A new ornithischian dinosaur and the terrestrial vertebrate fauna from a bone bed in the Wealden of Ardingly, West Sussex

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Abstract

The Wealden Supergroup of south-east England has long been of interest to palaeontologists because of its diverse flora and fauna. The Supergroup is Early Cretaceous in age, occupying the time period immediately after the enigmatic end-Jurassic extinction. Wealden faunas therefore have the potential to be informative about the tempo and mode of post-extinction recovery, but due to lack of exposure in this densely populated part of southern England, are difficult to sample. In the summer of 2012, a number of *ex situ* fossiliferous blocks of sandstone, siltstone and limestone were discovered from building excavations at Ardingly College, near Haywards Heath in West Sussex. The sedimentology of the blocks indicates that they are from the Valanginian

Hastings Group, and that Ardingly College is underlain by the Grinstead Clay Formation, rather than the Ardingly Sandstone Member. The blocks contain a diverse invertebrate fauna and flora, as well as vertebrate remains, which are found in a distinct sandstone horizon that probably represents the Top Lower Tunbridge Wells pebble bed. A tooth from an ornithschian dinosaur cannot be referred to any of the ornithischian taxa known from the Wealden Supergroup, and therefore represents a new taxon. Teeth of the crocodilian *Theriosuchus* extend the known range of this taxon in the Wealden, while teeth of an ornithocheird pterosaur confirm the presence of these animals in the skies above the Wealden sub-basins. Fusainized plant remains and the wing-case of a cupedid beatle indicate that wildfire was a ubiquitous feature of the Weald Sub-basin during the Valanginian.

Introduction

The Wealden Supergroup of the Weald Sub-basin of south-east England comprises a succession of alluvial, lacustrine and lagoonal facies deposited during the Early Cretaceous (Radley & Allen 2012). Documentation of the rocks and their fossils, mainly exposed in small, hand-worked quarries and on sea cliffs, began in the early part of the nineteenth century and continues to this day (Batten 2011). The historical significance of the Wealden strata to vertebrate palaeontologists cannot be overstated: some of the earliest recognised dinosaur remains from anywhere in the world were discovered here (Mantell 1825), and several bone beds within the Wealden succession are well-known (Allen 1949; Cook 1995). Lower Cretaceous faunas are significant because they appear soon after an enigmatic and poorly understood extinction event at the end of the Jurassic Period (e.g. Bambach 2006; Benson et al. 2010; Mannion et al. 2011; Upchurch et al. 2011; Lloyd 2012). Documentation of faunas of this age is therefore important to aid our understanding of the tempo, mode and mechanisms behind this purported extinction and the post-extinction recovery. Unfortunately, vertebrate faunas from the basalmost Cretaceous are poorly known worldwide: the Paleobiology Database (www.paleobiodb.org) lists just 380 collections worldwide for vertebrates from the Berriasian, and only 197 collections for the Valanginian.). The Hastings Beds Group, dating from the uppermost Berriasian to the Valanginian (Fig. 1; Batten & Austen 2011), is ideally placed stratigraphically to be a case study for this time period. However, many of the small stone quarries and brick pits that littered the landscape of the Weald in the 19th and early 20th centuries, from which dinosaur fossils were discovered, have closed and are overgrown, and opportunities to investigate the rocks and their fossil contents are therefore increasingly scarce.

In 2012, a number of *ex situ* fossiliferous sandstone blocks were collected from a spoil heap formed by excavations for a new building at Ardingly College, West Sussex (Fig. 1), by one of us (B.C.-S.). Examination of the blocks revealed the presence of large bone fragments, teeth and invertebrate remains. Subsequently, we set up a citizen science project involving students of Ardingly College and the local community to search the spoil heaps for more fossiliferous blocks on a number of 'dino dig days'. Herein, we describe the terrestrial vertebrate fauna discovered at Ardingly College, locate it stratigraphically, and discuss its implications for our understanding of Wealden faunas. All fossiliferous material is accessioned into the collections of the Science Department at Ardingly College.

A note on stratigraphic terminology

Terminology applied to the strata of the Wealden of the Weald Sub-basin has a complex history. The most commonly-used terminology, and that employed in recent publications such as Batten (2011) and Radley & Allen (2012), considers the Wealden to be a Supergroup, divided into the Hastings Beds Group and the Weald Clay Group, and that terminology is employed here (Fig. 1). It should be noted, however, that this differs from the scheme employed by the British Geological Survey (BGS; Hopson et al. 2008), who consider the Wealden a Group, and do not recognise the Hastings Beds Group.

Institutional abbreviations

ARD, Ardingly College, Ardingly, West Sussex, U.K.; **NHMUK,** The Natural History Museum, London, U.K.

