desmatosuchus haplocerus* (Reptilia: Archosauria: Stagonolepididae). *Zoological Journal of the Linnean Society*, 136(1):97–111.

Small, B. J. and Martz, J. W. (2013). A new aetosaur from the Upper Triassic Chinle Formation of the Eagle Basin, Colorado, USA. *Geological Society, London, Special Publications*, 379(1):393–412.

Small, E. (2011). The new Noah's Ark: beautiful and useful species only. Part 1. Biodiversity conservation issues and priorities. *Biodiversity*, 12(4):232–247.

Smith, A. B. (1994). *Systematics and the Fossil Record: Documenting Evolutionary Patterns*. Blackwell Science, Oxford. 223 pp.

Smith, A. B. and McGowan, A. J. (2007). The shape of the Phanerozoic marine palaeodiversity curve: how much can be predicted from the sedimentary rock record of western Europe? *Palaeontology*, 50(4):765–774.

Smith, A. B. and McGowan, A. J. (2011). The ties linking rock and fossil records and why they are important for palaeobiodiversity studies. *Geological Society, London, Special Publications*, 358(1):1–7.

Smith, A. C. (2011). *Description of Tanytrachelos ahynis and its implications for the phylogeny of Protorosauria*. PhD thesis, Virginia Polytechnic Institute and State University, Blacksburg. 118 pp.

Smith, A. S. (2015). Reassessment of '*Plesiosaurus*' *megacephalus* (Sauropterygia: Plesiosauria) from the Triassic-Jurassic boundary, UK. *Palaeontologia Electronica*, 18.1.20A:1–19.

Smith, A. S. and Dyke, G. J. (2008). The skull of the giant predatory pliosaur *Rhomaleosaurus cramptoni*: implications for plesiosaur phylogenetics. *Naturwissenschaften*, 95(10):975–980.

Smith, A. S. and Vincent, P. (2010). A new genus of pliosaur (Reptilia: Sauropterygia) from the Lower Jurassic of Holzmaden, Germany. *Palaeontology*, 53(5):1049–1063.

Smith, A. S. and Araújo, R. (2017). *Thaumatodracon wiedenrothi*, a morphometrically and stratigraphically intermediate new rhomaleosaurid plesiosaurian from the Lower Jurassic (Sinemurian) of Lyme Regis. *Palaeontographica Abteilung A*, 308(4–6):89–125.

Smith, A. S., Araújo, R., and Mateus, O. (2012a). A new plesiosauroid from the Toarcian (Lower Jurassic) of Alhadas, Portugal. *Acta Palaeontologica Polonica*, 57(2):257–266.

Smith, N. D. and Pol, D. (2007). Anatomy of a basal sauropodomorph dinosaur from the Early Jurassic Hanson Formation of Antarctica. *Acta Palaeontologica Polonica*, 52(4):657–674.

Smith, R. M. H., Sidor, C. A., Angielczyk, K. D., Nesbitt, S. J., and Tabor, N. J. (2018). Taphonomy and paleoenvironments of Middle Triassic bone accumulations in the Lifua Member of the Manda Beds, Songea Group (Ruhuhu Basin), Tanzania. *Journal of Vertebrate Paleontology*, 37(6, Supplement):65–79.

Smith, R. M. and Swart, R. (2002). Changing fluvial environments and vertebrate taphonomy in response to climatic drying in a mid-Triassic rift valley fill: the Omingonde Formation (Karoo Supergroup) of Central Namibia. *PALAIOS*, 17(3):249–267.

Smith, R. and Botha, J. (2005). The recovery of terrestrial vertebrate diversity in the South African Karoo Basin after the end-Permian extinction. *Comptes Rendus Palevol*, 4(6–7):623–636.

Smith, R., Rubidge, B., and van der Walt, M. (2012b). Therapsid Biodiversity Patterns and Paleoenvironments of the Karoo Basin, South Africa. In Chinsamy-Turan, A., editor, *Forerunners Of Mammals: Radiation, Histology, Biology*, chapter 2, pages 31–62. Indiana University Press, Bloomington, Indiana.

Smithson, T. R. and Clack, J. A. (2018). A new tetrapod from Romer's Gap reveals an early adaptation for walking. *Earth and Environmental Science Transactions of The Royal Society of Edinburgh*, 108(1):89–97.

Smithson, T. R., Wood, S. P., Marshall, J. E. A., and Clack, J. A. (2012). Earliest Carboniferous tetrapod and arthropod faunas from Scotland populate Romer's Gap. *Proceedings of the National Academy of Sciences*, 109(12):4532–4537.

Smithson, T. R., Browne, M. A. E., Davies, S. J., Marshall, J. E. A., Millward, D., Walsh, S. A., and Clack, J. A. (2017). A new Mississippian tetrapod from Fife, Scotland, and its environmental context. *Papers in Palaeontology*, 3(4):547–557.

Smithson, T. (2000). Anthracosaurs. In Heatwole, H. and Carroll, R. L., editors, *Amphibian Biology: Volume 4 - Paleontology*, chapter 5, pages 1053–1063. Surrey Bearry Press, Chipping Norton.

Snitting, D. and Blom, H. (2009). Correcting taxon names containing diacritics–examples from Paleozoic vertebrates. *Journal of Vertebrate Paleontology*, 29(1):269–270.

Sobral, G., Sues, H.-D., and Müller, J. (2015). Anatomy of the enigmatic reptile *Elachistosuchus huenei* Janensch, 1949 (Reptilia: Diapsida) from the Upper Triassic of Germany and its relevance for the origin of Sauria. *PLoS ONE*, 10(9):e0135114.

Sookias, R. B. (2016). The relationships of the Euparkeriidae and the rise of Archosauria. *Royal Society Open Science*, 3(3):150674.

Sookias, R. B., Benson, R. B. J., and Butler, R. J. (2012a). Biology, not environment, drives major patterns in maximum tetrapod body size through time. *Biology Letters*, 8(4):674–677.

Sookias, R. B., Butler, R. J., and Benson, R. B. J. (2012b). Rise of dinosaurs reveals major body-size transitions are driven by passive processes of trait evolution. *Proceedings of the Royal Society of London B: Biological Sciences*, 279(1736):2180–2187.

Sookias, R. B., Böhmer, C., and Clack, J. A. (2014a). Redescription and phylogenetic analysis of the mandible of an enigmatic Pennsylvanian (Late Carboniferous) tetrapod from Nova Scotia, and the lability of Meckelian jaw ossification. *PLoS ONE*, 9(10):e109717.

Sookias, R. B., Sullivan, C., Liu, J., and Butler, R. J. (2014b). Systematics of putative euparkeriids (Diapsida: Archosauriformes) from the Triassic of China. *PeerJ*, 2:e658.

Sookias, R. B., Sennikov, A. G., Gower, D. J., and Butler, R. J. (2014c). The monophyly of Euparkeriidae (Reptilia: Archosauriformes) and the origins of Archosauria: a revision of *Dorosuchus neoetus* from the Mid-Triassic of Russia. *Palaeontology*, 57(6):1177–1202.

Soul, L. C. and Friedman, M. (2015). Taxonomy and phylogeny can yield comparable results in comparative paleontological analyses. *Systematic Biology*, 64(4):608–620.

Soul, L. C. and Friedman, M. (2017). Bias in phylogenetic measurements of extinction and a case study of end-Permian tetrapods. *Palaeontology*, 60(2):169–185.

Spencer, P. S. (2000). The braincase structure of *Leptopleuron lacertinum* Owen (Parareptilia: Procolophonidae). *Journal of Vertebrate Paleontology*, 20(1):21–30.

Spencer, P. S. and Benton, M. J. (2000). Procolophonoids from the Permo-Triassic of Russia. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 160–176. Cambridge University Press, Cambridge.

Spencer, P. S. and Storrs, G. W. (2002). A re-evaluation of small tetrapods from the Middle Triassic Otter Sandstone Formation of Devon, England. *Palaeontology*, 45(3):447–467.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., and van Der Linde, A. (2002). Bayesian measures of model complexity and fit. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 64(4):583–639.

Spielmann, J. A. and Lucas, S. G. (2012). Tetrapod fauna of the Upper Triassic Redonda Formation, east-central New Mexico: the characteristic assemblage of the Apachean land-vertebrate faunachron. *New Mexico Museum of Natural History and Science Bulletin*, 55:1–119.

Spielmann, J. A., Lucas, S. G., Hunt, A. P., and Heckert, A. B. (2006). Reinterpretation of the holotype of *Malerisaurus langstoni*, a diapsid reptile from the Upper Triassic Chinle Group of West Texas. In Harris, J. D., Lucas, S. G., Spielmann, J. A., Lockley, M. G., Milner, A. R. C., and Kirkland, J. I., editors, *The Triassic-Jurassic Terrestrial Transition*, volume 37, pages 543–547. New Mexico Museum of Natural History.

Spielmann, J. A., Lucas, S. G., Heckert, A. B., Rinehart, L. F., and Hunt, A. P. (2007). Taxonomy and biostratigraphy of the Late Triassic archosauromorph *Trilophosaurus*. In Lucas, S. G. and Spielmann, J. A., editors, *Triassic of the American West*, volume 40, pages 231–240. New Mexico Museum of Natural History.

Spielmann, J. A., Lucas, S. G., Rinehart, L. F., and Heckert, A. B. (2008). The Late Triassic archosauromorph *Trilophosaurus*. *New Mexico Museum of Natural History and Science Bulletin*, 43:1–177.

Spindler, F. (2013). The Niederhäslich tetrapod assemblage (Early Permian, Döhlen basin) from Germany – new insights to ecology, reptiliomorph diversity, and the biology of *Palaeohatteria longicaudata* (basal Sphenacodontia). *SVP Program and Abstracts Book*, page 218.

Spindler, F. (2015). *The basal Sphenacodontia - systematic revision and evolutionary implications*. PhD thesis, Fakultät für Geowissenschaften, Geotechnik und Bergbau, Technische Universität Bergakademie Freiberg, Freiberg. 385 pp.

Spindler, F. (2016). Morphological description and taxonomic status of *Palaeohatteria* and *Pantelosaurus* (Synapsida: Sphenacodontia). *Freiberger Forschungshefte C*, 550(23):1–57.

