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Licenciado em Biologia



**Upper Jurassic dinosaur bonebeds at Ten Sleep,
Wyoming: stratigraphy, preliminary results and
field reports of 2016 and 2017**

Dissertação para obtenção do Grau de Mestre em Paleontologia

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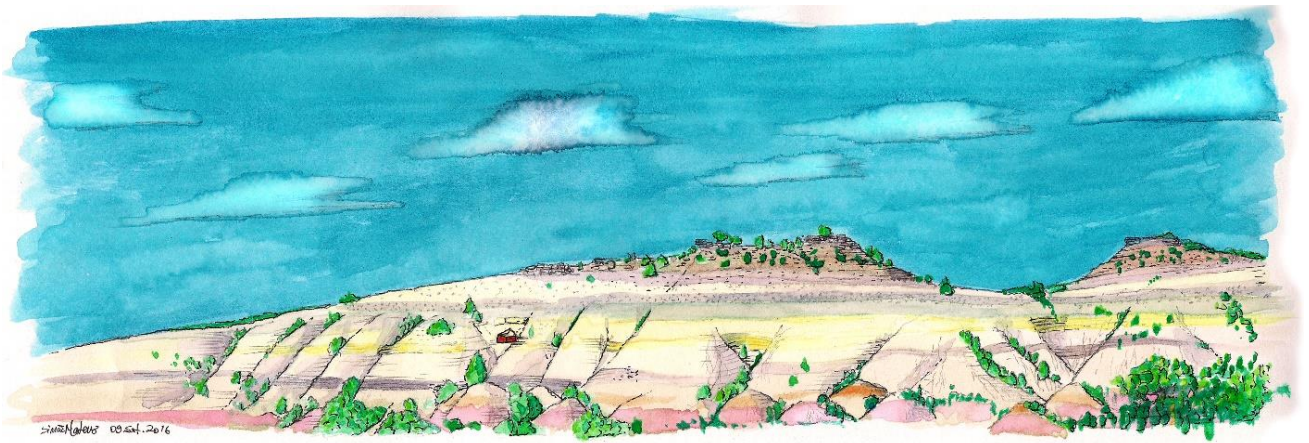
FACULDADE DE
CIÊNCIAS E TECNOLOGIA
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Setembro 2018

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Sketch of of Bobcat Hill by Simão Mateus

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Abstract

The Upper Jurassic Morrison Formation that outcrops throughout the Western Interior of the United States is well known for its diverse environments and for its vertebrate, invertebrate and floral biodiversity, in great part fueled by the numerous paleontological expeditions focused on extensive fossil record of the formation's dinosaurian fauna, since late 19th century.

In 2014, plans started to be made for a new expedition into the Morrison Fm. outcrops close to the town of Ten Sleep, where digs have been carried out in private land since 2006. This expedition represented the return of the American Museum of Natural History (AMNH) to the Big Horn Basin since Barnum Brown's Howe Ranch expedition in the early 1930s, however this time, work would be under taken in public land. As such, a project was submitted to the Bureau of Land Management in order to obtain permission to dig and survey two distinct localities between the towns of Ten Sleep and Hyattville: Cosm and Dana quarries. The expedition counted with elements from AMNH and Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa (FCT-UNL), and was carried out between the months of August and September, of 2016 and 2017.

At the end of two years, the yellowish to tan massive cross bedded sandstones that outcrop along the hills of the Ten Sleep-Hyattville area, have proven to rich fossiliferous riverbank deposits, both in quantity and diversity, mainly preserving dinosaurian remains (some preserving cranial elements) representative of the upper levels of the Morrison Fm. such as *Allosaurus* sp., *Apatosaurus* sp., *Camarasaurus* sp., and unidentified diplodocids, ornithopods, and stegosaurid. This information, along newer stratigraphical data for the area, and the detailed description of the digging season, are here reported as to record the first steps taken in what is to be a long term project.

Key words: *Morrison Formation, Upper Jurassic, Big Horn Basin, NOVA+AMNH Wyoming Paleontological Expedition, public land*

Resumo

A Formação de Morrison do Jurássico Superior, que aflora ao longo do Oeste Interior dos Estados Unidos, é conhecida pelo seu ambiente diverso e pela sua diversidade de vertebrados, invertebrados e flora, devido em grande parte às várias expedições paleontológicas focadas no extenso registo fóssil dos seus dinossauros, desde finais do Século XIX.

Em 2014 começaram a ser feitos planos para uma nova expedição aos afloramentos da Fm. de Morrison próximos de Ten Sleep, onde escavações têm sido levadas a cabo em terreno privado desde 2006. Esta expedição marcaria o regresso do American Museum of Natural History (AMNH) á Big Horn Basin desde a expedição de Barnum Brown a Howe Ranch no início dos anos 30, mas desta vez com o trabalho a ser realizado em terrenos públicos. Um projeto foi submetido ao Bureau of Land Management de modo a obter permissão para escavar e prospetar dois locais distintos entre Ten Sleep e Hyattville: as jazidas de Cosm e Dana. Esta expedição contou com elementos do AMNH e da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa (FCT-UNL), tendo sido levada a cabo entre os meses de Agosto e Setembro de 2016 e 2017.

Ao final de dois anos, os arenitos castanho claro e amarelados com sedimentação cruzada que afloram nas colinas da área de Ten Sleep-Hyattville provaram ser ricos depósitos fluviais fossilíferos, tanto em quantidade como diversidade, preservando maioritariamente vestígios de dinossauros (alguns com elementos cranianos preservados), representativos dos níveis superiores da Fm. de Morrison, como *Allosaurus* sp., *Apatosaurus* sp., *Camarasaurus* sp, e ainda diplodocídeos, ornitópodes e um stegosaurídeo por identificar. Esta informação, os novos dados estratigráficos para esta região e a detalhada descrição das temporadas de escavação são aqui reportadas de modo a registar os primeiros passos daquilo que será um projeto a longo prazo.

Palavras-chave: *Formação de Morrison, Jurássico Superior, Big Horn Basin, Expedição Paleontológica NOVA+AMNH Wyoming, terrenos públicos*

Abbreviation List

Institutional

AMNH: American Museum of Natural History, New York City, USA;

AMU: Aix-Marseille Université, Marseille, France;

BLM: Bureau of Land Management, USA;

FCT-UNL: Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal;

GMK: GeoCenter Møns Klint, Borre, Denmark;

KU: Københavns Universitet, Copenhagen, Denmark;

ML: Museu da Lourinhã, Lourinhã, Portugal;

UP: Universidade do Porto, Porto, Portugal;

UST: Università degli Studi di Torino, Turin, Italy;

Table of contents

Acknowledgments	iv
Abstract.....	vi
Resumo	vii
Abbreviation List.....	viii
Table of contents.....	ix
Table of figures.....	xi
1. Introduction.....	1
1.1 Morrison Formation synthesis	1
1.2 Historical context.....	6
1.3 Big Horn Basin	9
1.4 Bonebeds.....	10
2. Objectives	12
3. Field Reports (2016 and 2017)	13
3.1 Why dig in Ten Sleep?.....	13
3.2 Team members.....	13
3.3 BLM Permits.....	15
3.4 Project objectives.....	16
3.5 Inventory and expenses.....	16
3.6 Schedule.....	18
3.7 Dana Quarry.....	18
3.7.1. Description.....	18
3.7.2. 2016 Expedition.....	19
3.7.3. 2017 Expedition.....	20
3.7.4. Findings	22
3.8 Cosm Quarry.....	22
3.8.1. Description.....	22
3.8.2. 2016 expedition.....	23
3.8.3. 2017 Expedition.....	24
3.8.4. Findings	26
4. Stratigraphical work for the Ten Sleep-Hyattville area	27
4.1 Stratigraphic logs	28
4.1.1. Section 1: Bobcat Hill.....	28
4.1.2. Section 2: Bobcat hilltop.....	31
4.1.3. Section 3: Cosm Quarry (North).....	32
4.1.4. Section 4: Cosm Quarry (South).....	34
4.1.5. Section 5: Dana Quarry.....	36
4.2 Comparison and local correlation with previous works	38
4.3 Paleoenvironment	40
4.4 Age of Cosm and Dana quarries	42
5. Taxonomical description.....	44
5.1 Preparation.....	44

5.2	Specimens description	46
5.2.1.	AMNH FARB 33055	46
5.2.2.	AMNH FARB 33058	51
5.2.3.	AMNH FARB 33061	54
5.2.4.	AMNH FARB 33062	70
5.2.5.	AMNH FARB 33072	73
5.2.6.	AMNH FARB 33077	74
5.2.7.	AMNH FARB 33078	76
5.2.8.	AMNH FARB 33079	78
5.2.9.	AMNH FARB 33081	79
5.2.10.	AMNH FARB 33083	81
5.3	Taxonomical discussion	83
6.	Conclusion	86
	References	87
	Appendixes	95
3A.	Permit PA16-WY-245	96
3B.	Permit PA16-WY-255 – 2016	99
3C.	Permit PA16-WY-255 – 201	102
3D.	Permit PA16-WY-256 – 2016	105
3E.	Permit PA16-WY-256 – 2017	108
3F.	Paleontological locality forms	111
3G.	Simplified inventory list of used materials throughout the expedition	117
3H.	Log of expenses for 2016	119
3I.	Log of expenses for 2017	122
3J.	Team members' presence sheet	126
3K.	Cosm Quarry map by Vincent Cheng (2017)	128
3L.	Cosm-II map by Octávio Mateus (2017)	129
3M.	Dana Quarry map of theropod assemblage by Vincent Cheng (2017)	130
3N.	Dana Quarry map of the Apatosaurus specimen by Vincent Cheng (2017)	131
5A.	Specimen Transfer Form for the material collected during 2016	132
5B.	Specimen Transfer Form for the material collected during 2016	133
5C.	Loan document regarding the Cosm Quarry material prepared at Museu de Lourinhã	134
5D.	AMNH inventory sheet for the collected fossils of the 2016 expedition	136
5E.	AMNH inventory sheet for the collected fossils of the 2017 expedition	141
5F.	Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33058	145
5G.	Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33061	146
5H.	Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33062	148
5I.	Links to 3D models and model quality data provided by Marco Marzola	151
5J.	Theropod teeth measurements, following the anatomical, and morphometric terminology and measurement variables of Hendrickx et al., 2015	152

Table of figures

Figure 1.1: Total expansion of Morrison Fm. deposits and related beds	2
Figure 1.2: World paleogeography during the deposition of the Morrison sediments	2
Figure 1.3: Evolution of the Morrison Fm. environment through the Kimmeridgian an early Tithonian stages of the Upper Jurassic.....	5
Figure 1.4: Representation of a fluvial and floodplain environment of the Upper Jurassic	6
Figure 1.5: Stratigraphic section at the type locality of Morrison Fm.	7
Figure 1.6; Map of the Bighorn Basin, Wyoming, showing the surrounding mountain ranges.....	10
Figure 3.1: All members of the 2016 expedition team at Yellowstone National Park.....	14
Figure 3.2: Part of the 2017 expedition team at Dana Quarry	15
Figure 3.3: Aerial view of Dana Quarry 2017 digsite.....	19
Figure 3.4: Aerial view of Cosm Quarry and Cosm-II.	23
Figure 4.1: Stratigraphic Section 1, located on the south facing slope of Bobcat Hill, a few meters north of Cosm Quarry, Big Horn County, Wyoming, USA.....	29
Figure 4.2: Stratigraphic log of Section 1	30
Figure 4.3: Part of the Stratigraphic Section 2 exposure at the top of Bobcat Hill, Southwest of Cosm Quarry, Big Horn County, Wyoming, USA.....	31
Figure 4.4: Stratigraphic log of Section 2	32
Figure 4.5: Stratigraphic Section 3, on the norther section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.....	33
Figure 4.6: Stratigraphic log of Section 3	34
Figure 4.7: Stratigraphic Section 4, on the southern section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.....	35
Figure 4.8: Stratigraphic log of Section 4.....	36
Figure 4.9: Part of the Stratigraphic Section 5 exposure at the North faced hills of Dana Quarry, Washakie County, Wyoming, USA.	37
Figure 4.10: Stratigraphic log of Section 5	38
Figure 4.11: AMNH FI 113386 <i>Amplovalvata scabrada</i> specimens collected at Dana Quarry.....	41
Figure 4.12: AMNH FI 113385 <i>Unio</i> fragments collected at Dana Quarry.....	41
Figure 4.13: Assorted plant material collected at Cosm Quarry	43
Figure 5.1: <i>Allosaurus</i> sp. AMNH FARB 33055 left metatarsal II condyle.....	47
Figure 5.2: <i>Allosaurus</i> sp. AMNH FARB 33055 left metatarsal III condyle.....	48
Figure 5.3: <i>Allosaurus</i> sp. AMNH FARB 33055 phalanx IV-1.....	49
Figure 5.4: <i>Allosaurus</i> sp. AMNH FARB 33055 phalanx IV-2.....	50
Figure 5.5: <i>Camarasaurus</i> sp. AMNH FARB 33058 loose pre-max/maxillary tooth	52
Figure 5.6: <i>Camarasaurus</i> sp. AMNH FARB 33058 loose dentary tooth.....	53
Figure 5.7: <i>Allosaurus</i> sp. AMNH FARB 33061 left metatarsal I.....	55
Figure 5.8: <i>Allosaurus</i> sp. AMNH FARB 33061 articulated left metatarsals II, III, and IV	56
Figure 5.9: <i>Allosaurus</i> sp. AMNH FARB 33061 left metatarsal V	59
Figure 5.10: <i>Allosaurus</i> sp. AMNH FARB 33061 left phalanx I-1	60
Figure 5.11: <i>Allosaurus</i> sp. AMNH FARB 33061 left phalanx III-1.....	61
Figure 5.12: <i>Allosaurus</i> sp. AMNH FARB 33061 left phalanx III-2.....	62
Figure 5.13: <i>Allosaurus</i> sp. AMNH FARB 33061 left phalanx III-3.....	63
Figure 5.14: <i>Allosaurus</i> sp. AMNH FARB 33061 left ungual phalanx I.....	64