Methods

The sedimentology of the fossiliferous blocks was examined using traditional petrographic techniques; the fossils were examined using reflected light microscopy. Due to the wooded and residential nature of much of the Weald Sub-basin, few exposures are present. Subsurface sedimentological data in the area was obtained from borehole and trial pit logs drilled by Southern Testing Ltd, from freely available borehole data from the British Geological Survey (BGS; http://mapapps.bgs.ac.uk/geologyofbritain/home.html?mode=boreholes), from the BGS geological map of the area (Horsham Sheet, number 302; Gallois et al. 1972), and from descriptions of logged sections in quarries that are currently inaccessible in Radley & Allen (2012). These data were supplemented by field studies of exposures of the Ardingly Sandstone Member at Balcombe Lane, Ardingly (TQ 33530 29795) and Wakehurst Place (TQ 33636 31761), and of the Grinstead Clay Formation at Rocky Lane, Haywards Heath (TQ 32392 22268; Fig. 2). The latter was a road cutting exposed during building work, affording a rare opportunity to investigate the softer, rarely exposed Grinstead Clay Formation.

Sedimentology and stratigraphy

Sedimentological analysis of the fossiliferous blocks revealed that they could be divided into five broad lithologies, each with a distinct suite of fossils, indicating that more than one fossiliferous horizon was quarried at the Ardingly site. The five lithologies are: (1) fine-grained quartz arenite with some iron-rich cement; (2) fine-grained quartz arenite with significant iron-rich cement; (3) bioclastic limestone; (4) micritic limestone; and (5) finely laminated sandstone. Vertebrate remains are restricted to lithologies (1), (2) and (3). Organic remains generally show a preferred alignment.

Lithologies (1) and (2) comprise >95% sub-rounded, well-sorted quartz grains, with <5% plagioclase and muscovite. Hand specimens of lithology (2) are black to dark orange, witha pitted surface. The pits are 1-4mm wide and appear to be voids where organic material has been dissolved and/or preferentially weathered, or where clasts have been washed out. Thin-section petrography reveals an irregular, patchy red-brown to opaque cement. Shell moulds are present as voids, and are orientated with bedding. Nodules of an iron compound, 6-20 mm in diameter, are also present. Lithology (1) yields the freshwater bivalve *Unio* and the freshwater gastropod *Viviparus*, both preserved in monospecific assemblages. Indeterminate actinopterygian vertebrae are also present. Lithology (2) yields the vertebrate remains described below, teeth and scales of the lepisosteiform fish *Scheenstia* (formerly *Lepidotes*; Lopéz-Arbarello 2012;e.g. Fig. 3A; ARDB1; ARDB8A), teeth of the pycnodont fish *Ocloedus* (formerly *Coelodus*; Poyato-Ariza & Wenz 2002; ARDB1), and hybodont shark teeth (ARDB4A). Lithology (3) contains a monospecific assemblage of the bivalve *Neomiodon*, as well as the crocodylian teeth described below. Lithology (4) contains *Neomiodon*, and the fusainized wing case of a cupedid beetle (Fig. 3B; ARDL9), and numerous fusainized plant remains, including the ferns *Phlebopteris* (Fig. 3C; ARDL6B) and *Gleichenites* (ARDL13; ARDL14). Lithology (5) contained fusainized remains of the fern *Weichselia* (ARDL6A).

Several hand specimens preserve more than one of the lithologies described above along with way-up structures, allowing the stratigraphy to be elucidated. ARDL3 comprises laminated sandstone (lithology 5) with an irregular, erosive base overlying micritic limestone (lithology 4), while ARDL4 comprises rippled micritic limestone with laminated sandstone on the upper surface of the ripple. Imprints of *Neomiodon* valves are present on the underside of the ripple, indicating that the bioclastic limestone (lithology 3) underlies the micritic limestone. In specimen ARDY13, unpitted, orange quartz arenite (lithology 1) grades into pitted, black quartz arenite with increased iron cement (lithology 2).

According to the BGS geological map of the area, the Horsham Sheet (302; Gallois et al. 1972), Ardingly College (TQ 33969 28569) lies on the Ardingly Sandstone Member of the Lower Tunbridge Wells Sand Formation. Boreholes drilled for ground investigation on the College grounds kindly made available by Southern Testing Ltd reveal that the College is underlain by mudstone with sandy and silty lenses.

At the Balcombe Lane and Wakefield Place sites, the Ardingly Sandstone Member comprises up to 6 m of laterally continuous, fine-grained buff yellow to orange quartz arenite with darker iron staining in parts. It is massively bedded with occasional decimetre-scale cross-bedding. These observations are in accordance with published descriptions of the Ardingly Sandstone Member, which show it is a fine-grained sandstone, and contains ironstone nodules (e.g. Robinson & Williams 1976; Radley & Allen 2012). In contrast, at Rocky Lane, the Grinstead Clay Formation is composed of yellow-grey mudstone with iron nodules, abundant fining-upwards silt to very fine-grained sand lenses with plant material, several calcareous layers with ostracods, and very abundant lignite layers and lenses. The top of the section is marked by a buff yellow fine-grained sandstone that is finely laminated at its base but extending upwards contains decimetre-scale trough cross bedding. The Grinstead Clay at Freshfield Lane Brickworks, Horsted Keynes, close to Ardingly, was described as consisting of grey mudstones with ostracods and *Neomiodon*, overlain by a trough cross-bedded, fine-grained sandstone, identified as the Cuckfield Stone Member (Radley & Allen 2012), a discontinuous horizon within the Grinstead Clay (Michaelis 1969; Batten 2011).