Spindler, F., Scott, D., and Reisz, R. R. (2015). New information on the cranial and postcranial anatomy of the early synapsid *Ianthodon schultzei* (Sphenacomorpha: Sphenacodontia), and its evolutionary significance. *Fossil Record*, 18(1):17–30.

Spindler, F., Falconnet, J., and Fröbisch, J. (2016). *Callibrachion* and *Datheosaurus*, two historical and previously mistaken basal caseasaurian synapsids from Europe. *Acta Palaeontologica Polonica*, 61(3):597–616.

Spindler, F., Werneburg, R., Schneider, J. W., Luthardt, L., Annacker, V., and Rößler, R. (2018). First arboreal 'pelycosaurs' (Synapsida: Varanopidae) from the early Permian Chemnitz Fossil Lagerstätte, SE Germany, with a review of varanopid phylogeny. *Paläontologische Zeitschrift*, 92(2):315–364.

Štamberg, S. and Zajíc, J. (2008). *Carboniferous and Permian faunas and their occurence in the limnic basins of the Czech Republic*. Museum of Eastern Bohemia, Hradec Králové. 224 pp.

Stanley, S. M. (2016). Estimates of the magnitudes of major marine mass extinctions in earth history. *Proceedings of the National Academy of Sciences*, 113(42):E6325–E6334.

Starrfelt, J. and Liow, L. H. (2016). How many dinosaur species were there? Fossil bias and true richness estimated using a Poisson sampling model. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1691):20150219.

Stayton, C. T. (2006). Testing hypotheses of convergence with multivariate data: morphological and functional convergence among herbivorous lizards. *Evolution*, 60(4):824–841.

Stayton, C. T. and Ruta, M. (2006). Geometric morphometrics of the skull roof of stereospondyls (Amphibia: Temnospondyli). *Palaeontology*, 49(2):307–337.

Stecher, R. (2008). A new Triassic pterosaur from Switzerland (Central Austroalpine, Grisons), *Raeticodactylus filisurensis* gen. et sp. nov. *Swiss Journal of Geosciences*, 101(1):185–201.

Steel, R. (1973). *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 16: Crocodylia*. Verlag Dr. Friedrich Pfeil, München. 116 pp.

Stefanello, M., Müller, R. T., Kerber, L., Martínez, R. N., and Dias-da-Silva, S. (2018). Skull anatomy and phylogenetic assessment of a large specimen of Ecteniniidae (Eucynodontia: Probainognathia) from the Upper Triassic of southern Brazil. *Zootaxa*, 4457(3):351–378.

Stein, K., Palmer, C., Gill, P. G., and Benton, M. J. (2008). The aerodynamics of the British Late Triassic Kuehneosauridae. *Palaeontology*, 51(4):967–981.

Sterli, J. (2008). A new, nearly complete stem turtle from the Jurassic of South America with implications for turtle evolution. *Biology Letters*, 4(3):286–289.

Sterli, J. and de La Fuente, M. S. (2010). Anatomy of *Condorchelys antiqua* Sterli, 2008, and the origin of the modern jaw closure mechanism in turtles. *Journal of Vertebrate Paleontology*, 30(2):351–366.

Sterli, J., de La Fuente, M. S., and Krause, J. M. (2015). A new turtle from the Palaeogene of Patagonia (Argentina) sheds new light on the diversity and evolution of the bizarre clade of horned turtles (Meiolaniidae, Testudinata). *Zoological Journal of the Linnean Society*, 174(3):519–548.

Steyer, J. S. (2002). The first articulated trematosaur 'amphibian' from the Lower Triassic of Madagascar: implications for the Phylogeny of the Group. *Palaeontology*, 45(4):771–793.

Steyer, J.-S., Sanchez, S., Debriette, P. J., Valli, A. M., Escuille, F., Pohl, B., Dechambre, R.-P., Vacant, R., Spence, C., and de Ploëg, G. (2012). A new vertebrate Lagerstätte from the Lower Permian of France (Franchesse, Massif Central): palaeoenvironmental implications for the Bourbon-l'Archambault basin. *Bulletin de la Société Géologique de France*, 183(6):509–515.

Stigall, A. L. (2010). Invasive species and biodiversity crises: testing the link in the Late Devonian. *PLoS ONE*, 5(12):e15584.

Stimson, M., Lucas, S. G., and Melanson, G. (2012). The smallest known tetrapod footprints: *Batrachichnus salamandroides* from the Carboniferous of Joggins, Nova Scotia, Canada. *Ichnos*, 19(3):127–140.

Stockar, R., Baumgartner, P. O., and Condon, D. (2012). Integrated Ladinian bio-chronostratigraphy and geochrononology of Monte San Giorgio (Southern Alps, Switzerland). *Swiss Journal of Geosciences*, 105(1):85–108.

Stocker, M. R. (2010). A new taxon of phytosaur (Archosauria: Pseudosuchia) from the Late Triassic (Norian) Sonsela Member (Chinle Formation) in Arizona, and a critical reevaluation of *Leptosuchus* Case, 1922. *Palaeontology*, 53(5):997–1022.

Stocker, M. R. (2012). A new phytosaur (Archosauriformes, Phytosauria) from the Lot's Wife beds (Sonsela Member) within the Chinle Formation (Upper Triassic) of Petrified Forest National Park, Arizona. *Journal of Vertebrate Paleontology*, 32(3):573–586.

Stocker, M. R. (2013). *Conceptualizing vertebrate faunal dynamics: new perspectives from the Triassic and Eocene of Western North America*. PhD thesis, University of Texas, Austin. 297 pp.

Stocker, M. R. and Butler, R. J. (2013). Phytosauria. *Geological Society, London, Special Publications*, 379(1):91–117.

Stocker, M. R., Zhao, L.-J., Nesbitt, S. J., Wu, X.-C., and Li, C. (2017). A short-snouted, Middle Triassic phytosaur and its implications for the morphological evolution and biogeography of Phytosauria. *Scientific Reports*, 7:46028.

Stocker, M., Nesbitt, S., Criswell, K., Parker, W., Witmer, L., Rowe, T., Ridgely, R., and Brown, M. (2016). A dome-headed stem archosaur exemplifies convergence among dinosaurs and their distant relatives. *Current Biology*, 26(19):2674–2680.

Storrs, G. W. (1994). Fossil vertebrate faunas of the British Rhaetian (latest Triassic). *Zoological Journal of the Linnean Society*, 112:217–259.

Storrs, G. W. (1997). Chapter 6: Morphological and taxonomic clarification of the genus *Plesiosaurus*. In *Ancient Marine Reptiles*, pages 145–190. Academic Press.

Storrs, G. W. and Taylor, M. A. (1996). Cranial anatomy of a new plesiosaur genus from the lowermost Lias (Rhaetian/Hettangian) of Street, Somerset, England. *Journal of Vertebrate Paleontology*, 16(3):403–420.

Storrs, G. W., Gower, D. J., and Large, N. F. (1996). The diapsid reptile, *Pachystropheus rhaeticus*, a probable choristodere from the Rhaetian of Europe. *Palaeontology*, 39(2):323–349.

Storrs, G. W., Arkhangelsky, M. S., and Efimov, V. M. (2000). Mesozoic marine reptiles of Russia and other former Soviet republics. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 187–210. Cambridge University Press, Cambridge.

Stössel, I., Williams, E. A., and Higgs, K. T. (2016). Ichnology and depositional environment of the Middle Devonian Valentia Island tetrapod trackways, south-west Ireland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 462:16–40.

Strapasson, A., Pinheiro, F. L., and Soares, M. B. (2015). On a new stereospondylomorph temnospondyl from the Middle–Late Permian of southern Brazil. *Acta Palaeontologica Polonica*, 60(4):843–855.

Stubbs, T. L. and Benton, M. J. (2016). Ecomorphological diversifications of Mesozoic marine reptiles: the roles of ecological opportunity and extinction. *Paleobiology*, 42(4):547–573.

Stubbs, T. L., Pierce, S. E., Rayfield, E. J., and Anderson, P. S. L. (2013). Morphological and biomechanical disparity of crocodile-line archosaurs following the end-Triassic extinction. *Proceedings of the Royal Society of London B: Biological Sciences*, 280(1770):20131940.

Stumpf, S., Ansorge, J., and Krempien, W. (2015). Gravisaurian sauropod remains from the marine late Early Jurassic (Lower Toarcian) of North-Eastern Germany. *Geobios*, 48(3):271–279.

Sues, H.-D. (1985). First record of the tritylodontid *Oligokyphus* (Synapsida) from the Lower Jurassic of western North America. *Journal of Vertebrate Paleontology*, 5(4):328–335.

Sues, H.-D. (1987). Postcranial skeleton of *Pistosaurus* and interrelationships of the Sauropterygia (Diapsida). *Zoological Journal of the Linnean Society*, 90(2):109–131.

Sues, H.-D. (1991). Venom-conducting teeth in a Triassic reptile. *Nature*, 351(6322):141–143.

Sues, H.-D. (1992). A remarkable new armored archosaur from the Upper Triassic of Virginia. *Journal of Vertebrate Paleontology*, 12(2):142–149.

Sues, H.-D. (1996). A reptilian tooth with apparent venom canals from the Chinle Group (Upper Triassic) of Arizona. *Journal of Vertebrate Paleontology*, 16(3):571–572.

Sues, H.-D. (2001). On *Microconodon*, a Late Triassic cynodont from the Newark Supergroup of Eastern North America. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 156(1):37–48.

Sues, H.-D. (2003). An unusual new archosauromorph reptile from the Upper Triassic Wolfville Formation of Nova Scotia. *Canadian Journal of Earth Sciences*, 40(4):635–649.

Sues, H.-D. (2013). Comment on Case 3560: *Plateosaurus engelhardti* Meyer, 1837 (Dinosauria, Sauropodomorpha): proposed replacement of unidentifiable name-bearing type by a neotype (Case 3560). *Bulletin of Zoological Nomenclature*, 70(2):120–121.

Sues, H.-D. (2017). *Arctosaurus osborni*, a Late Triassic archosauromorph reptile from the Canadian Arctic Archipelago. *Canadian Journal of Earth Sciences*, 54(2):129–133.

Sues, H.-D. (2019). Authorship and date of publication of the name Tetrapoda. *Journal of Vertebrate Paleontology*, page e1564758.

Sues, H.-D. and Boy, J. A. (1988). A procynosuchid cynodont from central Europe. *Nature*, 331(6156):523–524.