Figure 5.15: <i>Allosaurus</i> sp. AMNH FARB 33061 left ungual phalanx III	65
Figure 5.16: <i>Allosaurus</i> sp. AMNH FARB 33061 left ungual phalanx IV	65
Figure 5.17: <i>Allosaurus</i> sp. AMNH FARB 33061 right metatarsal II condyle	66
Figure 5.18: <i>Allosaurus</i> sp. AMNH FARB 33061 right metatarsal III condyle	67
Figure 5.19: <i>Allosaurus</i> sp. AMNH FARB 33061 left maxillary tooth	68
Figure 5.20: <i>Allosaurus</i> sp. AMNH FARB 33062 left metatarsal IV	71
Figure 5.21: <i>Allosaurus</i> sp. AMNH FARB 33062 left phalanx IV-1	72
Figure 5.22: Unidentified ornithopod AMNH FARB 33072 isolated pedal phalax	73
Figure 5.23: <i>Allosaurus</i> sp. AMNH FARB 33077 isolated tooth	75
Figure 5.24: <i>Allosaurus</i> sp. AMNH FARB 33078 isolated tooth	77
Figure 5.25: <i>Allosaurus</i> sp. AMNH FARB 33079 isolated phalanx condyle	78
Figure 5.26: <i>Allosaurus</i> sp. AMNH FARB 33081 isolated tooth	80
Figure 5.27: <i>Allosaurus</i> sp. AMNH FARB 33082 isolated tooth	82

1. Introduction

1.1 Morrison Formation synthesis

The Morrison Fm. exposure extends along the western interior of the United States, from Montana to New Mexico, with major outcrops present in these two states, Colorado, Utah, and Wyoming, as well as northeastern Arizona, western end of the Oklahoma “panhandle”, and western South Dakota. The formation is also known to occur at the subsurface in western Kansas, Nebraska, and North Dakota, and at the northwestern end of the Texas “panhandle” (Foster, 2003). It has also been suggested that some sediments of the upper Morrison Fm. may be equivalent to the basal portion of the Kootenay Group in Canada (Gibson, 1985).

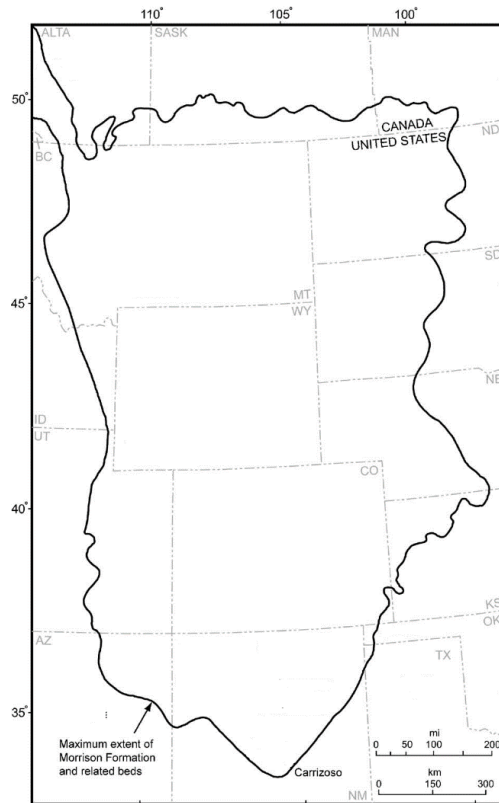


Figure 1.1: Total expansion of Morrison Fm. deposits and related beds. Modified from Parrish et al., 2004.

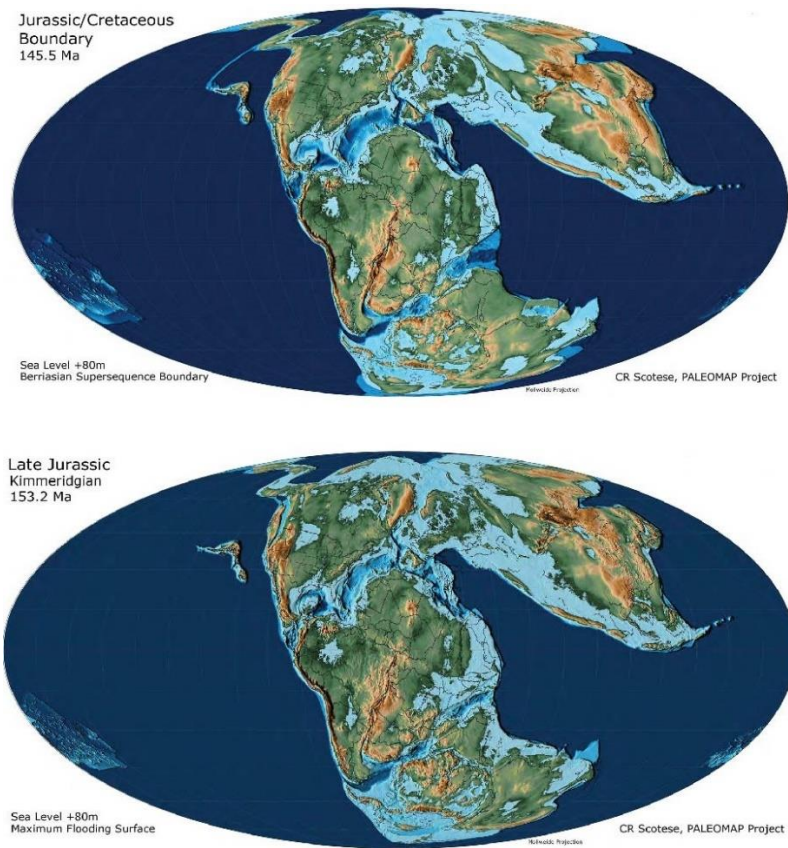


Figure 1.2: World paleogeography during the deposition of the Morrison sediments (Tithonian at the top, and Kimmeridgian at the bottom). Paleomaps from CR Scotese (PALEOMAP Project).

To the North, the Morrison Fm. overlays the Middle and Upper Jurassic deposits of the Sundance sea, while sabkha and aeolian dune facies representative of the sea's arid shores can be observed to the South. The overlying terrestrial foreland basin deposits, resulting of the Sevier orogeny, are comprised of grey-purple mudstones, fluvial sandstones, and, coarse conglomerates at their base, making up the contact between the Morrison and overlaying formation. Some authors (Pippiringos & O'Sullivan, 1978; Roca & Nadon, 2007) have correlated the bottom and top limits of the Morrison Fm. to unconformities observable through the western interior, namely the J-5 Unconformity at the base of the formation (although it may also represent the base of the Windy Hill Member), and the K-1 Unconformity at the base of several Cretaceous conglomeratic facies across the western interior.

This formation is characterized by variegated green, grey and red mudstones, tan to white sandstones, and grey limestones. Caliche nodules, reworked clasts, coal rich layers, ash and hard shales have also been recorded in the Morrison sediments. Due to its extent, the Morrison Fm. varies considerably in both in thickness and lithology, which is reflected on the rather large amount of members that have been proposed throughout the years, of which many are only observable, and locally recognizable (Peterson, 1994), at the southern exposures of the area of the Colorado Plateau, being divided into as many as nine distinct members (Foster, 2003). The number of members into which the Morrison Fm. is divided tends to decrease farther North, where many of the member of the Colorado Plateau not being recognizable, with other unformal divisions proposed (Foster, 2003).

Maidment and colleagues (2017) summarize the Morrison members at the Colorado Plateau region into three: Tidwell, Saltwash, and Brushy Basin members. Tidwell Member, at the base of the formation, comprises red-brown mudstones, thin sands, and gypsum, deposited in a sabkha and shallow marine environments, followed by the braided and anastomosing river deposits dominated Salt Wash Member, with a source area to the southwest. At the top of the formation, the Brushy Basin Member is recognized by its floodplain and lacustrine mudstones and sands deposited by low sinuosity, anastomosing rivers, as well as for its highly fossiliferous outcrops from which the majority of the vertebrate fauna is recovered in the Morrison Fm.

Although a subject of great discussion in the past, the age of the Morrison Fm. has since long been attributed to the Upper Jurassic. The methods of U/Pb and $^{40}\text{Ar}/^{39}\text{Ar}$ isotope dating have been widely used in order to place the base of the formation at approximately 156 Ma, close to the Oxfordian-Kimmeridgian limit, and the top at an age around 150 Ma to 147 Ma, in the Tithonian stage (Kowallis et al., 1998; Trujillo & Kowallis, 2016). Other attempted methods of relative dating and correlation between deposits across the formation include the study of the illitic to smectitic "clay change" (Peterson & Turner, 1998, Turner & Peterson, 1999), paleosols (Demko et al., 2004), biostratigraphy of charophytes, ostracods (Schudack et al. 1998), palynomorphs (Litwin et al. 1998), conchostrachans (Lucas and Kirkland 1998), mollusks (Evanoff et al. 1998), and dinosaurs (Bakker, 1996; Carpenter

1998; Turner and Peterson 1999), and also magnetostratigraphy and sequence stratigraphy (Steiner et al., 1994; Swierc and Johnson 1996; Currie 1997; Currie, 1998; Steiner 1998; Maidment et al. 2017).

The Morrison ecosystem has been described as a complex mosaic of paleoenvironments developed largely in response to the availability of water, and with communities adapted to the conditions associated with different depositional environments (Turner & Peterson, 2004). These environments ranged from humid and well-vegetated uplands, to streams, braided and meandering river channels, floodplains forming lakes and ponds, carbonate lacustrine wetlands, alkaline wetlands, and coal swamps and marshes in the northern part of the formation, as well some marine environments reminiscent from the Sundance sea and the regression of the interior seaway (Stokes, 1944; Lawton, 1977; Dodson et al., 1980; Lockley et al., 1986; Turner & Fishman, 1991; Peterson, 1994; Turner & Peterson, 2004). The climate in the Morrison depositional basin was warm and seasonal, progressing through time from dry semi-arid during the Kimmeridgian to humid semi-arid in the Tithonian, becoming slightly wetter because either precipitation levels became higher as time passed, lower evaporation rates by cooling temperatures, or by a conjunction of both factors (Parrish et al., 2004)