The descriptions of the Grinstead Clay Formation above closely match borehole data from the College grounds, indicating that Ardingly College is most probably immediately underlain by the Grinstead Clay Formation, rather than the Ardingly Sandstone Member, in contrast to what is shown on the BGS geological map. The strata excavated during building works that contain the fossils described herein are thus likely to be from both the Grinstead Clay Formation and underlying Ardingly Sandstone Member. Indeed, our observations of lithologies (1) and (2) are concordant with published descriptions of the Ardingly Sandstone Member. Many of the sands within the Hastings Group are capped by 'pebble beds', interpreted as transgressive lags (e.g. Allen 1960, 1967; Cook 1995; Batten 2011). The Top Lower Tunbridge Wells pebble bed (Allen 1949, 1960, 1967) has been recorded at Philpots Quarry in West Hoathly and Freshfield Lane Brickworksin Horsted Keynes (Radley & Allen 2012), and lithology (2), which contains the most abundant vertebrate remains, may be the local expression of the Top Lower Tunbridge Wells pebble bed. Lithologies (3) to (5) appear to be from the Grinstead Clay. Based on the descriptions above, lithology (5) may be from the basal part of the Cuckfield Stone Member of the Grinstead Clay Formation (Fig. 1).

Systematic Palaeontology

Dinosauria Owen, 1842

Ornithischia Seeley, 1887

Ornithischia indet.

Material

ARDB1, an isolated tooth (Fig. 4)

Locality and horizon

Ardingly Sandstone Member, Lower Tunbridge Wells Sand Formation, Hastings Group, Wealden Supergroup (Lower Cretaceous, Valanginian). Ardingly College, Ardingly, West Sussex, TQ 33969 28569.

Description

The isolated tooth is exposed in labial or lingual view (Fig. 4). It is 1.7 mm mesodistally and 2 mm apicobasially. The crown is mesodistally symmetrical and bears a labiolingual swelling, or cingulum, at its base. The surface of the crown bears a central eminence that extends apically from the cingulum to the apex. The margins of the tooth are finely denticulate; at least four denticles are present on the side of the tooth that is free from matrix.

Comparisons and systematic remarks

The maxillary and dentary teeth of ornithischian dinosaurs are characterised by being apicobasally short, sub-triangular and straight, and possessing marginal denticles and a labiolingual and mesodistal expansion known as the cingulum at the base of the crown (Butler et al. 2008). These features are clearly present in ARDB1. Although other Mesozoic archosaurs with a tooth morphology convergent on ornithischians are have been discovered (e.g. Parker et al. 2005), such archosaurs are known neither from this geologic time period nor geographic location and thus it is most parsimonious to consider that the specimen is from an ornithischian dinosaur.

The basal members of several ornithischian groups possess teeth that are similar in morphology to ARDB1. The most basal group of ornithischians, the heterodontosaurids (Butler et al. 2008) possess a variety of tooth morphologies, from relatively simple, triangular crowns with variably distributed denticles in taxa such as *Echinodon* (Norman & Barrett 2002) and *Fruitadens* (Butler et al. 2010) to the more derived dentition of *Heterodontosaurus,* in which the cheek teeth are columnar, lack a cingulum, and are characterised by pronounced wear facets (Norman et al. 2004; Norman et al. 2011). Basal thyreophorans such as *Lesothosaurus*, *Scutellosaurus, Emausaurus* and *Scelidosaurus* possess cheek teeth that are triangular with subequal apicobasal and mesiodistal lengths, possess a cingulum, and do not possess ridges on tooth crowns (Colbert 1981; Haubold 1990; Sereno 1991; Barrett 2001). The teeth of basal neornithischians, such as *Agilisaurus, Hexinlusaurus* (Barrett et al. 2005) and *Othneilosaurus* (Norman et al. 2004), possess triangular crowns with marginal denticles, a weak cingulum, and variably developed wear facets.

Heterodontosaurids are currently unknown from the Wealden Supergroup, but *Echinodon* is known from the Tithonian – Berriasian Purbeck Formation of Dorset (Norman & Barrett 2002). ARDB1 differs from the teeth of *Echinodon* in that in the latter, the denticles are restricted to the apex of the tooth (Norman & Barrett 2002; Butler et al. 2010). Basal thyreophorans are unknown from the Wealden Supergroup, but three derived thyreophorans are known from deposits contemporaneous with those at Ardingly: the ankylosaurs *Hylaeosaurus* and *Polacanthus*, from the Grinstead Clay Formation and the Tunbridge Wells Sand Formation respectively, and an indeterminate taxon known as '*Regnosaurus*' (NHMUK 2422), from the Grinstead Clay Formation (Barrett & Maidment 2011). ARDB1 appears unlike the teeth of ankylosaurs, however, because they possess prominent ridges, confluent with the denticles, which extend basally towards the root (e.g. Vickaryous et al. 2004: fig. 17.13; Barrett 2001). The teeth of *'Regnosaurus'* are unknown, but stegosaurs possess tooth crowns with apicobasal striations (Galton & Upchurch 2004: fig. 16.5; Maidment, pers. obs. 2004–2016). Basal neornithischians are also unknown from the Wealden Supergroup, but the ornithopod *Hypsilophodon* is known from the Wessex Formation of the Wealden Supergroup (Norman 2011), which is contemporaneous with the Hastings Group (Batten 2011). The teeth of *Hypsilophodon*, however, possess prominent longitudinal ridges and often have well-developed wear facets (Galton 1974; Galton 2009).