Sues, H.-D. and Olsen, P. E. (1993). A new procolophonid and a new tetrapod of uncertain, possibly procolophonian affinities from the Upper Triassic of Virginia. *Journal of Vertebrate Paleontology*, 13(3):282–286.

Sues, H.-D. and Reisz, R. R. (1995). First record of the early Mesozoic sphenodontian *Clevosaurus* (Lepidosauria: Rhynchocephalia) from the Southern Hemisphere. *Journal of Paleontology*, 69(1):123–126.

Sues, H.-D. and Reisz, R. R. (1998). Origins and early evolution of herbivory in tetrapods. *Trends in Ecology & Evolution*, 13(4):141–145.

Sues, H.-D. and Baird, D. (1998). Procolophonidae (Reptilia: Parareptilia) from the Upper Triassic Wolfville Formation of Nova Scotia, Canada. *Journal of Vertebrate Paleontology*, 18(3):525–532.

Sues, H.-D. and Jenkins, J. F. A. (2006). The Postcranial Skeleton of *Kayentatherium wellesi* from the Lower Jurassic Kayenta Formation of Arizona and the Phylogenetic Significance of Postcranial Features in Tritylodontid Cynodonts. In Carrano, M. T., Gaudin, T. J., Blob, R. W., and Wible, J. R., editors, *Amniote Paleobiology: Perspectives on the Evolution of Mammals, Birds, and Reptiles*, chapter 5, pages 114–152. University of Chicago Press, Chicago.

Sues, H.-D. and Reisz, R. R. (2008). Anatomy and phylogenetic relationships of *Sclerosaurus armatus* (Amniota: Parareptilia) from the Buntsandstein (Triassic) of Europe. *Journal of Vertebrate Paleontology*, 28(4):1031–1042.

Sues, H.-D. and Hopson, J. A. (2010). Anatomy and phylogenetic relationships of *Boreogomphodon jeffersoni* (Cynodontia: Gomphodontia) from the Upper Triassic of Virginia. *Journal of Vertebrate Paleontology*, 30(4):1202–1220.

Sues, H.-D. and Fraser, N. C. (2010). *Triassic Life on Land: The Great Transition*. The Critical Moments and Perspectives in Earth History and Paleobiology. Columbia University Press, New York. 224 pp.

Sues, H.-D. and Schoch, R. R. (2013a). Anatomy and phylogenetic relationships of *Calamops paludosus* (Temnospondyli, Stereospondyli) from the Triassic of the Newark Basin, Pennsylvania. *Journal of Vertebrate Paleontology*, 33(5):1061–1070.

Sues, H.-D. and Schoch, R. R. (2013b). First record of *Colognathus* (?Amniota) from the Middle Triassic of Europe. *Journal of Vertebrate Paleontology*, 33(4):998–1002.

Sues, H.-D. and Schoch, R. R. (2013c). Reassessment of cf. *Halticosaurus orbitoangulatus* from the Upper Triassic (Norian) of Germany – a pseudosuchian, not a dinosaur. *Zoological Journal of the Linnean Society*, 168(4):859–872.

Sues, H.-D. and Olsen, P. (2015). Stratigraphic and temporal context and faunal diversity of Permian-Jurassic continental tetrapod assemblages from the Fundy rift basin, eastern Canada. *Atlantic Geology*, 51(1):139–205.

Sues, H.-D., Clark, J. M., and Jenkins, Jr., F. A. (1994). A review of the Early Jurassic tetrapods from the Glen Canyon Group of the American Southwest. In Fraser, N. C. and Sues, H.-D., editors, *In the shadow of the dinosaurs - Early Mesozoic tetrapods*, chapter 16, pages 284–294. Cambridge University Press, Cambridge.

Sues, H.-D., Shubin, N. H., Olsen, P. E., and Amaral, W. W. (1996). On the cranial structure of a new protosuchid (Archosauria: Crocodyliformes) from the McCoy Brook Formation (Lower Jurassic) of Nova Scotia, Canada. *Journal of Vertebrate Paleontology*, 16(1):34–41.

Sues, H.-D., Olsen, P. E., Scott, D. M., and Spencer, P. S. (2000). Cranial osteology of *Hypsognathus fenneri*, a latest Triassic procolophonid reptile from the Newark Supergroup of eastern North America. *Journal of Vertebrate Paleontology*, 20(2):275–284.

Sues, H.-D., Nesbitt, S. J., Berman, D. S., and Henrici, A. C. (2011). A late-surviving basal theropod dinosaur from the latest Triassic of North America. *Proceedings of the Royal Society of London B: Biological Sciences*, 278(1723):3459–3464.

Sugiura, N. (1978). Further analysis of the data by Akaike' s information criterion and the finite corrections. *Communications in Statistics - Theory and Methods*, 7(1):13–26.

Sulej, T. (2002). Species discrimination of the Late Triassic temnospondyl amphibian *Metoposaurus diagnosticus*. *Acta Palaeontologica Polonica*, 47(3):535–546.

Sulej, T. (2005). A new rauisuchian reptile (Diapsida: Archosauria) from the Late Triassic of Poland. *Journal of Vertebrate Paleontology*, 25(1):78–86.

Sulej, T. (2007). Osteology, variability, and evolution of *Metoposaurus*, a temnospondyl from the Late Triassic of Poland. *Palaeontologia Polonica*, 64:29–139.

Sulej, T. (2009). Modyfikacja rekonstrukcji czaszki triasowego płaza *Tatrasuchus* z Tatr na podstawie interpretacji jego pokrewieństw. *Przegląd Geologiczny*, 57(8):719–722.

Sulej, T. and Niedźwiedzki, G. (2013). A new large capitosaurid temnospondyl amphibian from the Early Triassic of Poland. *Acta Palaeontologica Polonica*, 58(1):65–75.

Sulej, T. and Niedźwiedzki, G. (2019). An elephant-sized Late Triassic synapsid with erect limbs. *Science*, 363(6422):78–80.

Sulej, T., Niedźwiedzki, G., Tałanda, M., Dróżdż, D., and Hara, E. (2018). A new early Late Triassic non-mammaliaform eucynodont from Poland. *Historical Biology*, pages 1–13.

Sullivan, C. and Reisz, R. R. (2005). Cranial anatomy and taxonomy of the Late Permian dicynodont *Diictodon*. *Annals of Carnegie Museum*, 74(1):45–75.

Sullivan, C., Liu, J., Roberts, E. M., Huang, T. D., Yang, C., and Zhong, S. (2013). Pelvic morphology of a tritylodontid (Synapsida: Eucynodontia) from the Lower Jurassic of China, and some functional and phylogenetic implications. *Comptes Rendus Palevol*, 12(7–8):505–518.

Surkov, M. V. and Benton, M. J. (2008). Head kinematics and feeding adaptations of the Permian and Triassic dicynodonts. *Journal of Vertebrate Paleontology*, 28(4):1120–1129.

Surkov, M. V., Kalandadze, N. N., and Benton, M. J. (2005). *Lystrosaurus georgi*, a dicynodont from the Lower Triassic of Russia. *Journal of Vertebrate Paleontology*, 25(2):402–413.

Surmik, D. (2016). *Hemilopas mentzeli*, an enigmatic marine reptile from the Middle Triassic of Poland revisited. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 282(2):209–223.

Surmik, D., Skreczko, S., and Wolny, M. (2014). The results of palaeontological excavations in the Sadowa Góra quarry (2012-14). *Contemporary Trends in Geoscience*, 3:90–99.

SVP (2008a). Best practices from the Ethics Education Committee regarding research, publication, and museum work. Best practices, Society of Vertebrate Paleontology. 2 pp.

SVP (2008b). Statement from the Executive Committee about the allegations of unethical conduct from J. Martz, W. Parker, M. Taylor and M. Wedel against S. Lucas, A. Hunt, A. Heckert, and J. Spielmann. Review, Society of Vertebrate Paleontology. 4 pp.

Świło, M., Niedźwiedzki, G., and Sulej, T. (2014). Mammal-like tooth from the Upper Triassic of Poland. *Acta Palaeontologica Polonica*, 59(4):815–820.

Szczygielski, T. and Sulej, T. (2016). Revision of the Triassic European turtles *Proterochersis* and *Murrhardtia* (Reptilia, Testudinata, Proterochersidae), with the description of new taxa from Poland and Germany. *Zoological Journal of the Linnean Society*, 177(2):395–427.

Tatarinov, L. P. (1972). III. Seymouriamorphen aus der Fauna der USSR. In Carroll, R. L., Kuhn, O., and Tatarinov, L. P., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 5B: Batrachosauria (Anthracosauria) Gephyrostegida – Chroniosuchida*, pages 70–80. Verlag Dr. Friedrich Pfeil, München.

Tatarinov, L. P. (1974). Discovery of a bolosaur in the Lower Permian of the USSR. *Paleontological Journal*, 8(2):250–252.

Tatarinov, L. P. (2005). A new cynodont (Reptilia, Theriodontia) from the Madygen Formation (Triassic) of Fergana, Kyrgyzstan. *Paleontological Journal*, 39(2):192–198.

Tatarinov, L. P. (2008). [Infraclass Therosauria]. In Ivakhnenko, M. F. and Kurochkin, E. N., editors, *[Fossil vertebrates of Russia and adjacent countries: Fossil Reptiles and Birds. Part 1]*, pages 184–223. GEOS, Moscow. [In Russian].

Temminck, C. J. and Schlegel, H. (1842). *Fauna Japonica sive Descriptio animalium, quae in itinere per Japoniam, jußu et auspiciis superiorum, qui summum in India Batava imperium tenent, suscepto, annis 1825 – 1830 collegit, notis, observationibus et adumbrationibus illustravit Ph. Fr. de Siebold*, volume Pisces, Fauna Japonica Part 1. A. Arnz et Socios. 323 pp.

Thackeray, J. F. (2018). Do specimens attributed to *Lystrosaurus murrayi* and *L. declivis* (Triassic Therapsida) represent one species? *South African Journal of Science*, 114(3–4):1–2.

Thayer, D. W. (1985). New Pennsylvanian lepospondyl amphibians from the Swisshelm Mountains, Arizona. *Journal of Paleontology*, 59(3):684–700.

Theobald, D. L. (2010). A formal test of the theory of universal common ancestry. *Nature*, 465(7295):219–222.