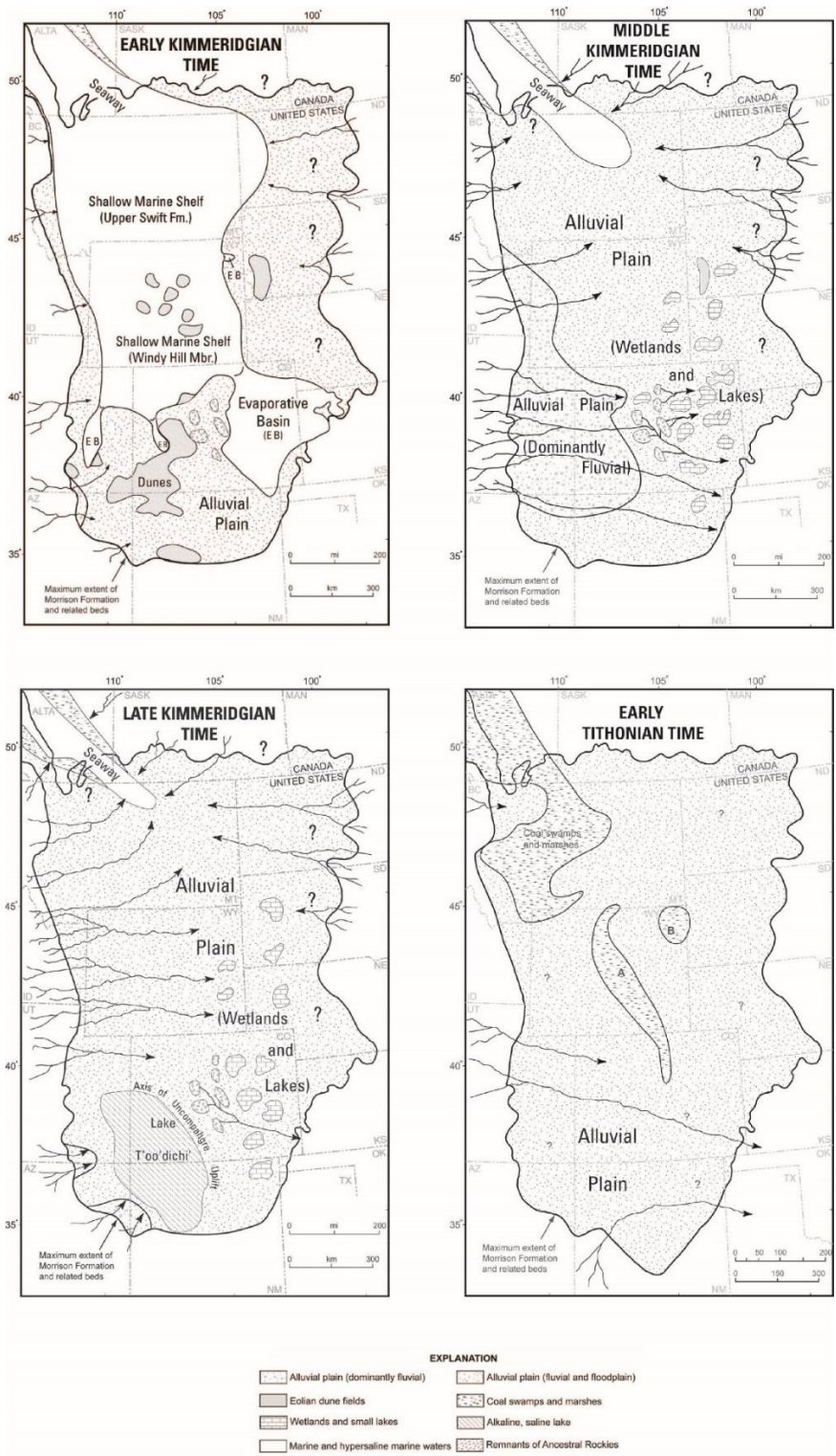


Figure 1.3: Evolution of the Morrison Fm. environment through the Kimmeridgian and early Tithonian stages of the Upper Jurassic. Adapted from Parrish et al., 2004.

The Morrison Fm. deposits are known for their diverse and well-preserved vertebrate fauna, with fish, frogs, salamanders, crocodiles, turtles, pterosaurs, lizards, mammals, and close to close to 30 dinosaur taxa so far discovered (Foster, 2007). This diversity extends to the well recorded invertebrate

fauna (crayfish, gastropods bivalves, conchostracans, and ostracods), and the flora (algae, bryophytes, ferns, horsetails, seed ferns, cycadophytes, ginkgos, and conifers), as well as to the several ichnofossils of both fauna and flora found in the Morrison Fm. (Chure et al., 2006; Foster, 2007). The Morrison faunal and floral diversity have been compared to the Lourinhã and Alcobaça Formations of Portugal, and to the Tendaguro Beds in Tanzania, all of which have similar aged deposits, paleoenvironments, lithology, and even sharing approximately 38% of their dinosaurian diversity (Mateus, 2006).



Figure 1.4: Representation of a fluvial and floodplain environment of the Upper Jurassic. Illustration by Mark Hallett (Hallett & Wedel, 2016).

1.2 Historical context

The name of the Morrison Fm. was used for the first time by Cross (1894), in the Pikes Peak atlas sheet, referring to Jurassic shales, marls, and sandstones, outcropping close to the town of Morrison in Colorado, similar to deposits previously described by Hayden (1869) for the Turkey Creek area, Marvine (1874) at Bear Creek, and Marsh's (1877) "*Atlantosaurus* beds" rich in dinosaurian remains.

The Morrison Fm. would be formally named, described and defined by Eldridge (Emmons et al., 1896), as Cretaceous deposits, close to the town of Morrison, consisting of fresh-water marls with an average thickness of approximately 200 feet (61 meters), intercalated by lenticular bodies of limestone and clay layers rich in dinosaurian remains towards its lower two thirds. The assignment of the Morrison deposits to the Cretaceous Period, although questioned by some authors at the time, lasted until Waldschmidt and LeRoy's (1944) reinterpretation of the formation, resulting in its age being attributed to the Jurassic Period, and a new type section 2 miles North (approximately 3 kilometers) from the town of Morrison (Figure 1.4), at what is nowadays known as Dinosaur Ridge, divided in six distinct units: (top to bottom) sandstone and shale, red shale, grey shale and sandstone, grey clay and limestone, grey and red shale, and a basal sandstone.

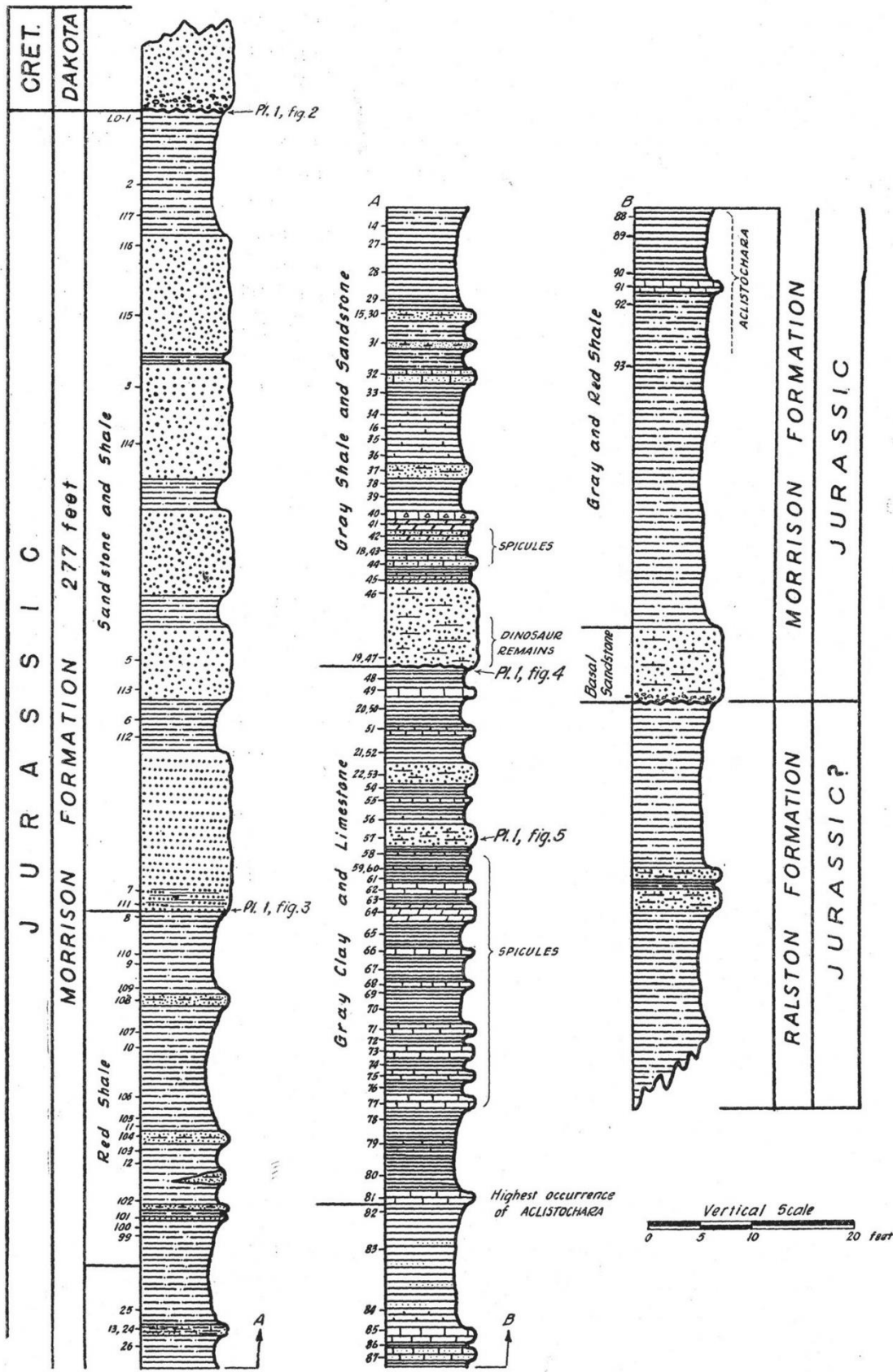


Figure 1.5: Stratigraphic section of Waldschmidt and LeRoy (1994) at the type locality of Morrison Fm. in Alameda Parkway Road outcrop, 2 miles north from Morrison, Jefferson County, Colorado, and respective sample numbering.

The first record of work done in the Morrison Fm. comes from discovery of the formation's first fossil vertebrate remains discovered by the physician and geologist John Newberry in 1859, and later named *Dystrophaeus viaemalae* Cope, 1877 (Foster, 2007). It would take ten years for new dinosaur remains to be found, and seven more until the Rocky Mountain region to become the focal point of the Morrison Fm. paleontological expeditions. During March of 1877, the discovery of the large sauropod bone assemblage of Como Bluff (Wyoming) discovered by William Reed and William Carlin, Edward Cope's expedition to recover sauropod bones near Garden Park (Colorado), and the discovery of large sauropod bones on the hill close to Morrison (Colorado) by Arthur Lakes and Henry Beckwith, began a period of frenzied collection of dinosaur material from the Morrison Fm. (Foster, 2007). This period would be known as "Bone Wars", and was mainly fueled by the competition between Cope and Marsh, resulting in numerous new species being dug and described at a fast pace, and an increased interest by several American institutions on these deposits, one of them being the American Museum of Natural History in New York (AMNH).

The AMNH's first expeditions to the Morrison Fm. deposits on the Rocky Mountain region took place in the late 1890s and were led by Henry Osborn, at the time head of the vertebrate paleontology program, and focused on the discovery of mammal and dinosaurian remains in the outcrops of Como Bluff, Wyoming, at Reed's Quarry 9 and 10 (Foster, 2007). These expeditions resulted in the discovery of partial skeletons of *Apatosaurus* Marsh, 1877b and *Diplodocus* Marsh, 1878, and one new mammal named *Araeodon intermissus* Simpson, 1937 (Foster, 2007). Reed's Quarry 9 would be later revisited by the AMNH, alongside Yale Peabody Museum, between the summers of 1968 to 1970, where a greater diversity of fossils were collected, including mollusk, fish, amphibian, turtle, squamate, sphenodontian, crocodylian, and dinosaurian remains, as well as several species of mammals (Prothero, 1981).

Soon after from 1889 to 1905, AMNH crews focused their work on a site in the plains North of Como Bluff named Bone Cabin Quarry. This site proved to be very productive with the crews collecting at least 50 individuals representative of a dozen distinct taxa, such as crocodiles, turtles, and dinosaurs such as *Apatosaurus*, *Allosaurus* Marsh, 1877b, *Camptosaurus* Marsh, 1877, *Ornitholestes* Osborn, 1903, and *Stegosaurus* Marsh, 1877a (Foster, 2007). Also in early 1900s, AMNH and Smithsonian crews collected in several quarries in the area of Sturgis, South Dakota, resulting in two *Camarasaurus* Cope, 1877 individuals and a diplodocid (Foster, 2007)

Many years after the expeditions in South Dakota, Barnum Brown, accompanied by two other men, returned to Wyoming in 1932, to the town of Greybull, on the west flank of the Bighorn Mountains. Less than 50 kilometers northeast of Greybull, he was shown several bones, which at first sight looked to belong to sauropods, on the eroding sandstones on the hillside of Barker Howe's ranch (Brown, 1935). Since they did not have enough human resources to start work at the ranch during that expedition season, Brown returned next year with a hired crew, and local help, to start working on the removal of the sandstone overlying the fossil. In 1934, fieldwork started at Howe Ranch funded by the Sinclair oil Company and it soon became clear how rich this site was, with approximately 4000 bones found

interlocked with one another and in several states of articulation, belonging to possibly more than 20 individuals, as well as sauropod skin impressions (Brown, 1935). At end of the expedition, the majority of the collected bones were identified as diplodocid sauropods, with other elements found being the remains of *Camarasaurus* and *Camptosaurus*, and teeth of *Allosaurus* (Brown, 1935; Foster 2007).