ARDB1 shares features with basal thyreophorans and basal neornithischians, but cannot be referred to any of the known taxa in the Wealden Supergroup or contemporaneous formations in geographical proximity, and therefore represents a new, probably basal ornithischian taxon.

Crocodylomorpha Walker, 1968

Crocodyliformes Hay, 1930

Mesoeucrocodylia Whetstone & Whybrow, 1983

Neosuchia Benton & Clark, 1988

Atoposauridae Gervais, 1871

Theriosuchus Owen, 1878

Type species

Theriosuchus pusillus Owen, 1878

Paratype

NHMUK PV OR48330, a complete skull

Lectotype

NHMUK PV OR48216, a nearly complete, partially articulated skeleton

Generic diagnosis

From Young et al. (2016): Atoposaurids with the following autapomorphies: (1) heterodont dentition, with pseudocaniniform, labiolingually compressed and lanceolate tooth crown morphotypes; (2) 'low crowned' teeth present; (3) progressive reduction in alveolus size form the fourth to the sixth dentary alveoli; (4) presence of false denticles on the posterior teeth; (5) some of the dentary alveoli form a confluent chain from dental alveolus D4-D8; (6) enlarged fifth maxillary tooth, typically with a corresponding notch on the dentary; (7) maxillary and dentary alveolar size is strongly heterogeneous; (8) dentary external surface is ornamented with heterogeneously spaced pits, and is ventrolaterally rugose; (9) supratemporal fenestrae and fossae proportionally large with respect to primary orbit.

***Theriosuchus* sp.**

Referred specimens

Three isolated teeth, ARDB1, ARDL1 (Fig. 5), and ARDB9A.

Locality and horizon

Ardingly Sandstone Member (ARDB1; ARDB9A) of the Lower Tunbridge Well Sand Formation, and Grinstead Clay Formation (ARDL1), Hastings Group, Wealden Supergroup (Lower Cretaceous, Valanginian). Ardingly College, Ardingly, West Sussex, TQ 33969 28569.

Description

ARDB1 is 1.5 mm long apicobasially. The tooth is lanceolate, with a bulbous and expanded base, tapering to a pointed apex. Striations are present near the apex, but diminish in prominence towards the base. ARDL1 (Fig. 5) and ARDB9A are similar in morphology. The former is 2 mm long but the apex is broken, while the latter is about 3 mm apicobasally. Both are slightly recurved along their lengths, and lack a bulbous base or prominent striations on the crown.

Comparisons

The dentition of *Theriosuchus* can be divided into three morphotypes (Schwarz & Salisbury 2005; Salisbury & Naish 2011): (1) Conical, slightly lingually recurved teeth with a circular cross section at the base of the crown, smooth enamel on the labial surface, and apicobasially-extending striations on the lingual surface; (2) lanceolate teeth with a bulbous base, weak labiolingual compression, and apicobasially-extending striations on both sides that extend from the apical half of the crown to the tip; (3) strongly labiolingually compressed crowns with apicobasially-extending striations on both sides and extending from apex to base. According to Salisbury & Naish (2011), morphotype (1) is restricted to the premaxillary and anteriormost maxillary and dentary dentition, morphotype (2) is present in the middle and posterior portions of the maxilla and dentary, and morphotype (3) is restricted to two species of *Theriosuchus*, one of which is known from the Wealden Supergroup. ARDB1 compares favourably with morphotype (2) of Schwarz & Salisbury (2005), and is similar to teeth of morphotype (2) preserved in NHMUK OR4284 *Theriosuchus pusillus*.

ARDL1 and ARDB9A are morphologically consistent with morphotype (1), and similar teeth can be observed in NHMUK OR48227 *Theriosuchus pusillus*, in which the teeth are preserved in labial view.

Systematic remarks

The presence of heterodont dentition is an autapomorphy of *Theriosuchus* (Young et al. 2016). Although the teeth are from different lithologies, and therefore different horizons with the Ardingly Sandstone and Grinstead Clay, and are thus not from a single individual, they can each be assigned to a dental morphotype described for *Theriosuchus* (Salisbury & Naish 2011). Isolated teeth from *Theriosuchus* are known from the Ashdown and Wadhurst Clay Formations of the Hastings Group (Salisbury & Naish 2011) and thus it is not unexpected that the genus might also be present in the slightly younger Ardingly Sandstone Member of the Lower Tunbridge Well Sand Formation and the Grinstead Clay Formation.