Thulborn, R. A. (1970). The skull of *Fabrosaurus australis*, a Triassic ornithischian dinosaur. *Palaeontology*, 13(3):414–432.

Thulborn, R. A. (1971). Tooth wear and jaw action in the Triassic ornithischian dinosaur *Fabrosaurus*. *Journal of Zoology*, 164(2):165–179.

Thulborn, R. A. (1972). The postcranial skeleton of the Triassic ornithischian dinosaur *Fabrosaurus australis*. *Palaeontology*, 15(1):29–60.

Thulborn, R. A. (1974). A new heterodontosaurid dinosaur (Reptilia: Ornithischia) from the Upper Triassic Red Beds of Lesotho. *Zoological Journal of the Linnean Society*, 55(2):151–175.

Thulborn, R. A. (1992). Taxonomic characters of *Fabrosaurus australis*, an ornithischian dinosaur from the Lower Jurassic of Southern Africa. *Geobios*, 25(2):283–292.

Tripathi, C. (1969). Fossil labyrinthodonts from the Panchet Series of the Indian Gondwanas. *Memoirs of the Geological Survey of India, Palaeontologia Indica, New Series*, 38:1–45.

Trotteyn, M. J., Arcucci, A. B., and Raugust, T. (2013). Proterochampsia: an endemic archosauriform clade from South America. *Geological Society, London, Special Publications*, 379(1):59–90.

Tsuji, L. A. (2013). Anatomy, cranial ontogeny and phylogenetic relationships of the pareiasaur *Deltavjatia rossicus* from the Late Permian of central Russia. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 104:81–122.

Tsuji, L. A. (2018). *Mandaphon nadra*, gen. et sp. nov., a new procolophonid from the Manda Beds of Tanzania. *Journal of Vertebrate Paleontology*, 37(6, Supplement):80–87.

Tsuji, L. A. and Müller, J. (2009). Assembling the history of the Parareptilia: phylogeny, diversification, and a new definition of the clade. *Fossil Record*, 12(1):71–81.

Tsuji, L. A., Müller, J., and Reisz, R. R. (2012). Anatomy of *Emeroleter levis* and the phylogeny of the nycteroleter parareptiles. *Journal of Vertebrate Paleontology*, 32(1):45–67.

Tsuji, L. A., Sobral, G., and Müller, J. (2013a). *Ruhuhuaria reiszi*, a new procolophonoid reptile from the Triassic Ruhuhu Basin of Tanzania. *Comptes Rendus Palevol*, 12(7–8):487–494.

Tsuji, L. A., Sidor, C. A., Steyer, J.-S., Smith, R. M. H., Tabor, N. J., and Ide, O. (2013b). The vertebrate fauna of the Upper Permian of Niger–VII. Cranial anatomy and relationships of *Bunostegos akokanensis* (Pareiasauria). *Journal of Vertebrate Paleontology*, 33(4):747–763.

Turner, A. H. and Nesbitt, S. J. (2013). Body size evolution during the Triassic archosauriform radiation. *Geological Society, London, Special Publications*, 379(1):573–597.

Turner, M. L., Tsuji, L. A., Ide, O., and Sidor, C. A. (2015). The vertebrate fauna of the upper Permian of Niger–IX. The appendicular skeleton of *Bunostegos akokanensis* (Parareptilia: Pareiasauria). *Journal of Vertebrate Paleontology*, 35(6):e994746.

Tverdokhlebov, V. P., Tverdokhlebova, G. I., Minikh, A. V., Surkov, M. V., and Benton, M. J. (2005). Upper Permian vertebrates and their sedimentological context in the South Urals, Russia. *Earth-Science Reviews*, 69(1–2):27–77.

Tverdokhlebova, G. I. and Ivakhnenko, M. F. (1984). Nycteroleters from the Permian of Eastern Europe. *Paleontological Journal*, 18(3):93–104.

Tykoski, R. S. and Rowe, T. (2004). Ceratosauria. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 47–70. University of California Press, Berkeley, Second edition.

Unwin, D. M., Alifanov, V. R., and Benton, M. J. (2000). Enigmatic small reptiles from the Middle–Late Triassic of Kirgizstan. In Benton, M. J., Shishkin, M. A., Unwin, D. M., and Kurochkin, E. N., editors, *The Age of Dinosaurs in Russia and Mongolia*, pages 177–186. Cambridge University Press, Cambridge.

Unwin, D. M., Rauhut, O. W. M., and Haluza, A. (2004). The first 'rhamphorhynchoid' from South America and the early history of pterosaurs. In Reitner, J., Reich, M., and Schmidt, G., editors, *Geobiologie: 74. Jahrestagung der Paläontologischen Gesellschaft, Göttingen, 02. bis 08. Oktober 2004. Kurzfassungen der Vorträge und Poster*, pages 234–237. Universitätsverlag Göttingen.

Upchurch, P., Barrett, P. M., and Dodson, P. (2004). Sauropoda. In Weishampel, D. B., Dodson, P., and Osmólska, H., editors, *The Dinosauria*, pages 259–322. University of California Press, Berkeley, Second edition.

Upchurch, P., Barrett, P. M., Zhao, X., and Xu, X. (2007). A re-evaluation of *Chinshakiangosaurus chunghoensis* Ye vide Dong 1992 (Dinosauria, Sauropodomorpha): implications for cranial evolution in basal sauropod dinosaurs. *Geological Magazine*, 144(2):247–262.

Upchurch, P., Mannion, P. D., and Taylor, M. P. (2015). The anatomy and phylogenetic relationships of *"Pelorosaurus" becklesii* (Neosauropoda, Macronaria) from the Early Cretaceous of England. *PLoS ONE*, 10(6):e0125819.

Uyeda, J. C. and Harmon, L. J. (2014). A novel Bayesian method for inferring and interpreting the dynamics of adaptive landscapes from phylogenetic comparative data. *Systematic Biology*, 63(6):902–918.

Vallin, G. and Laurin, M. (2004). Cranial morphology and affinities of *Microbrachis*, and a reappraisal of the phylogeny and lifestyle of the first amphibians. *Journal of Vertebrate Paleontology*, 24(1):56–72.

Van Damme, D., Bogan, A. E., and Dierick, M. (2015). A revision of the Mesozoic naiads (Unionoida) of Africa and the biogeographic implications. *Earth-Science Reviews*, 147:141–200.

Van den Brandt, M. J. and Abdala, F. (2018). Cranial morphology and phylogenetic analysis of *Cynosaurus suppostus* (Therapsida, Cynodontia) from the upper Permian of the Karoo Basin, South Africa. *Palaeontologia africana*, 52:201–221.

van den Heever, J. A. (1987). *The comparative and functional cranial morphology of the early Therocephalia (Amniota: Therapsida)*. Unpublished PhD thesis, University of Stellenbosch, Stellenbosch. 576 pp.

van den Heever, J. A. (1994). The cranial anatomy of the early Therocephalia (Amniota: Therapsida). *Universiteit van Stellenbosch Annale*, 1994(1):1–59.

van Heerden, J. (1972). Intraspecific variations and growth changes in the cynodont reptile *Thrinaxodon liorhinus*. *Researches of the National Museum*, 2(10):307–347.

van Heerden, J. (1979). The morphology and taxonomy of *Euskelosaurus* (Reptilia: Saurischia; Late Triassic) from South Africa. *Navorsinge van die Nasionale Museum, Bloemfontein*, 4(2):21–84.

van Heerden, J. and Rubidge, B. (1990). The affinities of the early cynodont reptile, *Nanictosaurus*. *Palaeontologia africana*, 27:41–44.

Vaughn, P. P. (1962). Vertebrates from the Halgaito tongue of the Cutler Formation, Permian of San Juan County, Utah. *Journal of Paleontology*, 36(3):529–539.

Vaughn, P. P. (1966). *Seymouria* from the Lower Permian of southeastern Utah, and possible sexual dimorphism in that genus. *Journal of Paleontology*, 40(3):603–612.

Vaughn, P. P. (1971). A *Platyhystrix*-like amphibian with fused vertebrae, from the Upper Pennsylvanian of Ohio. *Journal of Paleontology*, 45(3):464–469.

Vega-Dias, C., Maisch, M. W., and Schultz, C. L. (2004). A new phylogenetic analysis of Triassic dicynodonts (Therapsida) and the systematic position of *Jachaleria candelariensis* from the Upper Triassic of Brasil. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 231(2):145–166.

Vega-Dias, C., Maisch, M. W., and Schwanke, C. (2005). The taxonomic status of *Stahleckeria impotens* (Therapsida , Dicynodontia): redescription and discussion of its phylogenetic position. *Revista Brasileira de Paleontologia*, 8(3):221–228.

Veizer, J. and Prokoph, A. (2015). Temperatures and oxygen isotopic composition of Phanerozoic oceans. *Earth-Science Reviews*, 146:92–104.

Velazco, P. M., Buczek, A. J., and Novacek, M. J. (2017). Two new tritylodontids (Synapsida, Cynodontia, Mammaliamorpha) from the Upper Jurassic, southwestern Mongolia. *American Museum Novitates*, 3874:1–35.

Venditti, C., Meade, A., and Pagel, M. (2011). Multiple routes to mammalian diversity. *Nature*, 479(7373):393–396.

Verrière, A., Brocklehurst, N., and Fröbisch, J. (2016). Assessing the completeness of the fossil record: comparison of different methods applied to parareptilian tetrapods (Vertebrata: Sauropsida). *Paleobiology*, 42(4):680–695.

Vidovic, S. U. and Martill, D. M. (2017). The taxonomy and phylogeny of *Diopecephalus kochi* (Wagner, 1837) and '*Germanodactylus rhamphastinus*' (Wagner, 1851). figshare. 10.6084/m9.figshare.5139877.v1.

Vidovic, S. U. and Martill, D. M. (2018). The taxonomy and phylogeny of *Diopecephalus kochi* (Wagner, 1837) and '*Germanodactylus rhamphastinus*' (Wagner, 1851). *Geological Society, London, Special Publications*, 455(1):125–147.

Viglietti, P. A., Smith, R. M. H., Angielczyk, K. D., Kammerer, C. F., Fröbisch, J., and Rubidge, B. S. (2016). The *Daptocephalus* Assemblage Zone (Lopingian), South Africa: a proposed biostratigraphy based on a new compilation of stratigraphic ranges. *Journal of African Earth Sciences*, 113:153–164.