Although Brown's expedition to Howe Quarry was the first and last excursion of the AMNH into the area of Greybull, the story was just yet finished. In 1990, a team from Zurich led by Hans-Jakob Siber not only reopened the quarry, but also opened two new quarries, one 450 meters southwest of the original dig site, now known as Howe-Stevens Quarry, and another a few hundred meters from Howe Quarry, nowadays known as the Big Al Site. The former site was located in public land managed by the Bureau of Land Management (BLM), leading to the nearly complete *Allosaurus* specimen being confiscated by BLM responsible, and sent to the Museum of the Rockies in Bozeman, Montana. The expedition lasted from 1990 to 1999 resulting several dinosaurian individuals such as *Allosaurus*, *Apatosaurus*, *Barosaurus* Marsh, 1890, *Camarasaurus*, *Diplodocus*, *Dryosaurus* Marsh, 1094, *Stegosaurus*, *Othnielia* Galton, 1977, and on unidentified sauropod baby (Ayer, 1999).

1.3 Big Horn Basin

The Big Horn Basin is located in North Wyoming, being 193 kilometers long and 96 kilometers wide, and covering an area of around 16093 square kilometers. The basin is bounded to the east and northeast by the Big Horn and Pryor Mountains, south by the Bridger and Owl Creek mountains, and west by the, Absaroka, Beartooth, and Washakie Mountains, while to the north, the basin opens toward the plains of southern Montana, merging into the Crazy Mountain Basin (Hewett & Lupton. 1917; Lageson & Spearing, 2011).

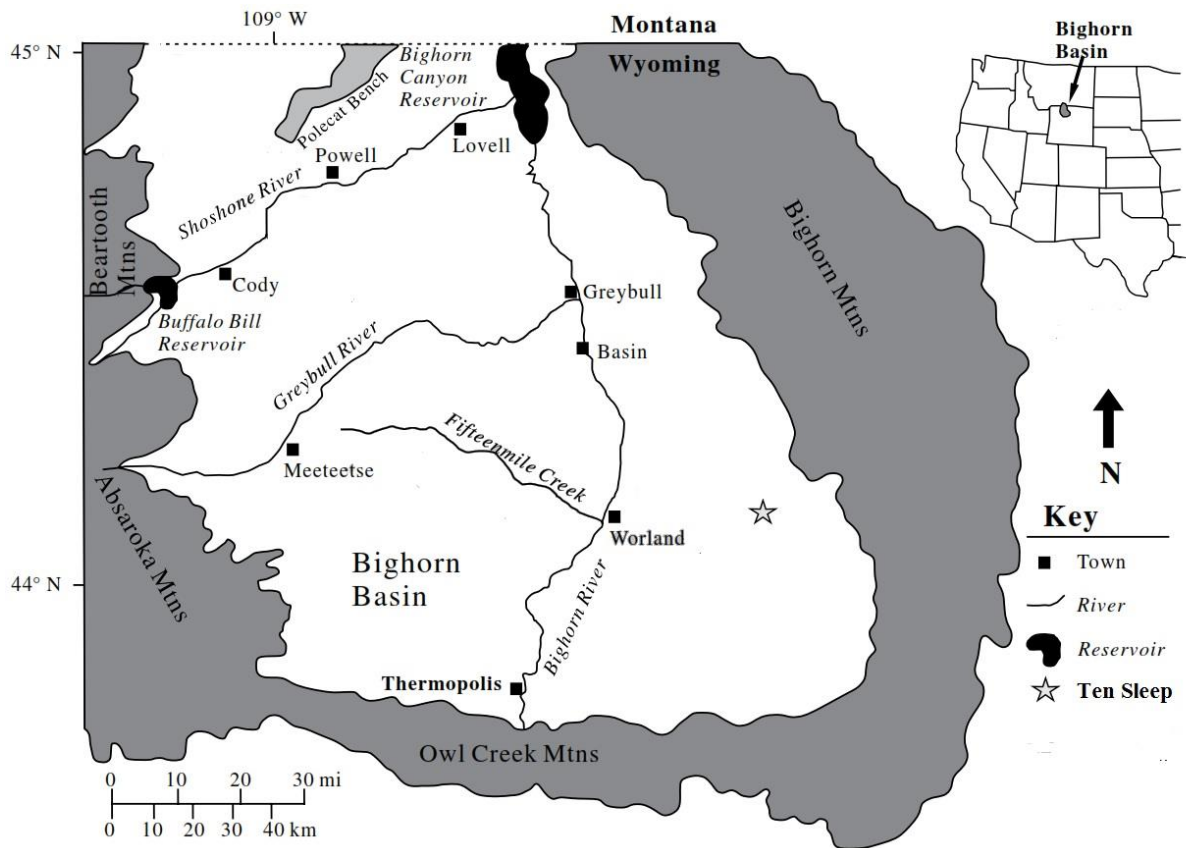


Figure 1.6; Map of the Bighorn Basin, Wyoming, showing the surrounding mountain ranges. Modified from Smith et al., 2008.

The surrounding mountain ranges developed during uplifting events of the Laramide orogeny, displacing the broad Cretaceous seas, leading in turn to thick continental sequences to be deposited east of the Great Plains of Wyoming and Montana during the later stages of the Cretaceous, followed by a great fluvial erosion period during the Eocene (Mackin, 1937). The uplift events brought thick series of Paleozoic and Mesozoic sedimentary rocks high above the Great Plains, and observable along the great anticline that forms Bighorn Mountains. Deep erosion of the crest of this uplift, resulted in the exposure of pre-Cambrian granites that make up this mountain range, along with Paleozoic, Mesozoic and Cenozoic exposed sedimentary deposits turn the Big Horn Mountain area into a great case study of stratigraphic relations and variation within the sedimentary basin (Darton, 1906).

1.4 Bonebeds

The term “bonebed” is frequently used to describe a dense concentration of fossilized bones in a specific geological level. These are seen as important windows to the past in vertebrate paleontology, as they provide valuable data regarding the conditions in which these bones fossilized, as well as providing insights to the environment in which these animals lived. However, this term is not a formal one since the definition of “bonebed” tends to change from author to author.

Rogers & Kidwell (2007) refer to bonebed as a “relative concentration of vertebrate hardparts preserved in a localized area or stratigraphically limited sedimentary unit (e.g., a bed, horizon, stratum) and derived from more than one individual”, and distinguishing two types: macrofossil and microfossil bonebeds.

According to Behrensmeyer (2007), a bonebed is “a single sedimentary stratum with a bone concentration that is unusually dense (often but not necessarily exceeding 5% bone by volume), relative to adjacent lateral and vertical deposits”, with more than one individual represented. He also put a lot of emphasis on the taxonomy the assembled osteological content as a mean to distinguish different types of bonebeds.

Eberth and colleagues (2007) define bonebed “as consisting of the complete or partial remains of more than one vertebrate animal in notable concentration along a bedding plane or erosional surface, or throughout a single bed”, in which “notable concentration” refers to an accumulation that “exceeds the normal (background) occurrence of fossil in the host formation or local strata”. The authors also describe in depth the different ways in which bonebeds can be classified. Regarding the size of the osteological content, Eberth and colleagues (2007) present microfossil bonebeds as sites where more than 75% of its fossil elements have a maximum dimension inferior to 5 centimeters, and macrofossil as sites where more than 75% of its fossil elements have maximum dimension above 5 centimeters.

Taxonomy also plays an important role when classifying bonebeds. Based on diversity, Eberth and colleagues (2007) refer to bonebeds with only one taxon recorded as monotaxic, while bonebeds preserving more than one taxon are considered multitaxic. These multitaxic bonebeds are considered to have high or low diversity depending on the number of taxa observed: low diversity with two to five taxa, high diversity with ten or more taxa. When the number of observed taxa in a bonebed is between six and nine, its diversity can be considered high or low depending on relative abundance of taxa, depositional system, paleoecology, and taphonomic processes, and a researcher’s experience and opinion. Regarding the relative abundance Eberth and colleagues (2007), consider these bonebeds as monodominant when the minimum number of individuals of one taxon is superior to 50% of the assemblage, or as multidominant when no taxon has a minimum number of individuals superior to 50% of the assemblage.

2. Objectives

There are three main goals for this thesis:

1) Practical contribute for the preparing, BML permits, fieldwork, field numbering and report of the NOVA+AMNH Wyoming Expeditions;

2) Scientific study of the Ten Sleep bonebeds in their various aspects: stratigraphy, sedimentology, paleontological contents, taxonomical identifications, osteological description, and an attempt to understand the bone bed origin;

3) Provide a document that records the main aspects of the past expeditions and helps to prepare the next ones.

3. Field Reports (2016 and 2017)

This section includes the yearly field report on the 2016 and 2017 expeditions to the Upper Jurassic bonebeds of the Ten Sleep-Hyattville area of Wyoming, USA provided to Bureau of Land Management (BLM) with some updates and improvements.

3.1 Why dig in Ten Sleep?

The NOVA+AMNH Wyoming Paleontological Expeditions started with an invitation by Mark Norell to Octávio Mateus on September 8th, 2014, in New York City, to the lead the excavation of the BLM side of Dana Quarry. Henri Galiano, who conducted the excavations in the private side of Dana Quarry, informed Norell about the potentiality of the site. Octávio Mateus filed the permit to the BLM in 2015. Carl Mehling conducted a visit in the spring of 2016 and a new locality was found with the assistance of Wesley Linster. The first expedition occurred in August and September of 2016.

3.2 Team members

The expedition counted with team members with various nationalities and education levels, mainly from FCT-NOVA and AMNH. The expedition PI is Prof. Octávio Mateus (FCT-NOVA) and as co-applicants in the BLM (Bureau of Land Management) permits are Prof. Mark Norell (AMNH), Dr. Emanuel Tschopp (AMNH and FCT-NOVA), and Carl Mehling (AMNH).

In the field, the 2016 expedition counted with contributions of the following team members (ordered alphabetically):

- Alexandra E. Fernandes (volunteer; AMNH);
- Alexandre Guillaume (researcher; AMU, ML);
- André Saleiro (MSc student; FCT-UNL, ML);
- Carl Mehling (researcher and Senior Museum Specialist; AMNH);
- Emanuel Tschopp (postdoc and researcher; FCT-UNL, ML, UST);
- João Marinheiro (researcher; FCT-UNL, ML);
- Marco Marzola (Phd student, researcher; FCT-UNL, GMK, KU, ML);
- Octávio Mateus (expedition leader, researcher; AMNH, FCT-UNL, ML);
- Simão Mateus (collections manager, researcher; ML, UP).



Figure 3.1: All members of the 2016 expedition team at Yellowstone National Park, from left to right: O. Mateus, E. Tschopp, S. Mateus, A. Saleiro, J. Marinheiro, A. Fernandes, M. Marzola, A. Guillaume, and C. Mehling.

In 2017 the team was:

- Alexandra E. Fernandes (MSc student, volunteer; AMNH, FCT-UNL)
- Alexandre Guillaume (MSc student, researcher; FCT-UNL, ML)
- André Saleiro (MSc student; FCT-UNL, ML)
- Carl Mehling (researcher and Senior Museum Specialist; AMNH)
- Emanuel Tschopp (postdoc, researcher; AMNH, FCT-UNL, ML)
- João Russo (Phd student, researcher; FCT-UNL, ML)
- Marco Marzola (Phd student, researcher; FCT-UNL, GF, KU, ML)
- Mark Norell (Museum Specialist, researcher; AMNH)
- Octávio Mateus (expedition leader, researcher; AMNH, FCT-UNL, ML)
- Vincent Cheng (MSc student; FCT-UNL)



Figure 3.2: Part of the 2017 expedition team at Dana Quarry, from left to right: Lucy, A. Fernandes, M. Marzola, A. Saleiro, V. Cheng, A. Guillaume, C. Mehling, J. Russo, E. Tschopp, and O. Mateus. Photo by Mike Eklund.

The field paleo-related visitors were: Marit Bovee, Brock Sisson, Carole Gee, Martin Sander, Cliff and Rowena Manuel, and Hans-Jakob Siber in 2016; and Will Harcourt-Smith, Jessica Oreck, Ana Sarzedas, Fiona Brady, Brent Breithaup, Erik Deitesfeld, Lowell Dingus, Mike Eklund, and Vivian Pan in 2017.

3.3 BLM Permits

The Bureau of Land Management (BLM) is the federal institution, within U.S. Department of the Interior, that manages all of its public land, administering more than 245.7 million acres (1,001,000 km²) of public lands in the United States, which constitutes about one-tenth of the country's land mass.[2] Most BLM administered lands are located the states of Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

In order to dig for paleontological purposes in public land, permissions need to be issued by the BLM validating the work being executed in such areas. In order to acquire these permissions, the applicant must fill out the BLM's Paleontological Resources Use Permit (PRUP). Personal information regarding the applicant (contact and institutional affiliation) must be given, along with the work site location, the nature of the fieldwork to be undertaken (survey or excavation), purposes and methodology, dates of proposed work, name and address of the collected material repository, and the name of other individuals responsible for the expedition (along with CVs). After the expedition, a field report detailing the work done, as well as new localities found (see **Appendix 3F**) must be sent to the BLM before the end of the year in which the permit was issued.