Pterosauria Kaup, 1834

Monofenestrata Lü, Unwin, Jin, Liu & Ji, 2010

Pterodactyloidea Pleininger, 1901

Ornithocheiridae Seeley, 1870

Ornithocheridae indet.

Material

ARDB2A, an isolated tooth (Fig. 6).

Locality and horizon

Ardingly Sandstone Member, Lower Tunbridge Wells Sand Formation, Hastings Group, Wealden Supergroup (Lower Cretaceous, Valanginian). Ardingly College, Ardingly, West Sussex, TQ 33969 28569.

Description

An elongate, recurved tooth crown that is 21 mm in apicobasal length (Fig. 6). The enamel is smooth and unornamented. Because the tooth is embedded in a sandstone slab, the cross-sectional shape of the crown cannot be determined. The apex appears to be broken.

Comparison

There are no synapomorphies of Pterosauria that relate to individual teeth (Nesbitt 2011), however, teeth of ornithocheirid pterosaurs are "elongate, recurved and fang-like" (Martill et al. 2011: 376), a description which compares favourably with the morphology of ARDB2A. Two species of ornithocheirid are currently known from the Wealden Supergroup, *Caulkicephalus trimicrodon* and *Coloborhynchus clavirostris* (Martill et al. 2011). The tooth is similar in morphology to an ornithocheirid tooth from the Wessex Formation of the Isle of Wight, IWCMS 2756, which was referred to *Caulkicephalus trimicrodon* by Sweetman & Martill (2010). ARDB2A also appears similar in morphology to teeth of various species of *Coloborhynchus* (Veldmeijer et al. 2006), although teeth are not preserved in *Coloborhynchus clavirostris*.

Systematic remarks

ARDB2A is elongate and recurved, with a smooth, adenticulate surface, suggesting that it is referable to an ornithocheirid pterosaur. The holotype materials of both *Caulkicephalus trimicrodon* and *Coloborhynchus clavirostris* lack dentition (Steel et al. 2005; Martill et al. 2011), and referral of isolated teeth to a species for which no teeth are known must be considered dubious. *Coloborhynchus* is known from the Hastings Group of the Weald Sub-basin, while *Caulkicephalus* is known from the younger Wessex Formation of the Wessex Sub-basin (Steel et al. 2005; Martill et al.

2011). Based on stratigraphy alone, ARDB2A might be considered more likely to belong to *Coloborhynchus*; however, we prefer to consider ARDB2A an indeterminate ornithocheirid pending further discoveries of Wealden pterosaur remains.

Discussion

The vertebrate finds from the Ardingly Sandstone Member and Grinstead Clay Formation at Ardingly College increase our knowledge of the fauna that was living alongside and within the lagoons of the Weald Sub-basin in the Valanginian. The presence of an indeterminate ornithischian dinosaur tooth that is not referable to the other ornithischians known from the basin suggests that these animals were a common part of the Wealden fauna and increases the number of ornithischians known from the Hastings Group.

The atoposaurid crocodyliform *Theriosuchus* was previously known from the slightly older Ashdown and Wadhurst Clay formations (Fig. 1), and finds at Ardingly demonstrate that the taxon continued to thrive in the lagoons of the Weald Sub-basin during Lower Tunbridge Wells Sand and Grinstead Clay times. A single ornithocheirid pterosaur, *Coloborhynchus*, is known from the Weald Sub-basin, and the presence of an ornithocheirid tooth in the Lower Tunbridge Wells Sand further demonstrates that pterosaurs frequented the Wealden lagoons.

The finds at Ardingly allow us to reconstruct the environment of the Hastings Group during the upper part of the Valanginian. The cyclicity of the Wealden Supergroup has long been recognised (Radley & Allen 2012). Predominantly arenaceous formations (e.g. Lower Tunbridge Wells Sand Formation) are interpreted as fluviodeltaic and overbank deposits that prograded into a freshwater or brackish lagoon in response to uplift of surrounding massifs and the resulting increased rainfall and erosion (Radley & Allen 2012). These are capped by transgressive lags: winnowed strandline deposits formed during transgression of the lagoon due to cessation of uplift and erosion of surrounding mountains. The arenaceous formations are overlain by predominantly argillaceous formations (e.g. Grinstead Clay Formation) that were deposited in the lagoon itself (Radley & Allen 2012).

The presence of freshwater bivalves and gastropods, as well as fish vertebrae, in the Ardingly Sandstone Member are supportive of a fluviodeltaic interpretation for this unit. Vertebrate finds are concentrated in a heavily iron-cemented layer at the top of the Ardingly Sandstone Member, which likely represents the Lower Tunbridge Wells pebble bed, a transgressive lag at the top of the Ardingly Sandstone Member. In the overlying Grinstead Clay Formation, the presence of monospecific assemblages of the bivalve *Neomiodon* indicate either raised salinities (Radley & Allen 2012), dysaerobic conditions (Munt et al. 2011) or both in the Wealden lagoons. Abundant lignite horizons and lenses, as well as fusainized plant and insect remains, indicate that wildfire was a common feature of the Wealden environment (Radley & Allen 2012).