Vignaud, P. (1998). Une nouvelle espece de *Steneosaurus* (Thalattosuchia, Teleosauridae) dans le Callovien du Poitou (France) et la systematique des *Steneosaurus* longirostres du Jurassique moyen d'Europe Occidentale. *Palaeovertebrata*, 27(1–2):19–44.

Vincent, P. and Benson, R. B. J. (2012). *Anningasaura*, a basal plesiosaurian (Reptilia, Plesiosauria) from the Lower Jurassic of Lyme Regis, United Kingdom. *Journal of Vertebrate Paleontology*, 32(5):1049–1063.

Vincent, P., Bardet, N., and Mattioli, E. (2013). A new pliosaurid from the Pliensbachian, Early Jurassic of Normandy, northern France. *Acta Palaeontologica Polonica*, 58(3):471–485.

Vincent, P., Taquet, P., Fischer, V., Bardet, N., Falconnet, J., and Godefroit, P. (2014). Mary Anning's legacy to French vertebrate palaeontology. *Geological Magazine*, 151(1):7–20.

Vincent, P., Weis, R., Kronz, G., and Delsate, D. (2019). *Microcleidus melusinae*, a new plesiosaurian (Reptilia, Plesiosauria) from the Toarcian of Luxembourg. *Geological Magazine*, 156(1):99–116.

Voeten, D. F., Sander, P. M., and Klein, N. (2015). Skeletal material from larger Eusauropterygia (Reptilia: Eosauropterygia) with nothosaurian and cymatosaurian affinities from the Lower Muschelkalk of Winterswijk, The Netherlands. *Paläontologische Zeitschrift*, 89(4):943–960.

Voigt, S., Haubold, H., Meng, S., Krause, D., Buchantschenko, J., Ruckwied, K., and Götz, A. E. (2006). Die Fossil-Lagerstätte Madygen: Ein Beitrag zur Geologie und Paläontologie der Madygen-Formation (Mittel-bis Ober-Trias, SW-Kirgisistan, Zentralasien). *Hallesches Jahrbuch für Geowissenschaften*, 22:85–119.

von Baczko, M. B. (2018). Rediscovered cranial material of *Venaticosuchus rusconii* allows the first jaw biomechanics in Ornithosuchidae (Archosauria: Pseudosuchia). *Ameghiniana*, 55(4):365–379.

von Baczko, M. B. and Ezcurra, M. D. (2013). Ornithosuchidae: a group of Triassic archosaurs with a unique ankle joint. *Geological Society, London, Special Publications*, 379(1):187–202.

von Baczko, M. B. and Desojo, J. B. (2016). Cranial anatomy and palaeoneurology of the archosaur *Riojasuchus tenuisceps* from the Los Colorados Formation, La Rioja, Argentina. *PLoS ONE*, 11(2):e0148575.

von Baczko, M. B. and Ezcurra, M. D. (2016). Taxonomy of the archosaur *Ornithosuchus*: reassessing *Ornithosuchus woodwardi* Newton, 1894 and *Dasygnathoides longidens* (Huxley 1877). *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 106(3):199–205.

von Baczko, M. B., Desojo, J. B., and Pol, D. (2014). Anatomy and phylogenetic position of *Venaticosuchus rusconii* Bonaparte, 1970 (Archosauria, Pseudosuchia), from the Ischigualasto Formation (Late Triassic), La Rioja, Argentina. *Journal of Vertebrate Paleontology*, 34(6):1342–1356.

von Baczko, M. B., Taborda, J. R. A., and Desojo, J. B. (2018). Paleoneuroanatomy of the aetosaur *Neoaetosauroides engaeus* (Archosauria: Pseudosuchia) and its paleobiological implications among archosauriforms. *PeerJ*, 6:e5456.

von Huene, F. R. (1956). *Paläontologie und Phylogenie der Niederen Tetrapoden*. Gustav Fischer Verlag, Jena. 716 pp.

von Huene, F. R. (1959). *Paläontologie und Phylogenie der Niederen Tetrapoden. Nachträge und Ergänzungen*. Gustav Fischer Verlag, Jena. 58 pp.

von Huene, F. (1913). The skull elements of the Permian Tetrapoda in the American Museum of Natural History, New York. *Bulletin of the American Museum of Natural History*, 32(18):315–386.

von Huene, F. (1916). Beiträge zur Kenntnis der Ichthyosaurier im deutschen Muschelkalk. *Palaeontographica*, 62(1):1–68.

von Huene, F. (1929). Über Rhynchosaurier und andere Reptilien aus den Gondwana-Ablagerungen Südamerikas. *Geologische und Paläontologische Abhandlungen, Neue Folge*, 17(1):1–62.

von Huene, F. (1932a). Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte. *Monographien zur Geologie und Palaeontologie, Serie 1*, 4(1):1–361.

von Huene, F. (1932b). Ein neuartiger Stegocephalen-Fund aus dem oberhessischen Buntsandstein. *Paläontologische Zeitschrift*, 14(3):200–228.

von Huene, F. (1934). Ein neuer Coelurosaurier in der thüringischen Trias. *Paläontologische Zeitschrift*, 16(3–4):145–170.

von Huene, F. (1938). *Stenaulorhynchus*, ein Rhynchosauride der ostafrikanischen Obertrias. *Nova Acta Leopoldina, Neue Folge*, 6(36):83–121.

Vorobyeva, E. I. (1977). [Morphology and nature of evolution of crossopterygian fishes]. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, 163:1–239. [In Russian].

Wainwright, P. C. (2007). Functional versus morphological diversity in macroevolution. *Annual Review of Ecology, Evolution, and Systematics*, 38(1):381–401.

Wainwright, P. C. and Richard, B. A. (1995). Predicting patterns of prey use from morphology of fishes. *Environmental Biology of Fishes*, 44(1–3):97–113.

Walker, A. D. (1961). Triassic reptiles from the Elgin area: *Stagonolepis*, *Dasygnathus* and their allies. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 244(709):103–204.

Walker, A. D. (1964). Triassic reptiles from the Elgin area: *Ornithosuchus* and the origin of carnosaurs. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 248(744):53–134.

Walker, A. D. (1968). *Protosuchus*, *Proterochampsa*, and the origin of phytosaurs and crocodiles. *Geological Magazine*, 105(1):1–14.

Walker, A. D. (1970). A revision of the Jurassic reptile *Hallopus victor* (Marsh), with remarks on the classification of crocodiles. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 257(816):323–372.

Walmsley, C. W., Smits, P. D., Quayle, M. R., McCurry, M. R., Richards, H. S., Oldfield, C. C., Wroe, S., Clausen, P. D., and McHenry, C. R. (2013). Why the long face? The mechanics of mandibular symphysis proportions in crocodiles. *PLoS ONE*, 8(1):e53873.

Wang, G.-F., You, H.-L., Pan, S.-G., and Wang, T. (2017a). A new crested theropod dinosaur from the Early Jurassic of Yunnan Province, China. *Vertebrata PalAsiatica*, 55(2):177–186.

Wang, M. and Lloyd, G. T. (2016). Rates of morphological evolution are heterogeneous in Early Cretaceous birds. *Proceedings of the Royal Society of London B: Biological Sciences*, 283(1828):20160214.

Wang, S., Stiegler, J., Amiot, R., Wang, X., Du, G.-h., Clark, J. M., and Xu, X. (2017b). Extreme ontogenetic changes in a ceratosaurian theropod. *Current Biology*, 27(1):144–148.

Wang, Y.-M., You, H.-L., and Wang, T. (2017c). A new basal sauropodiform dinosaur from the Lower Jurassic of Yunnan Province, China. *Scientific Reports*, 7:41881.

Wang, Y. (2006). Phylogeny and Early Radiation of Mesozoic Lissamphibians from East Asia. In Rong, J., Fang, Z., Zhou, Z., Zhan, R., Wang, X., and Yuan, X., editors, *Originations, Radiations and Biodiversity Changes–Evidences from the Chinese Fossil Record*, pages 643–663, 931–936. Science Press, Beijing. [In Chinese with English summary].

Wang, Y. and Evans, S. E. (2006). Advances in the study of fossil amphibians and squamates from China: the past fifteen years. *Vertebrata PalAsiatica*, 44(1):60–73.

Wang, Y., Zhang, G., and Sun, A. (2008). Tetrapoda. In Li, J., Wu, X., and Zhang, F., editors, *The Chinese Fossil Reptiles and Their Kin*, pages 1–26. Science Press, Bejing, Second edition.

Ward, P. D., Botha, J., Buick, R., Kock, M. O. D., Erwin, D. H., Garrison, G. H., Kirschvink, J. L., and Smith, R. (2005). Abrupt and gradual extinction among Late Permian land vertebrates in the Karoo Basin, South Africa. *Science*, 307(5710):709–714.

Ward, P., Labandeira, C., Laurin, M., and Berner, R. A. (2006). Confirmation of Romer's Gap as a low oxygen interval constraining the timing of initial arthropod and vertebrate terrestrialization. *Proceedings of the National Academy of Sciences*, 103(45):16818–16822.

Warren, A. (1985). Triassic Australian plagiosauroid. *Journal of Paleontology*, 59(1):236–241.

Warren, A. (1995). *Plagiosternum granulosum* E. Fraas: a plagiosaurid temnospondyl from the Middle Triassic of Crailsheim, Germany. *Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, 229:1–8.

Warren, A. (1998). *Laidleria* uncovered: a redescription of *Laidleria gracilis* Kitching (1957), a temnospondyl from the *Cynognathus* Zone of South Africa. *Zoological Journal of the Linnean Society*, 122(1–2):167–185.

Warren, A. (1999). Karoo tupilakosaurid: a relict from Gondwana. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 89(3):145–160.

Warren, A. (2000). Secondarily Aquatic Temnospondyls of the Upper Permian and Mesozoic. In Heatwole, H. and Carroll, R. L., editors, *Amphibian Biology: Volume 4 - Paleontology*, chapter 8, pages 1121–1149. Surrey Bearry Press, Chipping Norton.

Warren, A. (2012). The South African stereospondyl *Microposaurus* from the Middle Triassic of the Sydney Basin, Australia. *Journal of Vertebrate Paleontology*, 32(3):538–544.