Our expeditions were conducted under the following permits (see **Appendixes 3A-3E**):

- PA16-WY-245: permit for paleontological excavation of Jurassic fossil material on BLM-administered land, at Dana Quarry. Issued on 17/08/2017;
- PA16-WY-255: permit for paleontological excavation of Jurassic fossil material on BLM-administered land. This permit originally only figured one locality by the name of Dana Quarry, however, another site was discovered after the PRUP's submission. As to allow us to work on both sites, before the permit was issued, the PRUP was amended to include bot. On the second year of the expedition (2017), this permit only allowed work in Cosm Quarry. Issued on 01/08/2016, and renewed on 06/06/2017.
- PA16-WY-256: permit for survey and limited surface collection of Mesozoic outcrops around the Ten Sleep-Hyattville area. Issued on 01/08/2016, and renewed on 16/05/2017.

3.4 Project objectives

The objectives of the NOVA+AMNH Wyoming Paleontological Expedition present in the BLM permit application are as follows:

- 1) Understanding of the anatomy and taxonomy of the dinosaurs from the Morrison Formation;
- 2) Understand the stratigraphy, paleoecology and taphonomy of the Morrison Formation, with hypotheses on the presence and the significance of the high number and large size of the bone beds among this formation;
- 3) Address the phylogenetic position of the diplodocids called "*Amphicoelias brontodiplodocus*" by Galiano & Albersdörfer (2010).

3.5 Inventory and expenses

Organizing a scientific expedition is an elaborate juggling act requiring a lot of forethought coupled with varied experience, and often even involves spontaneous innovation. The intricacies of each discipline vary widely but even within one area, in this case paleontology, many factors (i.e., where the dig will take place, how long it will be, in what season, and for how many participants) affect all the decisions to be made prior to setting off.

Looking at our first two seasons (three weeks of summer 2016 & four weeks of 2017) collecting in the Late Jurassic of Wyoming, a broad-brush picture can be painted outlining some of the typical concerns for a paleontological field trip. We would be spending a month each time in a hot, dry place but one that could get impenetrably muddy in a sudden storm. On both years, we had a big American/European crew requiring lodging, transportation, and all basic living requirements, expecting to find a good amount of large dinosaur material.

Expedition coordinators and participants Carl Mehling, AMNH Senior Museum Specialist, and Alexandra Fernandes, AMNH Volunteer were in charge of the process of assembling equipment and all

other logistics. Their task began several months prior to departure, when a list was disseminated among the coordinators to begin assembling a general blueprint for what would eventually become a master list of supplies. As an AMNH expedition, we were originating from an institution with many resources and plenty of experience. Some of the needed supplies were directly gathered from the vertebrate paleontology preparation lab (i.e., toilet paper, adhesives, acetone, plaster bandages, burlap, brushes, gloves, foil, Ziplock® bags, markers), also ordering more of the same, where we needed more than was available, plus a lot of our tools and other supplies (i.e., plaster, cooler, jackhammer, geological hammers, chisels, first aid kit). It was helpful to break the supplies into categories like digging equipment, plastering supplies, and safety equipment, and to double-check what would be needed. Across said categories one can break things into consumables (things that will get used up like plaster and adhesives) and non-consumables (things that can be used repeatedly like chisels and the cooler). Everything was cross-referenced against the master supply list as it was being loaded into the field vehicle, and quantities of all supplies were also notated so that a real-time inventory of materials was created. This inventory list was put into an online spreadsheet that could be easily accessed from any location, and simultaneously modified at any time by the coordinators (a simplified inventory list can be consulted in **Appendix 3G**).

Since the AMNH has a field vehicle, which cuts some of the costs, the material was loaded that up in NYC. Whether using our own or rented vehicles, there is always the substantial gas cost to add to the list of expenses, but unexpected expenses as towing and repairs should always be in the back of the mind. Assembling a team coming from as many places as ours does sometimes takes days of travel, which means accounting for room and board along the way, with some of the airfares also being covered.

If one's expedition is to a very remote place, there might not be much expenditure of money along the duration of the trip because you will have had to bring everything along at the beginning. Luckily, our expedition was close to facilities where we could buy our food while out there, replenish any consumable supplies we run out of, and purchase any extra or replacement tools or other things or services we find we need along the way. Moreover, since we were staying at a house, we were able to arrange certain items, like plaster, to be shipped directly to us.

At the conclusion of the excavation, all materials and quantities thereof were inventoried as they were placed into a storage unit for the following year. This process is helpful in accounting for damaged or lost tools or equipment, but also in gaining a general idea of how much material is consumed per year, and what amount is needed to cover what quantity of found specimens. All quantitative differences in material (since day one of the excavation) have been recorded on the spreadsheet, and items that need re-ordering for the following year were highlighted, with recommended future quantities also notated. Supplier contact information for individual specialty items were also included in the spreadsheet so that any future coordinators could easily gain access to these resources. This spreadsheet is a particularly helpful reminder in cases where long spans of time elapse in between excavations. Additionally, if any member of the dig team comes up with anything new or vital in the off-season that may be an asset for

the upcoming season, they can easily add this to the spreadsheet from anywhere, anytime, and with the other coordinators being instantly alerted to the change.

Some significant things separate the expenses of our two trips. A larger portion of the funding provided for first expedition was spent on non-consumables, prior to the start of fieldwork. The 2017 field season ran one week longer than the previous year with several new expenses arising due to the needed to upgrade the size of the storage unit maintained near our sites (in which we store supplies and sometimes specimens), and to hire someone to use a backhoe (for exploratory digging, refilling the holes made in, and to move out largest jacket), and a helicopter (to airlift out the large jackets).

The expenses of the first 2 years of this expedition were handled directly by the AMNH. Aside from what was acquired directly from the AMNH preparation lab, or purchased through it, the 2016 expedition cost about \$23,000 USD, while the 2017 expedition cost 31,327.34 USD (for detailed expenses logs consult **Appendixes 3H** and **3I**).

3.6 Schedule

On the first year of expedition, 2016, the fieldwork started on 29th of August, lasting until the 15th of September. In 2017, it started on the 16th of August, and lasted until the 9th of September, with three days of break in between. The two years of expeditions totaled 39 days, with approximately 265 hours of work: 118 hours in 2016, and 147 in 2017. Two tables detailing team members' presence on the field can be consulted, as sent to BLM, on Appendix 3J.

3.7 Dana Quarry

3.7.1. Description

This site is located in the Washakie County, between the towns of Ten Sleep and Hyattville, with a fence running across part of the quarry, dividing it in two distinct areas: one, south of this fence, being private property, and another being public land under the administration of the BLM, in which our expeditions took place.

Our knowledge about this quarry comes from the work of Galiano and Albersdörfer (2010) regarding the private land site (as no work had done on the BLM portion of Dana prior to our first expedition), where they describe the expeditions started in 2006 by Dinosauria International, LLC. Team, as well report some of the fossils there collected throughout the years. Most fossils from this area are representative of the Upper Jurassic dinosaur fauna from North America, and were collected in a nearly complete state of preservation, some being articulated, with the following taxa documented by Galiano & Albersdörfer (2010): *Allosaurus jimmadseni* Chure, 2000; *Amphicoelias* “*brontodiplodocus*” Galiano & Albersdörfer, 2010; *Brachiosaurus* sp. Riggs, 1903; *Camarasaurus* sp.; *Camptosaurus* sp.; *Ceratops* sp. Marsh, 1884a; cf. *Coelurus* sp. Marsh, 1879; *Diplodocus* sp.; *Hesperosaurus mjosi*

thinner), fill fractures on the bones, and/or glue fragments of bone that may have broken (thicker due to a higher concentration).

As soon as the bones of this specimen were fully exposed, their positions on the matrix were photographed as well as their relative position to each other before their removal began, in order to avoid losing any spatial information since the bones needed to be retrieved in different blocks. To do so, a trench was dug around and between the bones, creating a chalice-like structure on the rocks. After this, the exposed bones were covered with tinfoil before being encased in a plaster jacket. Once the plaster was dry, the foot of the chalice was broken and the block flipped in order to repeat the process on the other side. The blocks were identified with a field number and a date of collection on both sides of the plaster jacket. Before leaving, the team covered the site again with the overburden with the help of buckets, shovels, and hoes.

It should be noted that little work was done in Dana by the team this year, in part due to not having suitable equipment, such as a backhoe to dig the hard sandstone in which the bones were preserved, and the lack of shelter in an area without any shade, making the working conditions harsher.

3.7.3. 2017 Expedition

Just like the previous year, we started our work in Dana by surveying for exposed bones in the light brown sandstone layers, in order to find a good place to start our digging efforts. From this survey resulted two possible dig sites, both bearing sauropod remains on the surface.

The located close to the fence, that divided the BLM side of Dana from the private side, proved not only more interesting, as theropod remains were found very close to the sauropod bones already observed, but also allowed an easier access for the backhoe provided by the Tanners.

The use of the backhoe had been previously discussed with the BLM, since it would make it easier to open a quarry in this hard sandstone. With the backhoe part of a big sauropod limb bone was discovered, although the bone shaft was in poor condition. After this, a tarp was set in place over the area surrounding the bone and the team started picking the bone fragments belonging to the sauropod bone, as well as the many theropod bone fragments, and storing them in Ziplock® bags and cleaning the quarry using shovels, brooms, draw hoes, and dustpans.

During the cleaning process more bones started to become visible, both the sauropod and theropod, making the site become four times bigger that it was originally. Most of the bones found bared several cracks, some being held together only by the matrix surrounding the bones. As such, the area close to the bones was cleaned using the smallest brushes at hand, and a large amount of Paraloid B-72® diluted in acetone was applied to not only protect and consolidate the exposed bone surface, but as an attempt to fill the crack as fissures of these bones.

Most of the digging work was done using small chisels, mallets, screwdrivers, gardening shovels, and knives, since not only the matrix surrounding the bones became gradually softer as we dug

as the fossiliferous sandstone layer bared mudstone lenses on some parts of the quarry, but also because the fragility of the bones required us to use less aggressive digging methods.

Once most bones were exposed and consolidated, and the quarry cleaned, some metal stakes were hammered into the ground to serve as reference for mapping the quarry, where the first one to be placed is the main reference stake of which the placement of all other reference stakes is dependent. After the main reference is placed and its coordinates noted down, a second one was placed 3 m from the main stake in the North cardinal direction, and a third one placed 32 meters from the main stake in the East cardinal direction, before several other references were put in place. The map was drawn onto sheets of millimetric paper with a 1:5 cm scale using a 1x0.5 cm grid sub divided in 10x10 cm squares. The several pieces of the map were then copied by hand onto tracing paper with thick black contours outlining the fossils, and then digitalized (see **Appendixes 3M** and **3N**). With the quarry mapped, some blocks were individualized and plaster jacketed, with anatomical, taxonomical, and numeral identification written on both sides of the jacket, as well as the day of collection. Most blocks collected to the cars either by hand or with a net (sometimes requiring the use of the octopus), however, the sauropod material, due to its size and state of preservation, required to be collected as one single 3x1.5 m block.

In order to collect this block, a trench with approximately 90 cm in depth was dug around the articulated bones. The exposed bones were covered with wet toilet paper and, once it dried, the top surface of the block was covered with two layers of plaster and burlap, and two 4x4 wood beams. These beams were placed parallel to each other on top of the block and covered by plaster and burlap in order to make sure they remain attached to the jacket. Then we started to undercut the sediment and dig a tunnel at its midpoint, making the block stand on to columns, after which we started to apply plaster-covered burlap on these undercut surfaces in order to make the whole block more stable before it was flipped. As soon as the plaster dried, we used the remaining wood beams as lever to flip the block, and, after it was flipped, we finished the jacket by applying several layers of plaster and burlap on top of the block, and properly identifying it.

Before closing this site the bones that were still exposed and not going to be collected got covered by wet toilet paper and plaster. Once the plaster were dried, they were covered with an erosion mat, held to the ground by biodegradable stakes, and then hidden with the overburden created during the expedition, in order to leave no traces of our work.

Close to the end of the expedition, while surveying the northernmost edge of Dana, some remains of a small theropod, including a claw and a tooth, were found loose in a dark grey layer of mudstone overlaid by a hard yellowish brown sandstone layer. This finding prompted the team to dig out this sediment and dry sieve it in order to find more bones belonging to this specimen. All bones and fragments were collected to Ziplock® bags and properly labeled, before the dig site was refilled with the overburden created.

The collected material from Dana was then stored in a storage unit on the outskirts of Ten Sleep, along with the material collected in Cosm and all the expedition equipment.

3.7.4. Findings

During the first year of excavations not much was discovered in the surveyed area of Dana, with the only material of notice being two limb bones possibly belonging to a stegosaurid. However, the 2017 expedition proved to be more fruitful as we found sauropod material, including the remains of a camarasaurid and the articulated remains of an *Apatosaurus*-like diplodocid, next to the remains of an allosaurid, and several bones belonging to a small coeluraurid theropod preliminarily identified as *Ornitholestes* (from a different locality in Dana).