The collection of vertebrate remains found at Ardingly College took place as part of a 'citizen science' project, in which members of the local community were engaged to help excavate fossiliferous blocks from the spoil heaps generated by building works. In this case, plans were in place for the spoil heaps to be landscaped, and thus it was important to collect as much material as possible before the blocks became covered. Projects such as this have great value in that they allow a relatively large amount of material to be examined and sorted in a short amount of time. Furthermore, they engage the local community, school children, and the media, and produce excitement and enthusiasm about palaeontology. Such projects are able to generate measurable impact: this project led directly to several members of the public taking an interest in other organized fieldwork in the Wealden Supergroup for the first time. At a broader level, citizen science projects can play a crucial role in changing stereotypical perceptions about scientists.

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Figure Captions

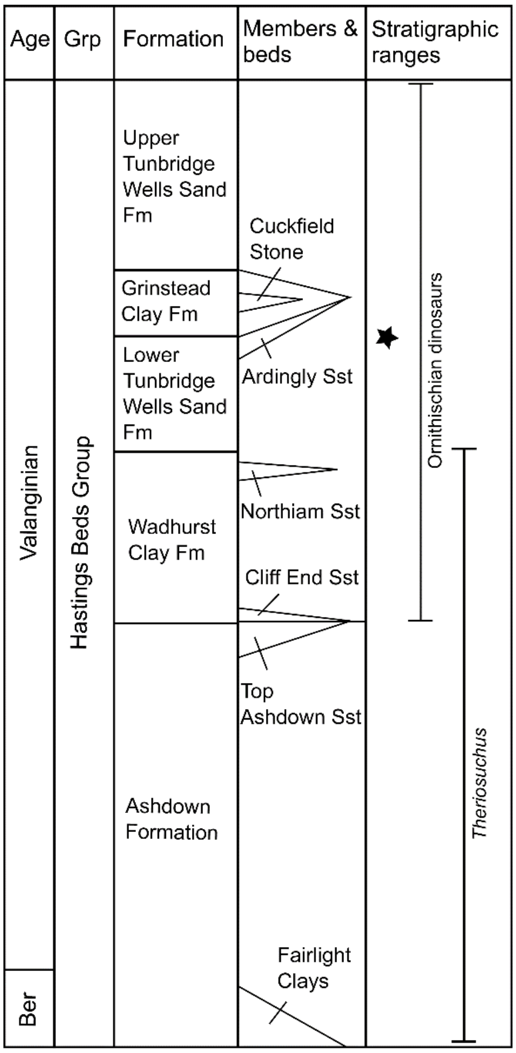

Figure one. Stratigraphic column showing the terminology used herein (after Batten & Austen 2011). The stratigraphic location of the Ardingly finds is indicated by a star. The known stratigraphic ranges of ornithischian dinosaurs (including thyreophorans and ornithopods; data from Barrett & Maidment 2011 and Norman 2011) and the crocodilian *Theriosuchus* (data from Salisbury & Naish 2011) before the Ardingly fossils were discovered is shown. The Ardingly discoveries therefore extend the range of

Theriosuchus into the upper part of the Hastings Beds Group. The stratigraphic horizon within the Hastings Beds Group that yielded the pterosaur *Coloborhynchus* is unknown (Martill et al. 2011). **Ber**, Berriasian; **Fm**, Formation; **Grp**, Group; **Sst**, Sandstone. Stratigraphic thickness is not to scale.