Warren, A. and Black, T. (1985). A new rhytidosteid (Amphibia, Labyrinthodontia) from the Early Triassic Arcadia Formation of Queensland, Australia, and the relationships of Triassic temnospondyls. *Journal of Vertebrate Paleontology*, 5(4):303–327.

Warren, A. and Marsicano, C. (2000). A phylogeny of the Brachyopoidea (Temnospondyli, Stereospondyli). *Journal of Vertebrate Paleontology*, 20(3):462–483.

Warren, A. and Turner, S. (2004). The first stem tetrapod from the Lower Carboniferous of Gondwana. *Palaeontology*, 47(1):151–184.

Warren, A., Damiani, R., and Sengupta, D. P. (2009). Unique stereospondyl mandibles from the Early Triassic Panchet Formation of India and the Arcadia Formation of Australia. *Special Papers in Palaeontology*, 81:161–173.

Warren, A., Rozefelds, A. C., and Bull, S. (2011). Tupilakosaur-like vertebrae in *Bothriceps australis*, an Australian brachyopid stereospondyl. *Journal of Vertebrate Paleontology*, 31(4):738–753.

Watson, D. M. S. (1911). The Upper Liassic Reptilia. Part III. *Microcleidus macropterus* (Seeley) and the limbs of *Microcleidus homalospondylus* (Owen). *Memoirs of the Manchester Literary and Philosophical Society*, 55(17):1–9.

Watson, D. M. S. (1914a). *Broomia perplexa*, gen. et sp. n., a fossil reptile from South Africa. *Proceedings of the Zoological Society of London*, 84(4):995–1010.

Watson, D. M. S. (1914b). On the nomenclature of the South-African pariasaurians. *Annals and Magazine of Natural History*, 8th series: 14(79):98–102.

Watson, D. M. S. (1954). On *Bolosaurus* and the origin and classification of reptiles. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 111(9):297–449.

Watson, D. M. S. and Romer, A. S. (1956). A classification of therapsid reptiles. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 114:35–89.

Weide, D. M., Sidor, C. A., Angielczyk, K. D., and Smith, R. M. H. (2009). A new record of *Procynosuchus delaharpeae* (Therapsida: Cynodontia) from the Upper Permian Usili Formation, Tanzania. *Palaeontologia africana*, 44:21–26.

Weinbaum, J. C. (2011). The skull of *Postosuchus kirkpatricki* (Archosauria: Paracrocodyliformes) from the Upper Triassic of the United States. *PaleoBios*, 30(1):18–44.

Weinbaum, J. C. (2013). Postcranial skeleton of *Postosuchus kirkpatricki* (Archosauria: Paracrocodylomorpha), from the Upper Triassic of the United States. *Geological Society, London, Special Publications*, 379(1):525–553.

Weinbaum, J. C. and Hungerbühler, A. (2007). A revision of *Poposaurus gracilis* (Archosauria: Suchia) based on two new specimens from the Late Triassic of the southwestern U.S.A. *Paläontologische Zeitschrift*, 81(2):131–145.

Welles, S. P. (1947). Vertebrates from the Upper Moenkopi Formation of northern Arizona. *University of California Publications - Bulletin of the Department of Geological Sciences*, 27(7):241–294.

Welles, S. P. (1993). A review of the lonchorhynchine trematosaurs (Labyrinthodontia), and a description of a new genus and species from the Lower Moenkopi Formation of Arizona. *PaleoBios*, 14(3):1–24.

Wellnhofer, P. (2003). A Late Triassic pterosaur from the Northern Calcareous Alps (Tyrol, Austria). *Geological Society, London, Special Publications*, 217(1):5–22.

Wellstead, C. F. (1998). Order Lysorophia Romer 1930. In Carroll, R. L., Bossy, K. A., Milner, A. C., Andrews, S. M., and Wellstead, C. F., editors, *Handbuch der Paläoherpetologie – Encyclopedia of Paleoherpetology Part 1: Lepospondyli*, pages 133–148. Verlag Dr. Friedrich Pfeil, München.

Werneburg, I. (2013). The tendinous framework in the temporal skull region of turtles and considerations about its morphological implications in amniotes: a review. *Zoological Science*, 30(3):141–153.

Werneburg, R. (1986). Branchiosaurier aus dem Rotliegenden (Unterperm) der ČSSR. *Zeitschrift für geologische Wissenschaften*, 14(6):673–686.

Werneburg, R. (1988). Die Stegocephalen der Goldlauterer Schichten (Unterrotliegendes, Unterperm), Teil II: *Apatheon kontheri* n. sp., *Melanerpeton eisfeldi* n. sp. des Thüringer Waldes und andere. *Freiberger Forschungshefte C*, 427(Paläontologie):7–29.

Werneburg, R. (1989). Labyrinthodontier (Amphibia) aus dem Oberkarbon und Unterperm Mitteleuropas – Systematik, Phylogenie und Biostratigraphie. *Freiberger Forschungshefte C*, 436:7–57.

Werneburg, R. (1993). *Trematosaurus* (Amphibia) aus dem Mittleren Buntsandstein (Untertrias) von Thüringen. *Veröffentlichungen Naturhistorisches Museum Schleusingen*, 7/8:17–29.

Werneburg, R. (1996). Temnospondyle Amphibien aus dem Karbon Mitteldeutschlands. *Veröffentlichungen Naturhistorisches Museum Schleusingen*, 11:23–64.

Werneburg, R. (2001). *Apateon dracyiensis* – eine frühe Pionierform der Branchiosaurier aus dem Europäischen Rotliegend. Teil 1: Morphologie. *Veröffentlichungen Naturhistorisches Museum Schleusingen*, 16:17–36.

Werneburg, R. (2007). Der "Manebacher Saurier" – ein neuer großer Eryopide (*Onchiodon*) aus dem Rotliegend (Unter-Perm) des Thüringer Waldes. *Veröffentlichungen Naturhistorisches Museum Schleusingen*, 22:3–40.

Werneburg, R. (2012). Dissorophoide Amphibien aus dem Westphalian D (Ober-Karbon) von Nýřany in Böhmen (Tschechische Republik) – der Schlüssel zum Verständnis der frühen ‚Branchiosaurier'. *Semana*, 27:3–50.

Werneburg, R. and Schneider, J. (1996). The Permian temnospondyl amphibians of India. *Special Papers in Palaeontology*, 52:105–128.

Werneburg, R. and Steyer, J.-S. (1999). Redescription of the holotypeof *Actinodon frossardi* (Amphibia, Temnospondyli) from the Lower Permian of the Autun basin (France). *Geobios*, 32(4):599–607.

Werneburg, R. and Schneider, J. W. (2006). Amphibian biostratigraphy of the European Permo-Carboniferous. *Geological Society, London, Special Publications*, 265(1):201–215.

Werneburg, R. and Berman, D. S. (2012). Revision of the aquatic eryopid temnospondyl *Glaukerpeton avinoffi* Romer, 1952, from the Upper Pennsylvanian of North America. *Annals of Carnegie Museum*, 81(1):33–60.

Werneburg, R., Steyer, J. S., Sommer, G., Gand, G., Schneider, J. W., and Vianey-Liaud, M. (2007a). The earliest tupilakosaurid amphibian with diplospondylous vertebrae from the Late Permian of southern France. *Journal of Vertebrate Paleontology*, 27(1):26–30.

Werneburg, R., Ronchi, A., and Schneider, J. W. (2007b). The Early Permian branchiosaurids (Amphibia) of Sardinia (Italy): systematic palaeontology, palaeoecology, biostratigraphy and palaeobiogeographic problems. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 252(3–4):383–404.

Werneburg, R., Schneider, J. W., and Lucas, S. G. (2013). The dissorophoid *Milnererpeton huberi* (Temnospondyli) from the Late Pennsylvanian Kinney Brick Quarry in New Mexico restudied – paleontology, paleoenvironment, and age. In Lucas, S. G., Nelson, W. J., DiMichele, W. A., Spielmann, J. A., Krainer, K., Barrick, J. E., Elrick, S., and Voigt, S., editors, *Carboniferous-Permian Transition in Central New Mexico*, volume 59, pages 349–369. New Mexico Museum of Natural History.

Westneat, M. W. (1994). Transmission of force and velocity in the feeding mechanisms of labrid fishes (Teleostei, Perciformes). *Zoomorphology*, 114(2):103–118.

Westneat, M. W. (2003). A biomechanical model for analysis of muscle force, power output and lower jaw motion in fishes. *Journal of Theoretical Biology*, 223(3):269–281.

Westneat, M. W. (2004). Evolution of levers and linkages in the feeding mechanisms of fishes. *Integrative and Comparative Biology*, 44(5):378–389.

Westphal, F. (1961). Zur Systematik der deutschen und englischen Lias-Krokodilier. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 113(2):207–217.

Westphal, F. (1962). Die Krokodilier der deutschen und englischen Oberen Lias. *Palaeontographica Abteilung A*, 118(1–3):23–118.

Whatley, R. L. (2005). *Phylogenetic relationships of Isalorhynchus genovefae, the rhynchosaur (Reptilia, Archosaurmorpha) from Madagascar*. PhD thesis, University of California, Santa Barbara. 276 pp.

Whetstone, K. N. and Whybrow, P. J. (1983). A “cursorial” crocodilian from the Triassic of Lesotho (Basutoland), Southern Africa. *Occasional Papers of the Museum of Natural History, The University of Kansas*, 106:1–37.

White, E. P., Ernest, S. K. M., Kerkhoff, A. J., and Enquist, B. J. (2007). Relationships between body size and abundance in ecology. *Trends in Ecology & Evolution*, 22(6):323–330.

White, I. C. (1917). Note by I. C. White, state geologist. *West Virginia Geological Survey: Braxton and Clay Counties*, pages 822–829.

Whiteside, D. I. and Duffin, C. J. (2017). Late Triassic terrestrial microvertebrates from Charles Moore's '*Microlestes*' quarry, Holwell, Somerset, UK. *Zoological Journal of the Linnean Society*, 179(3):677–705.

Whiteside, D. I., Duffin, C. J., Gill, P. G., Marshall, J. E. A., and Benton, M. J. (2016). The Late Triassic and Early Jurassic fissure faunas from Bristol and South Wales: stratigraphy and setting. *Palaeontologia Polonica*, 67:257–287.