3.8 Cosm Quarry

3.8.1. Description

Cosm Quarry is located close to the southern border of Big Horn County, northwest from Ten Sleep, near an area known to the locals as Bobcat Hill/Ridge.

The quarry site is a very recent discovery. It was reported to Carl Mehling during his first visit to the region in the summer of 2016, while checking on the Dana Quarry outcrops, by a local named Wesley Linster. Mr. Linster, locally known for digging dinosaur remains in Dana and other sites on the farmland belonging to the Tanner family, took him to an area of this hill where several bone fragments were visible along the face of the hill. These fragments were in a very bad state, with most being discolored due to long exposure to the sun, and not preserving any bone surface.

The only thing of notice were a couple of bones in a yellowish brown sandstone layer, protected bellow a tree root from being washed away by the upper layers' overburden. The bones preserved both their surface and color, and at first sight looked to be part of a jaw belonging to a theropod dinosaur, possibly *Allosaurus*.

As this discovery was outside of the expeditions digging limits imposed by the BLM, no collection was made. Instead, a new permission was requested before the start of the expedition for this specific area, in order to allow us to dig any other fossil remains on the Jurassic outcrops of this hill.



Figure 3.4: Aerial view of Cosm Quarry (red and yellow tarp) and Cosm-II (blue tarp on the right). Drone picture by Erik Deitesfeld.

3.8.2. 2016 expedition

Before any work could be done on this site, some preparations needed to be made. A safety rope was tied around a tree on top of the hillside in order to make our descent with the tools a bit easier. After that, a tarp was set, not only to provide the team with some shade, but also to give some cover to the tools while they were left in the field overnight.

While these safety measures were being taken care of, part of the team was scattered on the hillside of the site ground looking and picking for loose bones and fragments, collecting them into sample bags.

Cleaning the hillside was not an easy task due to the fact the draw hoe and brooms we were using not only removed the soil covering the rock, but also made it possible for the soil of the top of the hill to slide down to our level. This resulted in a stable and strong foothold on the side of the hill (since the soil that came down made an overhang at the base of the dig site) and resulted in a good exposure of several layers of bone. In fact, most of the bones preserved in these layers were found during this cleaning phase.

Due to the sediment layers on this site having different levels of hardness, a bigger array of tools was used when compared to Dana. Small chisels, mallets, screwdrivers, gardening shovels, knives, and brushes were enough to dig in soft sandstone and mudstone, harder sandstone and conglomeratic layers required bigger tools such as pickaxes, big chisels, screwdrivers, mallets, geological hammers, and shovels. In some parts of the site, the sandstone was so hard that we were left with no other choice

but to use a jackhammer powered by a portable generator. This generator was put on the top of the hill, with a tarp below it in order to prevent it from leaking oil into the ground, being only fully covered by the tarp when it was not being used.

Another thing to be noted is the fact that many of the fossils found while digging either presented fractures or were on the verge of breaking, therefore high quantities of thick Paraloid B-72™ were applied to said bones as soon as any signs of weakness were shown. These weaknesses were caused not only by the sedimentary environment in which they were deposited, but also by several veins of gypsum crystals that sometimes filled the fissures and cracks of the bones.

As new bones were being found, a field number was given to isolated bones or to groups of bones, whether they were collected or not. Photos were taken as a record and their relative positions recorded on a simplified dig site map.

The method used to collect big blocks of rock with bones was the same applied to the Dana Quarry material (plaster jacketing). For smaller blocks, instead of using burlap and plaster, medical bandages were used, while isolated or small bones were either enveloped in toilet paper and paper tape or tinfoil and duct tape or simply put in a sample bag. To carry the bigger blocks up the hill a net was used to make it easier for several people to transport them to the cars, as well as ropes and tools with sturdy handles (shovels and brooms).

This site was also very rich in layers filled with plant material. Most of it was collected due to the extraction of blocks from the ground, while some just happened to dissociate from the layers during the cleaning process. However, to collect this material we had to keep in mind not to cover it with Paraloid B-72™ (so the cuticle, if present, could remain intact) and always envelope the material collected in toilet paper (in order to avoid even more weathering of the already fragile structures).

Before closing down the dig site for this season, all of the exposed bones that were not collected were covered with wet toilet paper, followed by plaster to protect them until the next digging season. Before the plaster was fully dried, loose soil was dusted over it in order to give it a darker colour thus making it easier to disguise. Once this was done, we made the upper layer of soil slide down the hill using shovels, brooms, and draw hoes, covering all digging traces that could still be seen.

As for difficulties faced while digging on this site, the main one was the inclination. This not only delayed our work a bit (as we dug the lower fossiliferous layers the soil was covering, the soil layers above would eventually slide and cover them) but also made it difficult to make a proper field map due to the overlay of exposed bones and the quarry's surface inclination.

3.8.3. 2017 Expedition

We started by cleaning the quarry, removing all the washed down soil that had accumulated over the dig site using shovels, brooms, and draw hoes, until the plaster protections from the previous expedition could be seen.

Unlike the previous year, it was decided that the best way to work on this quarry would be a top-down approach. As such, the use of the generator powered jackhammer in order to dig the harder sandstone overlaying our fossiliferous layer. As this layer was being dug, the resulting overburden was being removed from the dig site with shovels and draw hoes in order to keep the fossiliferous layer and plaster protection visible. This resulted in a vertical cut of ~3 m high, and a more horizontal exposure of the first fossiliferous layers to serve as our digging area.

To level out the surface area we required pickaxes, big chisels, screwdrivers, mallets, geological hammers, and shovels to move the harder sediment and to start trenching the big blocks jacketed in 2016. As we got closer to the newly exposed bones and the plaster-caped bones from the previous expedition smaller chisels and mallets, screwdrivers, gardening shovels, knives, and brushes were used as digging tools.

Some of the bones from the 2016 expedition had to be uncapped as the paper used as a barrier between the bones and the plaster had been consumed by termites, making some of the plaster caps become looser and unfit to be used as part of a plaster jacket. Most of this uncapped bones, as well as some of the newly exposed bones, required either consolidation of fissures and cracks or to be glued back together. Paraloid B-72™ was applied in several concentrations depending on the task: more diluted to fill small fissures and consolidate the bone surface, and thicker concentrations used to fill cracks and to attach bone fragments back together.

The flatness of this year's dig site made it possible to draw out the quarry map. The method applied was the same as the one used in Dana: several reference metal stakes put in place, with their position based the main (and permanent) reference, then, using the same grid, the exposed bones and jackets were drawn onto millimetric paper using a 1:40 cm scale. The map was eventually copied to tracing paper, using a black marker, and digitalized (see **Appendix 3K**).

While surveying the hillside for other exposures of the yellowish brown sandstone layer we had been focusing our work on, a new outcrop of this fossiliferous bed was discovered and nicknamed Cosm-II. At first, only some bone fragments were visible on the loose soil and some worn out bones sticking out the sandstone, but after the soil was removed, several bones in situ were exposed along an almost vertical wall, spanning 17 meters wide and 3 meters high. This sandstone layer bared several cracks and shifted blocks resulting in the poor state of preservation of some of the bones here preserved. As such, after the surface was cleaned, using brooms and brushes, all exposed bones were consolidated using Paraloid B-72™ and a field sketch was made of the vertical wall at 1:20 cm scale in order to record the relative position of the visible bone surfaces (see **Appendix 3L**).

A small portion of this wall was directly below a massive sandstone block. This overhanging block was brought down using the generator-powered jackhammer, making it easier to work on the bones exposed below it. Very little digging work was done at Cosm-II, with the team focusing on the other portion of Cosm and on Dana. Only the bones more at risk, either for being preserved in a shifted

block or being poorly attached to the matrix, were dug, using small chisels and hammers, dentistry tools, and brushes, and collected.

Towards the end of the dig, some blocks started to be isolated, jacketed, properly identified, and transported uphill to the cars, with two of these being left at the foot of the hill in order to be picked up by helicopter due to their weight, while some of the smaller bones and plant material were collected to labeled sample bags. Similar to the year before some of this material was wrapped in either toilet paper and paper tape or toilet paper and duct tape, and properly labeled afterwards.

The exposed bones in both Cosm and Cosm-II that would not be collected were covered with wet toilet paper and plaster, and dusted over with loose soil. Afterwards, erosion mats were spread over the digging areas of the quarry and nailed to the ground with biodegradable stakes, and covered with the overburden and overlaying loose soil.

3.8.4. Findings

As of 2017, Cosm Quarry produced several bones of sauropods, including two skulls of camarasaurid and diplodocid species, at least three specimens of allosaurid dinosaurs, two with preserved cranial elements, along with shed teeth, and small remains of an unidentified ornithopod. Plant material including trunk fragments, branches, cones, isolated cone scales, and seeds belonging to Araucareacea were found along with millimetric amber nodules.

4. Stratigraphical work for the Ten Sleep-Hyattville area

The first records of stratigraphical work focused on the Morrison Fm. in Ten Sleep area come from the work of Darton (1904) on the stratigraphical comparison of the Big Horn Basin with other geological regions of Wyoming and Colorado. He briefly describes the Morrison Fm. in this basin as easily recognizable, with features shared with outcrops of the Black Hills area and Colorado, dominated by pale green or maroon chalky shales with massive or joint clay structure, also bearing darker clays towards the top levels, and light gray to buff sandstone beds. He would later write about the geology of the Big Horn Basin (Darton, 1906), where he described the Morrison Fm. outcrops in different locations of the basin. He observed that in this area of Wyoming, the fluvial sediments of this formation were overlaying the marine Jurassic sediments of the Sundance Fm., and underlying the Cretaceous sediments of the Cloverly Fm. He also documented the first stratigraphical sequence of the Morrison Fm. outcrops, around 250 feet thick (~76.2 meters), West and South of Ten Sleep, where five different units were recognizable: greenish-gray to reddish sandy shale, sandstone, maroon to red clays, greenish-grey clays, and grey shales (top-to-bottom). Mook (1916) would later represent this outcrop in the form of a simplified geological log in study of the Morrison Fm.

Lee (1927) in his attempt at correlating the geological formations of Colorado, Wyoming, and Montana, observes 262 feet (~79 meters) of the variegated shale and sandstone units of the Morrison Fm. at a cut west of Ten Sleep, and being overlain by a yellow to brown, coal-bearing, conglomeratic sandstone of the Kootenai Fm. He also took note of dinosaur bones on the Morrison sandstones, and fresh-water bivalve shells 50 feet (~15 meters) from the top. He also observed these units north of Ten Sleep, in cuts close to Hyattville and Bonanza, with the latter exposure showing the shale of the Morrison Fm. overlain by a brown conglomerate unit, similar to what the author observed in Thermopolis, on the southern portion of the Big Horn Basin. Wilson Jr. (1938) also took note of the Morrison sediments 1 mile west (1.6 km) of Ten Sleep, south of the Tensleep fault, observing a 185 feet (~56 meters) thick exposure of maroon shales, variegated brown, gray, and green shales with thin sandstone layers, and black shales.

A detailed description of the Morrison layers on the southern Big Horn Mountains is presented by Mirsky (1962), revisiting the approximate location of Darton's (1906) section west of Ten Sleep, and observing 14 distinct layers representative of the Morrison Fm. along an exposure of 236 feet (72 meters) thick. The Morrison portion of this cut was dominated by grey sandstones (nine distinct layers) intercalated by dark greenish grey to red brown soft calcareous mudstone layers at lower half of the cut (represented by two distinct layers), and a black and dark grey successive mudstone layers close to the top limit of the Morrison at this outcrop. The contact between Morrison and Cloverly formations is located at the disconform upper limit of a massive and well cemented dark olive-green siltstone contacting with a white to grey, thick bedded, well cemented sandstone, with white chert grains, ferruginous nodules, and conglomeratic lenses towards its lower half.

The last record of stratigraphical work on this area comes from Ostrom's (1970) work focused on the early Cretaceous Cloverly Fm., and its overlaying and underlying formations, Skyes Mountain and Morrison (respectively), where he revisits and re-describes the outcrops previously described by Darton (1906), Lee (1927), and Mirsky (1962). He describes only three layers for the Morrison at the Ten Sleep cut (66 meters thick, in a total of 104 meters of exposure), with the lowest being an yellow to greenish-gray, silty or sandy, unstratified, calcareous claystone, with occasional thin yellow or buff sandstone lenses. Overlaying the previous layer, is an yellow to white, medium-grained sandstone, with quartz and white chert, cross-laminations, and massive bedding, which in turn is underlying an unstratified and nonfissile variegated claystone (greenish to yellow-tan in upper part, orange to pale-red in lower part) with several yellow or tan sandstone and siltstone lenses. At the Hyattville cut, however, the Morrison is only represent by only 9.40 meters of a white to light-gray, massive, fine to medium-grained, well cemented and prominent sandstone, with quartz, white chert and feldspar in its composition, as the underlain sediments are described to be concealed by valley alluvium.