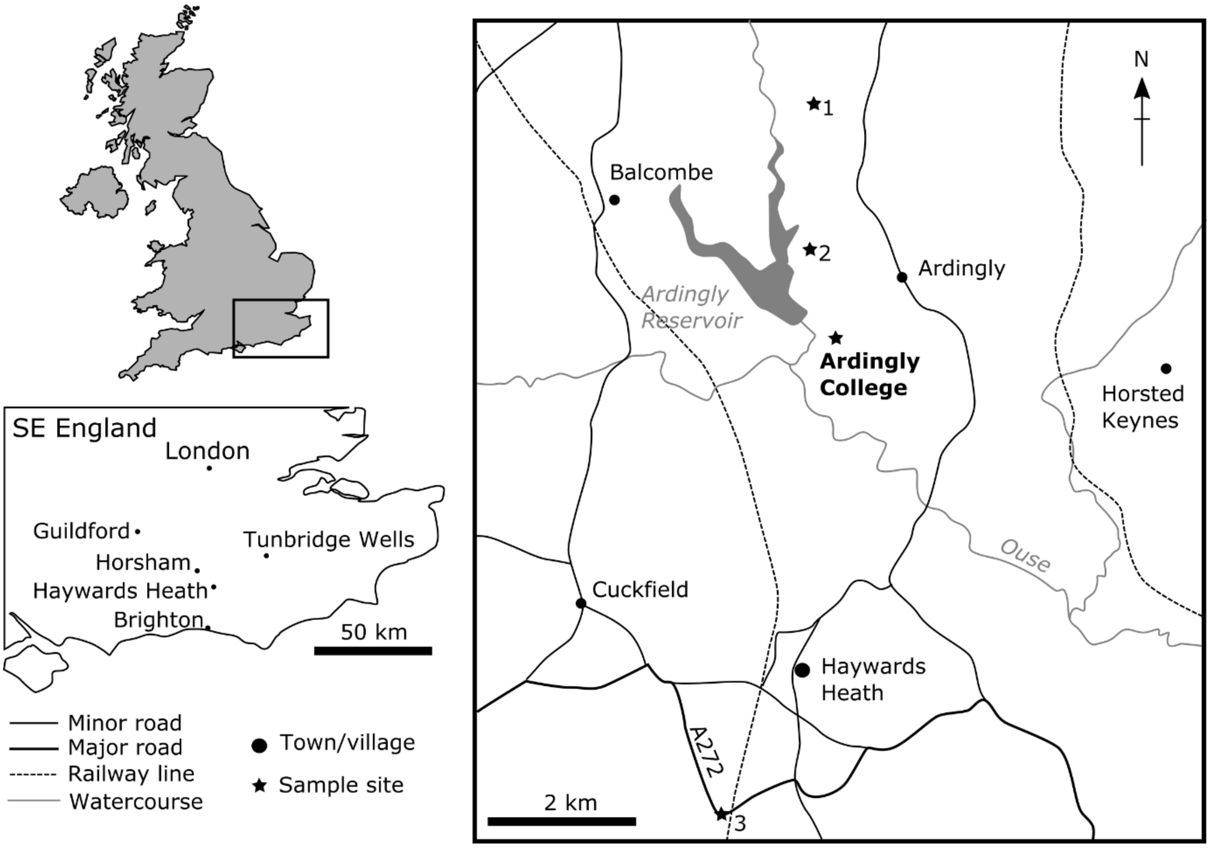

Figure two. Map showing the location of Ardingly College, close to Haywards Heath, SE England. **1**, Wakefield Place; **2**, Balcombe Lane; **3**, Rocky Lane.

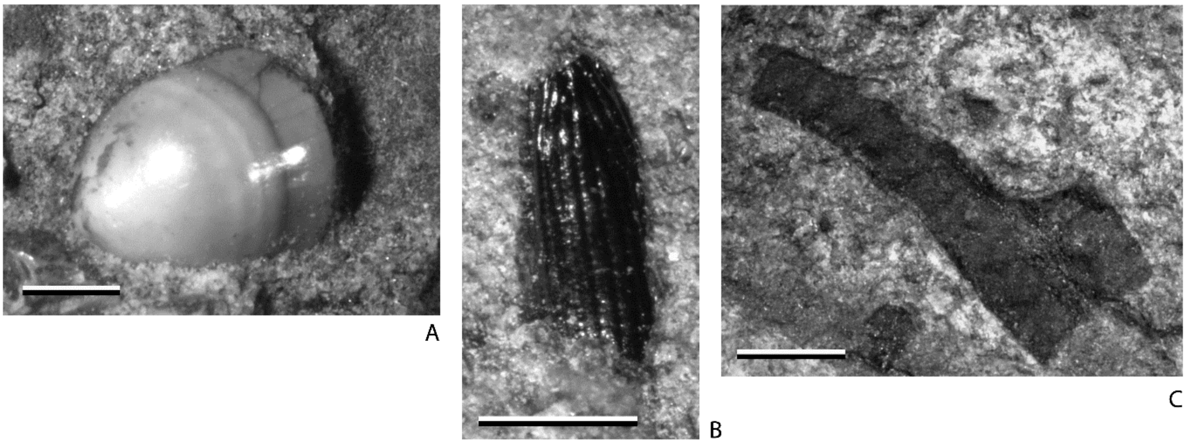

Figure three. **A**, tooth of the lepisosteiform fish *Scheenstia* (ARDB1); **B**, fusainized wing case of a cupedid beatle (ARDL9); **C**, fusainized fragment of the fern *Phlebopteris* (ARDL6B). Scale bars equal to 1 mm for **A** and **B**, and 2 mm for **C**.