Whiteside, D. I., Duffin, C. J., and Furrer, H. (2017). The Late Triassic lepidosaur fauna from Hallau, north-eastern Switzerland, and a new 'basal' rhynchocephalian *Deltadectes elvetica* gen. et sp. nov. *Neues Jahrbuch für Geologie und Paläontologie - Abhandlungen*, 285(1):53–74.

Whiteside, J. H., Grogan, D. S., Olsen, P. E., and Kent, D. V. (2011). Climatically driven biogeographic provinces of Late Triassic tropical Pangea. *Proceedings of the National Academy of Sciences*, 108(22):8972–8977.

Whiteside, J. H., Lindström, S., Irmis, R. B., Glasspool, I. J., Schaller, M. F., Dunlavey, M., Nesbitt, S. J., Smith, N. D., and Turner, A. H. (2015). Extreme ecosystem instability suppressed tropical dinosaur dominance for 30 million years. *Proceedings of the National Academy of Sciences*, 112(26):7909–7913.

Wideman, N. K., Sumida, S. S., and O'Neil, M. (2005). A reassessment of the taxonomic status of the materials assigned to the Early Permian tetrapod genera *Limnosceloides* and *Limnoscelops*. In Lucas, S. G. and Zeigler, K. E., editors, *The Nonmarine Permian*, volume 30, pages 358–362. New Mexico Museum of Natural History.

Wideman, N. and Sumida, S. (2004). Taxonomic status of the tetrapod *Limnostygis relictus* and its bearing on the temporal distribution of basal amniotes. *Journal of Vertebrate Paleontology*, 24(Supp. to 3):129A.

Wiens, J. J. (2015). Explaining large-scale patterns of vertebrate diversity. *Biology Letters*, 11(7):20150506.

Wignall, P. (2001). Large igneous provinces and mass extinctions. *Earth-Science Reviews*, 53(1–2):1–33.

Wilberg, E. W. (2015a). A new metriorhynchoid (Crocodylomorpha, Thalattosuchia) from the Middle Jurassic of Oregon and the evolutionary timing of marine adaptations in thalattosuchian crocodylomorphs. *Journal of Vertebrate Paleontology*, 35(2):e902846.

Wilberg, E. W. (2015b). What's in an outgroup? The impact of outgroup choice on the phylogenetic position of Thalattosuchia (Crocodylomorpha) and the origin of Crocodyliformes. *Systematic Biology*, 64(4):621–637.

Wilberg, E. W. (2017). Investigating patterns of crocodyliform cranial disparity through the Mesozoic and Cenozoic. *Zoological Journal of the Linnean Society*, 181(1):189–208.

Wild, R. and Oosterink, H. (1984). *Tanystropheus* (Reptilia: Squamata) aus dem Unteren Muschelkalk von Winterswijk, Holland. *Grondboor en Hamer*, 38(5):142–148.

Wiman, C. (1916). Notes on the marine Triassic reptile fauna of Spitzbergen. *University of California Publications - Bulletin of the Department of Geology*, 10(5):63–73.

Wintrich, T., Hayashi, S., Houssaye, A., Nakajima, Y., and Sander, P. M. (2017a). A Triassic plesiosaurian skeleton and bone histology inform on evolution of a unique body plan. *Science Advances*, 3(12):e1701144.

Wintrich, T., Hagdorn, H., and Sander, P. M. (2017b). An enigmatic marine reptile–the actual first record of *Omphalosaurus* in the Muschelkalk of the Germanic basin. *Journal of Vertebrate Paleontology*, 37(6):e1384739.

Witmer, L. M. (2002). The Debate on Avian Ancestry - Phylogeny, Function, and Fossils. In Chiappe, L. M. and Witmer, L. M., editors, *Mesozoic Birds - Above the Heads of Dinosaurs*, pages 3–30. University of California Press, Berkeley.

Witzmann, F. (2013a). Phylogenetic patterns of character evolution in the hyobranchial apparatus of early tetrapods. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 104:145–167.

Witzmann, F. (2013b). The stratigraphically oldest eryopoid temnospondyl from the Permo-Carboniferous Saar-Nahe Basin, Germany. *Paläontologische Zeitschrift*, 87(2):259–267.

Witzmann, F. and Scholz, H. (2007). Morphometric study of allometric skull growth in the temnospondyl *Archegosaurus decheni* from the Permian/Carboniferous of Germany. *Geobios*, 40(4):541–554.

Witzmann, F. and Brainerd, E. (2017). Modeling the physiology of the aquatic temnospondyl *Archegosaurus decheni* from the early Permian of Germany. *Fossil Record*, 20(2):105–127.

Witzmann, F. and Schoch, R. R. (2018). Skull and postcranium of the bystrowianid *Bystrowiella schumanni* from the Middle Triassic of Germany, and the position of chroniosuchians within Tetrapoda. *Journal of Systematic Palaeontology*, 16(9):711–739.

Witzmann, F., Schwarz-Wings, D., Hampe, O., Fritsch, G., and Asbach, P. (2014). Evidence of spondyloarthropathy in the spine of a phytosaur (Reptilia: Archosauriformes) from the Late Triassic of Halberstadt, Germany. *PLoS ONE*, 9(1):e85511.

Witzmann, F., Sachs, S., and Nyhuis, C. J. (2016). A new species of *Cyclotosaurus* (Stereospondyli, Capitosauria) from the Late Triassic of Bielefeld, NW Germany, and the intrarelationships of the genus. *Fossil Record*, 19(2):83–100.

Witzmann, F., Werneburg, R., and Milner, A. R. (2017). A partial skull roof of an embolomere from Linton, Ohio (Middle Pennsylvanian) and its phylogenetic affinities. *Paläontologische Zeitschrift*, 91(3):399–408.

Woodruff, D. C., Carr, T. D., Storrs, G. W., Waskow, K., Scannella, J. B., Nordén, K. K., and Wilson, J. P. (2018). The smallest diplodocid skull reveals cranial ontogeny and growth-related dietary changes in the largest dinosaurs. *Scientific Reports*, 8:14341.

Wu, X.-C. and Chatterjee, S. (1993). *Dibothrosuchus elaphros*, a crocodylomorph from the Lower Jurassic of China and the phylogeny of the Sphenosuchia. *Journal of Vertebrate Paleontology*, 13(1):58–89.

Wu, X.-C. and Sues, H.-D. (1996). Reassessment of *Platyognathus hsui* Young, 1944 (Archosauria: Crocodyliformes) from the Lower Lufeng Formation (Lower Jurassic) of Yunnan, China. *Journal of Vertebrate Paleontology*, 16(1):42–48.

Wu, X.-C. and Russell, A. P. (2001). Redescription of *Turfanosuchus dabanensis* (Archosauriformes) and new information on its phylogenetic relationships. *Journal of Vertebrate Paleontology*, 21(1):40–50.

Wu, X.-C., Brinkman, D. B., and Lu, J.-C. (1994). A new species of *Shantungosuchus* from the Lower Cretaceous of Inner Mongolia (China), with comments on *S. chuhsienensis* Young, 1961 and the phylogenetic position of the genus. *Journal of Vertebrate Paleontology*, 14(2):210–229.

Wu, X.-C., Liu, J., and Li, J.-L. (2001). The anatomy of the first archosauriform (Diapsida) from the terrestrial Upper Triassic of China. *Vertebrata PalAsiatica*, 39(4):251–265.

Wu, X.-C., Cheng, Y.-N., Sato, T., and Shan, H.-Y. (2009). *Miodentosaurus brevis* Cheng et al., 2007 (Diapsida: Thalattosauria): its postcranial skeleton and phylogenetic relationships. *Vertebrata PalAsiatica*, 47(1):1–20.

Wyllie, A. (2003). A review of Robert Broom's therapsid holotypes: have they survived the test of time? *Palaeontologia africana*, 39:1–19.

Wynd, B. M., Peecook, B. R., Whitney, M. R., and Sidor, C. A. (2018). The first occurrence of *Cynognathus crateronotus* (Cynodontia: Cynognathia) in Tanzania and Zambia, with implications for the age and biostratigraphic correlation of Triassic strata in southern Pangea. *Journal of Vertebrate Paleontology*, 37(6, Supplement):228–239.

Xie, W., Lewis, P. O., Fan, Y., Kuo, L., and Chen, M.-H. (2011). Improving marginal likelihood estimation for Bayesian phylogenetic model selection. *Systematic Biology*, 60(2):150–160.

Xing, L., Bell, P. R., Rothschild, B. M., Ran, H., Zhang, J., Dong, Z., Zhang, W., and Currie, P. J. (2013). Tooth loss and alveolar remodeling in *Sinosaurus triassicus* (Dinosauria: Theropoda) from the Lower Jurassic strata of the Lufeng Basin, China. *Chinese Science Bulletin*, 58(16):1931–1935.

Xing, L., Paulina-Carabajal, A., Currie, P. J., Xu, X., Zhang, J., Wang, T., Burns, M. E., and Dong, Z. (2014a). Braincase anatomy of the basal theropod *Sinosaurus* from the Early Jurassic of China. *Acta Geologica Sinica - English Edition*, 88(6):1653–1664.

Xing, L., Peng, G., Ye, Y., Lockley, M. G., Klein, H., Persons IV, W. S., Zhang, J., Shu, C., and Hao, B. (2014b). Sauropod and small theropod tracks from the Lower Jurassic Ziliujing Formation of Zigong City, Sichuan, China, with an overview of Triassic–Jurassic dinosaur fossils and footprints of the Sichuan Basin. *Ichnos*, 21(2):119–130.

Xing, L., Miyashita, T., Currie, P. J., You, H., Zhang, J., and Dong, Z. (2015a). A new basal eusauropod from the Middle Jurassic of Yunnan, China, and faunal compositions and transitions of asian sauropodomorph dinosaurs. *Acta Palaeontologica Polonica*, 60(1):145–154.

Xing, L., Miyashita, T., Zhang, J., Li, D., Ye, Y., Sekiya, T., Wang, F., and Currie, P. J. (2015b). A new sauropod dinosaur from the Late Jurassic of China and the diversity, distribution, and relationships of mamenchisaurids. *Journal of Vertebrate Paleontology*, 35(1):e889701.

Xing, L., Lockley, M. G., Zhang, J., You, H., Klein, H., Persons, IV, W. S., Dai, H., and Dong, Z. (2016). First Early Jurassic ornithischian and theropod footprint assemblage and a new ichnotaxon *Shenmuichnus wangi* ichnosp. nov. from Yunnan Province, southwestern China. *Historical Biology*, 28(6):721–733.