4.1 *Stratigraphic logs*

During the two years of expedition, a total of five stratigraphic logs were made of outcrops close to the digging sites of Cosm and Dana in order to better understand the placement of the quarries' fossiliferous layers within the Ten Sleep-Hyattville area of the Big Horn Basin, and the Morrison Fm, by comparing them to previous reports on the area, as well as to try and correlate the two quarries. Of the five stratigraphic logs, only one is representative of Dana Quarry, with the others representing outcrops in the Bobcat Hill area (two of which are logs of the North and South sections of Cosm Quarry).

4.1.1. Section 1: Bobcat Hill

The exposure at Bobcat Hill (Figures 4.1 and 4.2) has the following stratigraphic sequence, from base to top:

- L1: greenish grey sandstone (thickness: 15 meters);
- L2: brownish grey claystone, compact and fine-grained (thickness: 4.05 meters);
- L3: light grey claystone, slightly sandy, coarse-grained (thickness: 7.20 meters);
- L4: red claystone, fine-grained (thickness: 8.85 meters);
- L5: light tan sandstone, coarse grained, with millimetric fine-grained laminae (thickness: 0.60 meters);
- L6: light grey sandstone, medium-grained (thickness: 4.05 meters);
- L7: yellowish grey sandstone, fine-grained (thickness: 1.95 meters);
- L8: grey claystone, compact, fine-grained (thickness: 1.95 meters);
- L9: light grey sandstone, coarse to fine-grained, with planar bedding (thickness: 0.60 meters);

- L10: dark grey claystone, compact, fine-grained (thickness: 4.05 meters);
- L11: variegated purple and dark grey claystone, compact, with the grey portions of this layer being slightly finer than the purple ones (thickness: 2.10 meters);
- L12: purplish grey claystone, compact, fine-grained (thickness: 3 meters);
- L13: whitish gray sandstone, coarse-grained, with cross bedding (thickness: 0.3 meters);
- L14: variegated purple and dark grey claystone, fine-grained, with rare millimetric orange claystone laminae (thickness: 3.90 meters);
- L15: light grey claystone, compact, fine-grained (thickness: 3 meters);
- L16: yellowish brown sandstone, compact, coarse to fine-grained, conglomeratic towards the bottom (pebbles not larger than 1 centimeter, held together by a coarse dark orange to yellowish brown coarse sandstone matrix), with crossbedding, bearing vertebrate and plant fossil remains, and gypsum crystals inside fractures (thickness: 3.30 meters);
- L17: yellowish brown to light tan sandstone, medium to fine-grained, bearing bone fragments (thickness: 8.10 meters);
- L18: yellowish brown sandstone, compact, coarse to medium-grained, (thickness: 2.75 meters);
- L19: light tan sandstone, very fine-grained, with bone fragments at the surface (thickness: 3.90 meters);
- L20: dark tan sandstone, coarse to medium-grained (thickness: 3.60 meters);
- L21: dark grey muddy sandstone, fine-grained (thickness: 1.35 meters exposed);
- L22: whitish to light grey sandstone, orange to tan on the surface, low carbonate content close to the top, conglomeratic towards the bottom contact (pebbles not larger than 2 centimeters, held together by a coarse grey sandstone matrix), very compact, fine-grained, with crossbedding, and large tabular concretions up 1 meter in diameter (thickness: 5.40 meters).



Figure 4.1: Stratigraphic Section 1, located on the south facing slope of Bobcat Hill, a few meters north of Cosm Quarry, Big Horn County, Wyoming, USA.

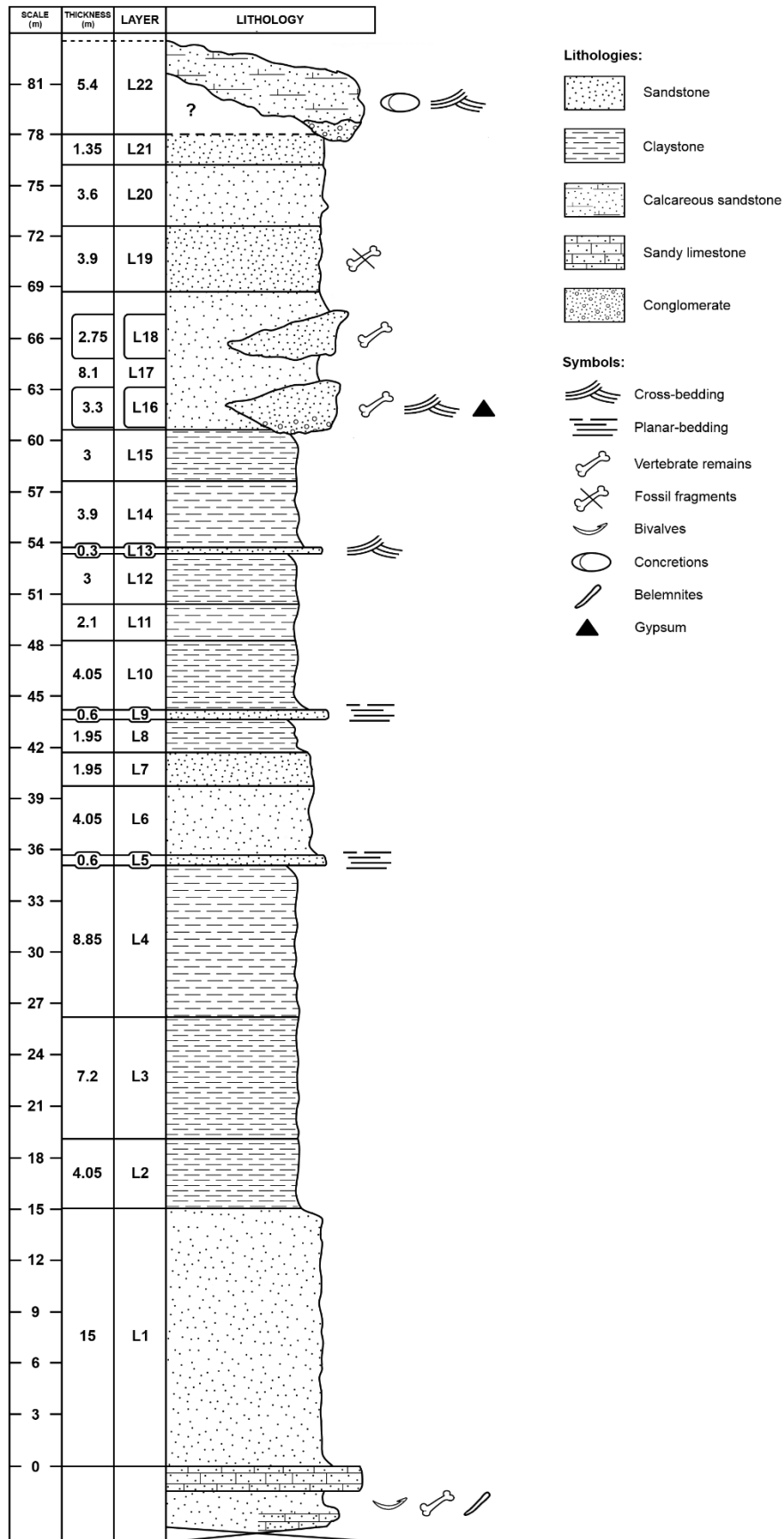


Figure 4.2: Stratigraphic log of Section 1 located on the south facing slope of Bobcat Hill, a few meters north of Cosm Quarry, Big Horn County, Wyoming, USA..

4.1.2. Section 2: Bobcat hilltop

The exposure at the top of Bobcat Hill (Figures 4.3 and 4.4) has the following stratigraphic sequence, from top to base:

BH-1: whitish to light grey sandstone, fine-grained, erosive bottom contact (thickness: 50 centimeters);

BH-2: light grey sandstone, very coarse-grained, gravelly to conglomeratic, matrix supported (50% clasts and 50% matrix), and irregular bottom contact (thickness: 20 centimeters);

BH-3: whitish grey sandstone, medium to fine-grained, with cross and planar bedding, alternating polarity of clasts, and irregular bottom contact (thickness: 1.20 meters);

BH-4: light grey sandstone, coarse to fine-grained, with planar bedding, and slightly irregular and sharp bottom contact (thickness: estimated 40 centimeters);

BH-5: grey sandstone, coarse to conglomeratic, pebble supported (55% clasts, 45% matrix, and high lateral variation), with cross bedding, thin fine-grained sandstone lenses, and planar bottom contact (thickness: 1.80 meters);

BH-6: light grey sandstone, medium to fine-grained and coarser towards the top, with planar bedding at the base and three distinct laminae (red, orange, and yellow), reversed grading of the clasts, and sharp to slightly irregular bottom contact (thickness: 80 centimeters).



Figure 4.3: Part of the Stratigraphic Section 2 exposure at the top of Bobcat Hill, Southwest of Cosm Quarry, Big Horn County, Wyoming, USA.

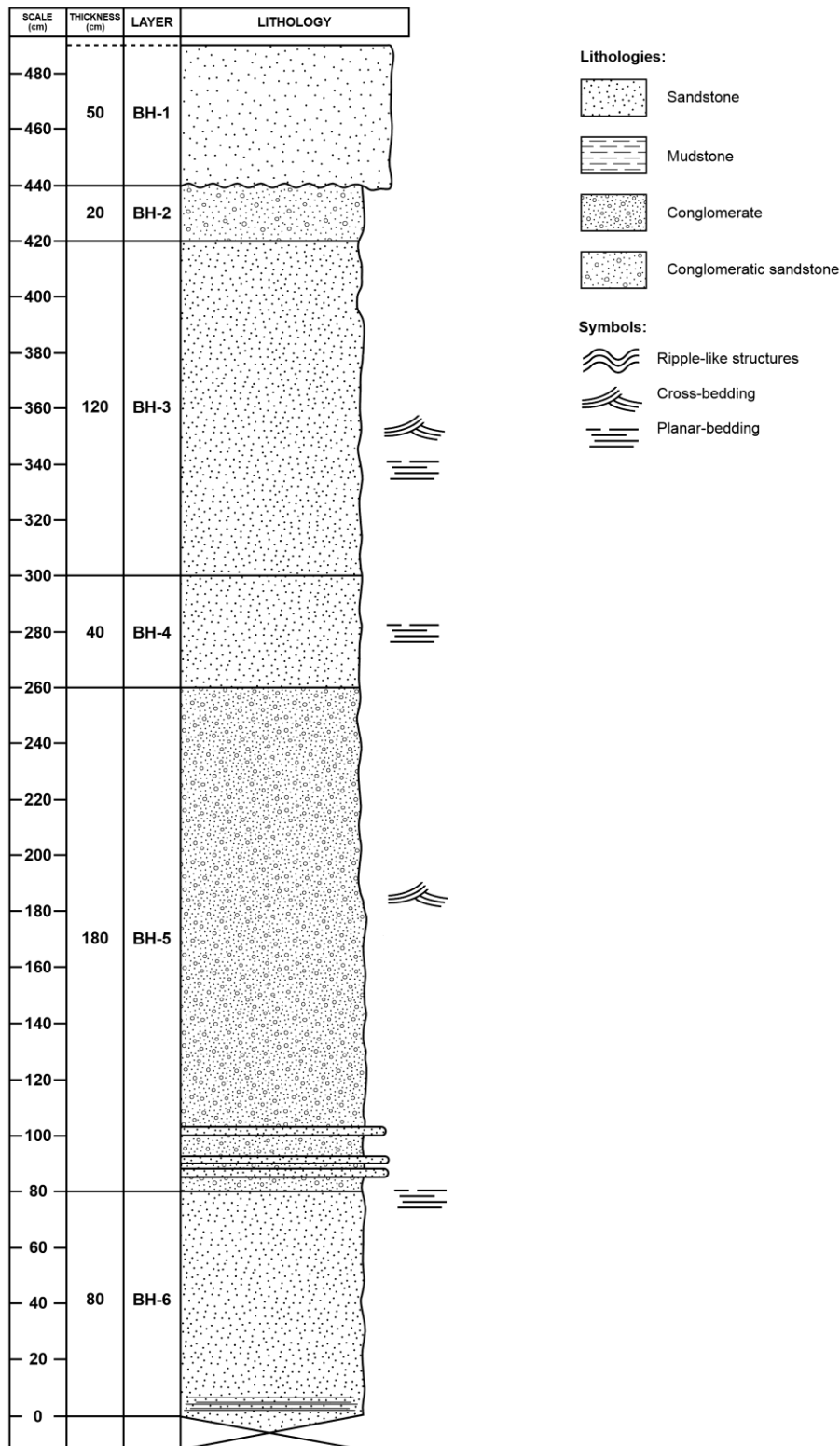


Figure 4.4: Stratigraphic log of Section 2 exposure at the top of Bobcat Hill, Southwest of Cosm Quarry, Big Horn County, Wyoming, USA.