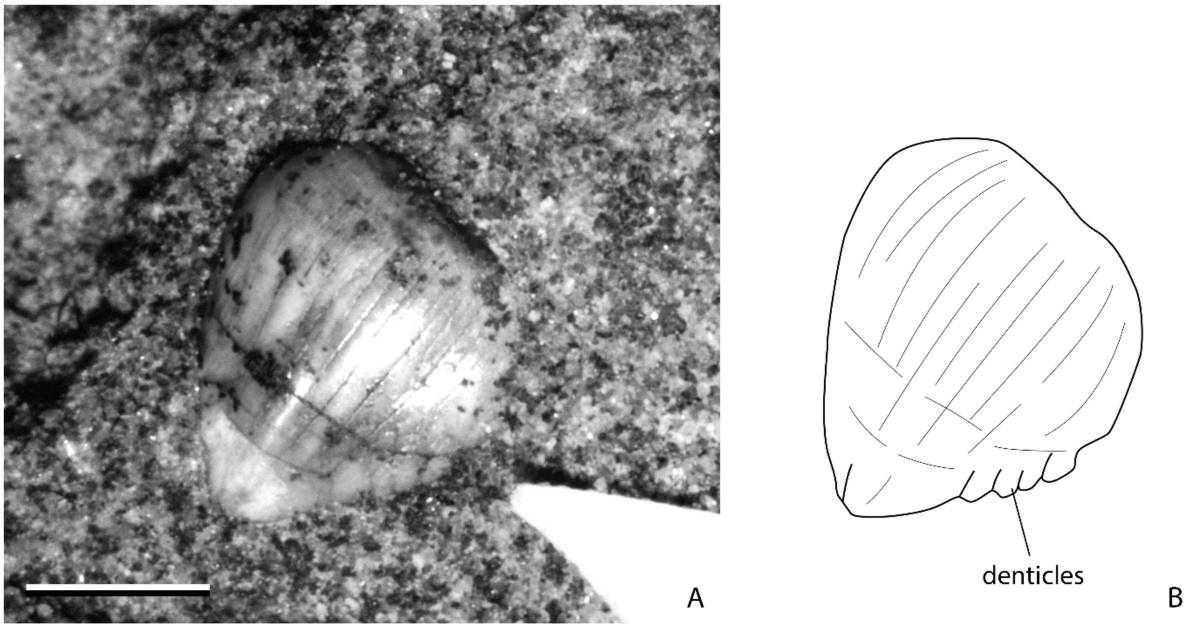

Figure four. ARDB1, an indeterminate thyreophoran dinosaur tooth from the Ardingly Sandstone Member. **A,** photograph and **B,** interpretive drawing. Scale bar equal to 1 mm.

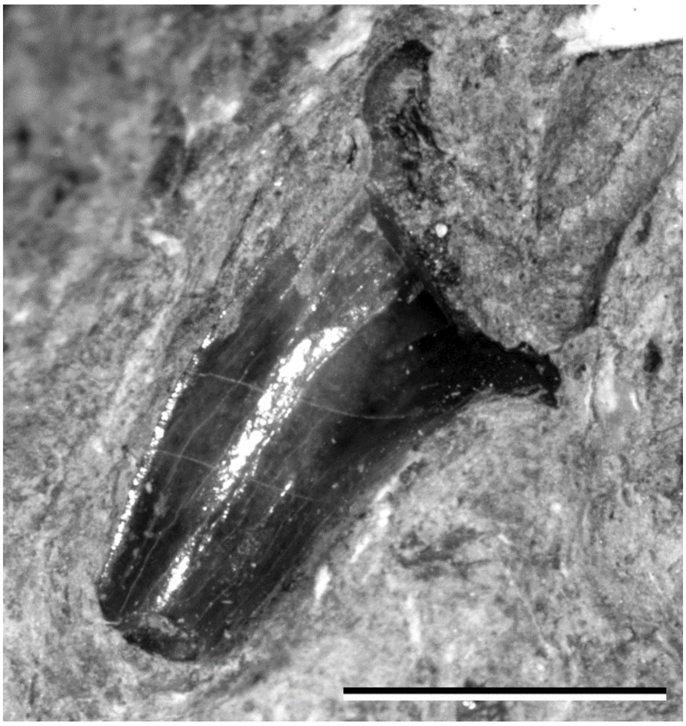

Figure five. ARDL1, *Theriosuchus pusillus* tooth from the Grinstead Clay Formation. Scale bar equal to 2 mm.

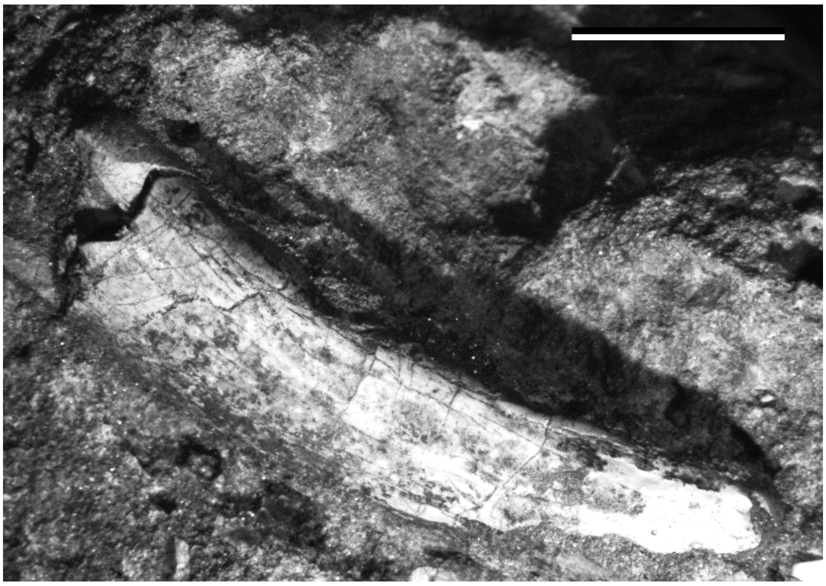

Figure six. ARDB2A, an indeterminate ornithocheirid pterosaur tooth from the Ardingly Sandstone Member. Scale bar equal to 5 mm.