Xu, L., Li, X.-W., Jia, S.-H., and Liu, J. (2015). The Jiyuan tetrapod fauna of the Upper Permian of China: new pareiasaur material and the reestablishment of *Honania complicidentata*. *Acta Palaeontologica Polonica*, 60(3):689–700.

Xu, X., Zhao, X., and Clark, J. M. (2001). A new therizinosaur from the Lower Jurassic lower Lufeng Formation of Yunnan, China. *Journal of Vertebrate Paleontology*, 21(3):477–483.

Yadagiri, P. (1985). An amphidontid symmetrodont from the Early Jurassic Kota Formation, India. *Zoological Journal of the Linnean Society*, 85(4):411–417.

Yang, C.-Y. (2013). Systematic analysis method of sauropod: a case study of *Tonganosaurus hei*. *Acta Geologica Sinica*, 87(12):1826–1833. [In Chinese with English abstract].

Yang, Z. (2002). Inference of selection from multiple species alignments. *Current Opinion in Genetics & Development*, 12(6):688–694.

Yang, Z. (2006). *Computational Molecular Evolution*. Oxford University Press, Oxford. 357 pp.

Yates, A. M. (2003a). A definite prosauropod dinosaur from the Lower Elliot Formation (Norian: Upper Triassic) of South Africa. *Palaeontologia africana*, 39:63–68.

Yates, A. M. (2003b). A new species of the primitive dinosaur *Thecodontosaurus* (Saurischia: Sauropodomorpha) and its implications for the systematics of early dinosaurs. *Journal of Systematic Palaeontology*, 1(1):1–42.

Yates, A. M. (2003c). The species taxonomy of the sauropodomorph dinosaurs from the Löwenstein Formation (Norian, Late Triassic) of Germany. *Palaeontology*, 46(2):317–337.

Yates, A. M. (2004). *Anchisaurus polyzelus* (Hitchcock): the smallest known sauropod dinosaur and the evolution of gigantism among sauropodomorph dinosaurs. *Postilla*, 230:1–58.

Yates, A. M. (2007a). Solving a dinosaurian puzzle: the identity of *Aliwalia rex* Galton. *Historical Biology*, 19(1):93–123.

Yates, A. M. (2007b). The first complete skull of the Triassic dinosaur *Melanorosaurus* Haughton (Sauropodomorpha: Anchisauria). *Special Papers in Palaeontology*, 77:9–55.

Yates, A. M. (2010). A revision of the problematic sauropodomorph dinosaurs from Manchester, Connecticut and the status of *Anchisaurus* Marsh. *Palaeontology*, 53(4):739–752.

Yates, A. M. and Sengupta, D. P. (2002). A lapillopsid temnospondyl from the Early Triassic of India. *Alcheringa: An Australasian Journal of Palaeontology*, 26(2):201–208.

Yates, A. M., Bonnan, M. F., Neveling, J., Chinsamy, A., and Blackbeard, M. G. (2010). A new transitional sauropodomorph dinosaur from the Early Jurassic of South Africa and the evolution of sauropod feeding and quadrupedalism. *Proceedings of the Royal Society B: Biological Sciences*, 277(1682):787–794.

Yates, A. M., Bonnan, M. F., and Neveling, J. (2011). A new basal sauropodomorph dinosaur from the Early Jurassic of South Africa. *Journal of Vertebrate Paleontology*, 31(3):610–625.

Yates, A. M., Wedel, M. J., and Bonnan, M. F. (2012). The early evolution of postcranial skeletal pneumaticity in sauropodomorph dinosaurs. *Acta Palaeontologica Polonica*, 57(1):85–100.

Yeakel, J. D., Kempes, C. P., and Redner, S. (2018). Dynamics of starvation and recovery predict extinction risk and both Damuth's law and Cope's rule. *Nature Communications*, 9:657.

Yezerinac, S. M., Lougheed, S. C., and Handford, P. (1992). Measurement error and morphometric studies: statistical power and observer experience. *Systematic Biology*, 41(4):471–482.

Yin, C., Hao, W., Sun, Z., Sun, Y., and Jiang, D. (2014). New material of *Nothosaurus yangjuanensis* from the Middle Anisian (Middle Triassic) of Guizhou Province, southwestern China. *Acta Scientiarum Naturalium Universitatis Pekinensis*, 50(3):467–475. [In Chinese with English abstract].

You, H.-L., Azuma, Y., Wang, T., Wang, Y.-M., and Dong, Z.-M. (2014). The first well-preserved coelophysoid theropod dinosaur from Asia. *Zootaxa*, 3873(3):233–249.

Young, C.-C. (1942). *Yunnanosaurus huangi* Young (gen. et sp. nov.), a new Prosauropoda from the Red Beds at Lufeng, Yunnan. *Bulletin of the Geological Society of China*, 22(1–2):63–104.

Young, C.-C. (1948). On two new saurischians from Lufeng, Yunnan. *Bulletin of the Geological Society of China*, 28(1–2):75–90.

Young, C. C. (1978). [A complete skeleton of *Chasmatosaurus yuani* from Xinjinang]. *Memoirs of the Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica, Series B*, 13:26–46. [In Chinese].

Young, M. T., Brusatte, S. L., Ruta, M., and De Andrade, M. B. (2010). The evolution of Metriorhynchoidea (Mesoeucrocodylia, Thalattosuchia): an integrated approach using geometric morphometrics, analysis of disparity, and biomechanics. *Zoological Journal of the Linnean Society*, 158(4):801–859.

Young, M. T., Rabi, M., Bell, M. A., Foffa, D., Steel, L., Sachs, S., and Peyer, K. (2016a). Big-headed marine crocodyliforms and why we must be cautious when using extant species as body length proxies for long-extinct relatives. *Palaeontologia Electronica*, 19.3.30A:1–14.

Young, M. T., Tennant, J. P., Brusatte, S. L., Challands, T. J., Fraser, N. C., Clark, N. D. L., and Ross, D. A. (2016b). The first definitive Middle Jurassic atoposaurid (Crocodylomorpha, Neosuchia), and a discussion on the genus *Theriosuchus*. *Zoological Journal of the Linnean Society*, 176(2):443–462.

Young, M. T., Hastings, A. K., Allain, R., and Smith, T. J. (2017). Revision of the enigmatic crocodyliform *Elosuchus felixi* de Lapparent de Broin, 2002 from the Lower–Upper Cretaceous boundary of Niger: potential evidence for an early origin of the clade Dyrosauridae. *Zoological Journal of the Linnean Society*, 179(2):377–403.

Yu, G., Smith, D. K., Zhu, H., Guan, Y., and Lam, T. T.-Y. (2017). ggtree: an R package for visualization and annotation of phylogenetic trees with their covariates and other associated data. *Methods in Ecology and Evolution*, 8(1):28–36.

Zaher, M., Coram, R. A., and Benton, M. J. (2019). The Middle Triassic procolophonid *Kapes bentoni*: computed tomography of the skull and skeleton. *Papers in Palaeontology*, 5(1):111–138.

Zanno, L. E. (2010). A taxonomic and phylogenetic re-evaluation of Therizinosauria (Dinosauria: Maniraptora). *Journal of Systematic Palaeontology*, 8(4):503–543.

Zanno, L. E., Drymala, S., Nesbitt, S. J., and Schneider, V. P. (2015). Early crocodylomorph increases top tier predator diversity during rise of dinosaurs. *Scientific Reports*, 5:9276.

Zapfe, H. (1976). Ein großer Ichthyosaurier aus den Kössener Schichten der Nordalpen. *Annalen des Naturhistorischen Museums in Wien*, 80:239–250.

Zatoń, M., Niedźwiedzki, G., Marynowski, L., Benzerara, K., Pott, C., Cosmidis, J., Krzykawski, T., and Paweł, F. (2015). Coprolites of Late Triassic carnivorous vertebrates from Poland: an integrative approach. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 430:21–46.

Zawiskie, J. M. (1986). Terrestrial vertebrate faunal succession during the Triassic. In Padian, K., editor, *The Beginning of the Age of Dinosaurs: Faunal change across the Triassic–Jurassic Boundary*, chapter 26, pages 353–362. Cambridge University Press, Cambridge.

Zawiskie, J., Dawley, R., and Nesbitt, S. (2011). The relationships and type locality *Heptasuchus clarki*, Chugwater Group (Middle to Upper Triassic), southeastern Big Horn Mountains, Wyoming, USA. *Journal of Vertebrate Paleontology, SVP Program and Abstracts Book*, 31(sup2):219.

Zeigler, K. E., Lucas, S. G., and Heckert, A. B. (2002). A phytosaur skull from the Upper Triassic Snyder Quarry (Petrified Forest Formation, Chinle Group) of north-central New Mexico. In Heckert, A. B. and Lucas, S. G., editors, *Upper Triassic Stratigraphy and Paleontology*, volume 21, pages 171–178. New Mexico Museum of Natural History.

Zhang, F. (1984). Fossil record of Mesozoic mammals of China. *Vertebrata PalAsiatica*, 22(1):29–38. [In Chinese with English abstract].

Zhang, F., Li, Y., and Wan, X. (1984). A new occurrence of Permian seymouriamorphs in Xinjiang, China. *Vertebrata PalAsiatica*, 22(4):294–304. [In Chinese with extended English abstract].

Zhang, Q.-N., You, H.-L., Wang, T., and Chatterjee, S. (2018). A new sauropodiform dinosaur with a ‘sauropodan’ skull from the Lower Jurassic Lufeng Formation of Yunnan Province, China. *Scientific Reports*, 8:13464.

Zhang, Y.-H. and Yang, Z.-L. (1994). *A new complete osteology of Prosauropoda in Lufeng Basin, Yunnan, China*. Yunnan Publishing House of Science and Technology, Kunming. 100 pp. [In Chinese with English summary].

Zheng, X.-T., You, H.-L., Xu, X., and Dong, Z.-M. (2009). An Early Cretaceous heterodontosaurid dinosaur with filamentous integumentary structures. *Nature*, 458(7236):333–336.

Zhu, M., Ahlberg, P. E., Zhao, W., and Jia, L. (2002). First Devonian tetrapod from Asia. *Nature*, 420(6917):760–761.