4.1.3. Section 3: Cosm Quarry (North)

The exposure at the North section of Cosm Quarry (Figures 4.5 and 4.6) has the following stratigraphic sequence, from base to top:

CQ-N 1: tan sandstone, medium grained (unknown thickness);

CQ-N 2: orange pebble supported conglomerate, with sandy matrix and tan sandstone lenses, preserving bone fragments (thickness: 25 centimeters);

CQ-N 3: yellowish brown sandstone , coarse to fine-grained, compact, with a conglomerate lens at 5 centimeters from the base (both 10 cm thick, pebble supported, orange sandy matrix, preserving bone fragments), bearing plant and vertebrate fossil remains (thickness: 65 centimeters);

CQ-N 4: Tan sandstone, medium-grained, very compact, with conglomerate intercalations at the base, and 60 centimeters from the top (both 5 cm thick, pebble supported, orange sandy matrix, preserving bone fragments), mudstone lens overlaying the bottom conglomeratic one (preserving amber fragments), bearing plant and vertebrate fossil remains, and gypsum crystal (thickness: 1.50 meters);

CQ-N 5: grey sandy mudstone, medium to fine-grained, with large white clasts between 5 and 12 centimeters in diameter (thickness: 2.60 meters);

CQ-N 6: yellowish brown sandstone, compact, coarse to medium-grained, (thickness: 2.20 meters)



Figure 4.5: Stratigraphic Section 3, on the norther section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.

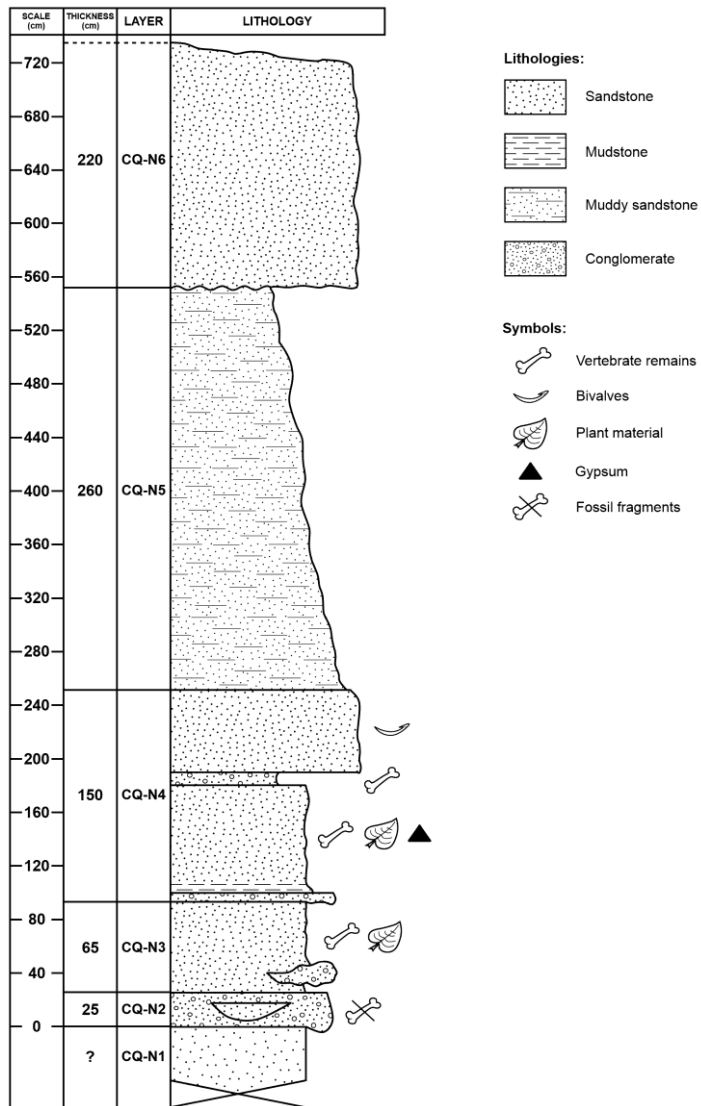


Figure 4.6: Stratigraphic log of Section 3, on the norther section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.

4.1.4. Section 4: Cosm Quarry (South)

The exposure at the South section of Cosm Quarry (Figures 4.7 and 4.8) has the following stratigraphic sequence, from base to top:

CQ-S 1: tan sandstone, medium grained and erosive upper contact (thickness: 40 centimeters of exposure);

CQ-S 2: yellowish brown sandstone, coarse to fine-grained, compact, bearing vertebrate fossil remains, with greenish grey mudstone pockets, and planar upper contact (thickness: 25 centimeters);

CQ-S 3: tan sandstone, medium-grained, compact, with greenish grey mudstone at the base (close to 5 centimeters thick), and planar upper contact (thickness: 20 centimeters);

CQ-S 4: greenish grey mudstone, fine-grained, thinly laminated, and with planar upper contact (thickness: 15 centimeters);

CQ-S 5: tan sandstone, medium-grained, compact, bearing vertebrate fossil remains close to the top and bottom of the layer, with greenish grey mudstone at the top, and erosive upper contact (thickness: 30 centimeters);

CQ-S 6: yellowish brown sandstone, coarse to fine-grained, compact, bearing vertebrate fossil remains, with crossbedding and wave lamination towards the top, gypsum crystals filling in the fractures, and erosive upper contact (thickness: 45 centimeters);

CQ-S 7: yellowish brown sandstone, coarse to fine-grained, compact, bearing vertebrate fossil remains, with greenish grey mudstone lenses, and erosive upper contact (thickness: 60 centimeters);

CQ-S 8: grey to tan sandstone, medium to fine-grained, very eroded surface (thickness: approximately 1 meter).

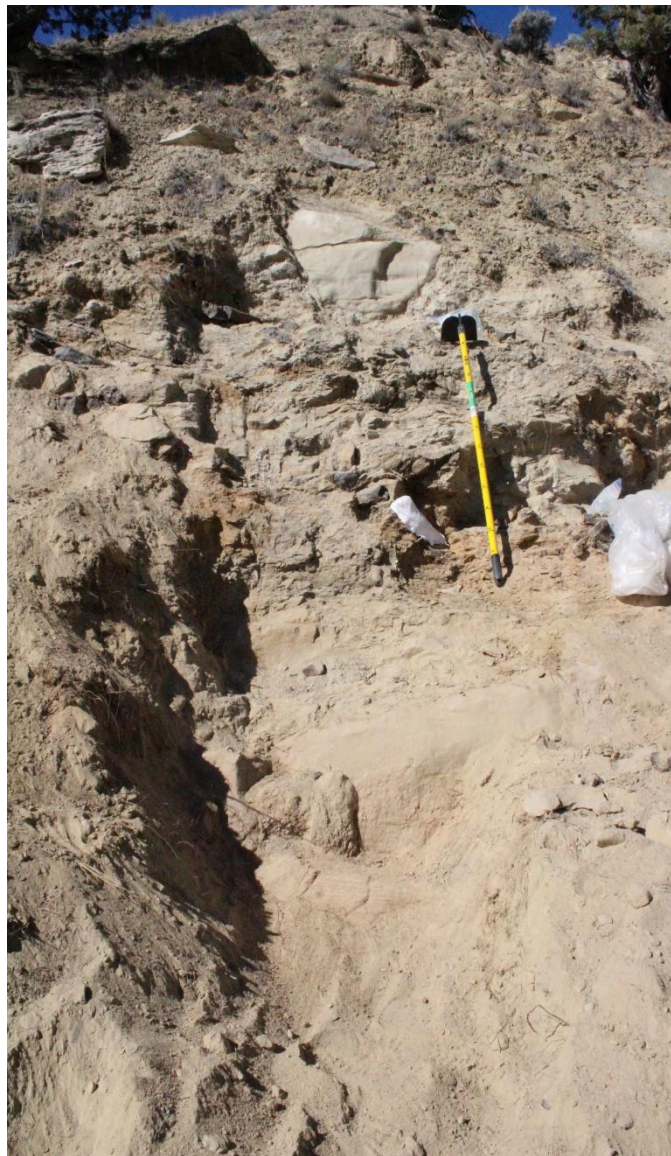


Figure 4.7: Stratigraphic Section 4, on the southern section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.

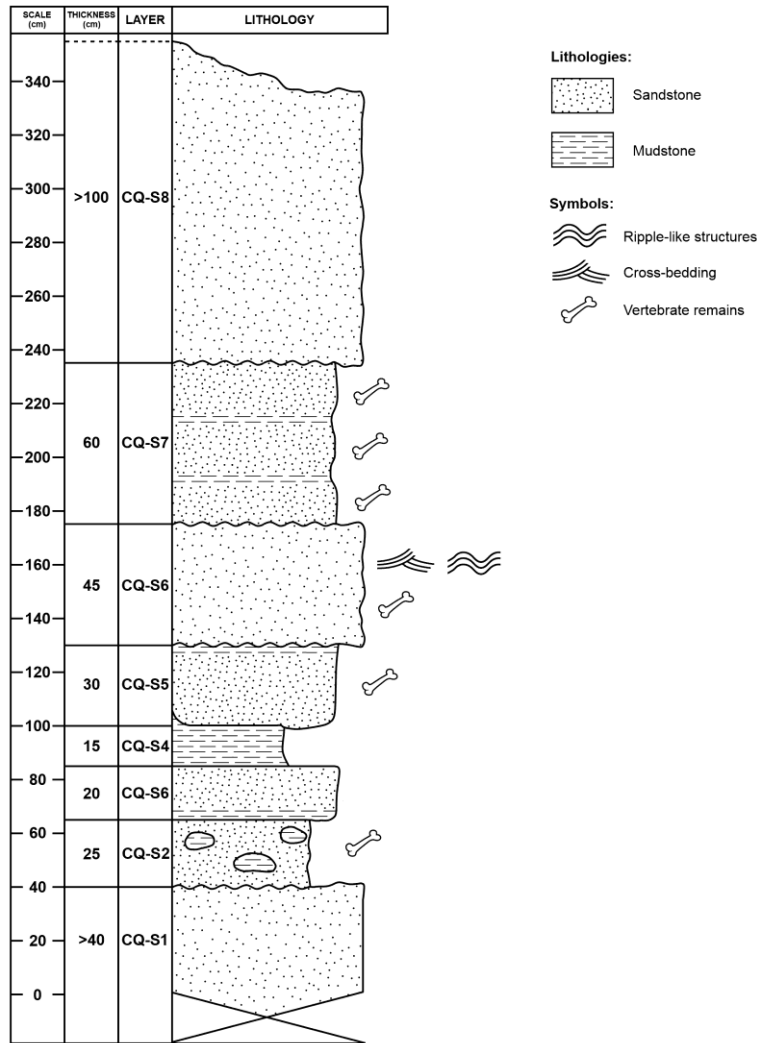


Figure 4.8: Stratigraphic log of Section 4, on the southern section of Cosm Quarry in the in the west-facing slope of Bobcat Hill, Big Horn County, Wyoming, USA.

4.1.5. Section 5: Dana Quarry

The exposure at the northern slope of Dana Quarry (Figures 4.9 and 4.10) has the following stratigraphic sequence, from base to top:

DQ 0: grey to brownish grey cross-bedded sandstone, carbonate, fine grained, with ripple like structures at the top of the layer, suggesting a southbound current, and scarcely preserving bivalve fossils (thickness unknown);

DQ 1: grey muddy sandstone, coarser toward its base, and showing some bedding structures (thickness: 2.40 meters);

DQ 2: grey sandstone, with thin mudstone intercalations, and ripple structures indicating an East-to-West oriented flow (thickness: 50 centimeters);

DQ 3: grey mudstone gradually becoming sandier towards the top, with scattered sandstone pockets, caliche, and dinosaur infill tracks (thickness: estimated 2.80 meters);

DQ 4: intercalating red and grey sandy mudstone, sharp upper contact, bearing thin grey sandstone lenses, and with fossilized wood remains observed at the top of the layer (thickness: estimated 8.60 meters);

DQ 5: grey mudstone, with thin sandstone lenses intercalations (from 50 to 150 centimeters above its bottom contact, and from 10 to 80 centimeters below its upper contact), and with cross bedding towards the top (thickness: estimated 4.30 meters);

DQ 6: grey mudstone, with thin tan sandstone laminae, gastropod and bivalve fossil remains, and theropod remains close to the upper contact (thickness: estimated 10.20 meters);

DQ 7: yellowish brown sandstone, coarse to medium-grained, eroded at the surface (sometimes fully covered by vegetation), and bearing vertebrate fossil remains (thickness: estimated between 5 and 10 meters).



Figure 4.9: Part of the Stratigraphic Section 5 exposure at the North faced hills of Dana Quarry, Washakie County, Wyoming, USA.

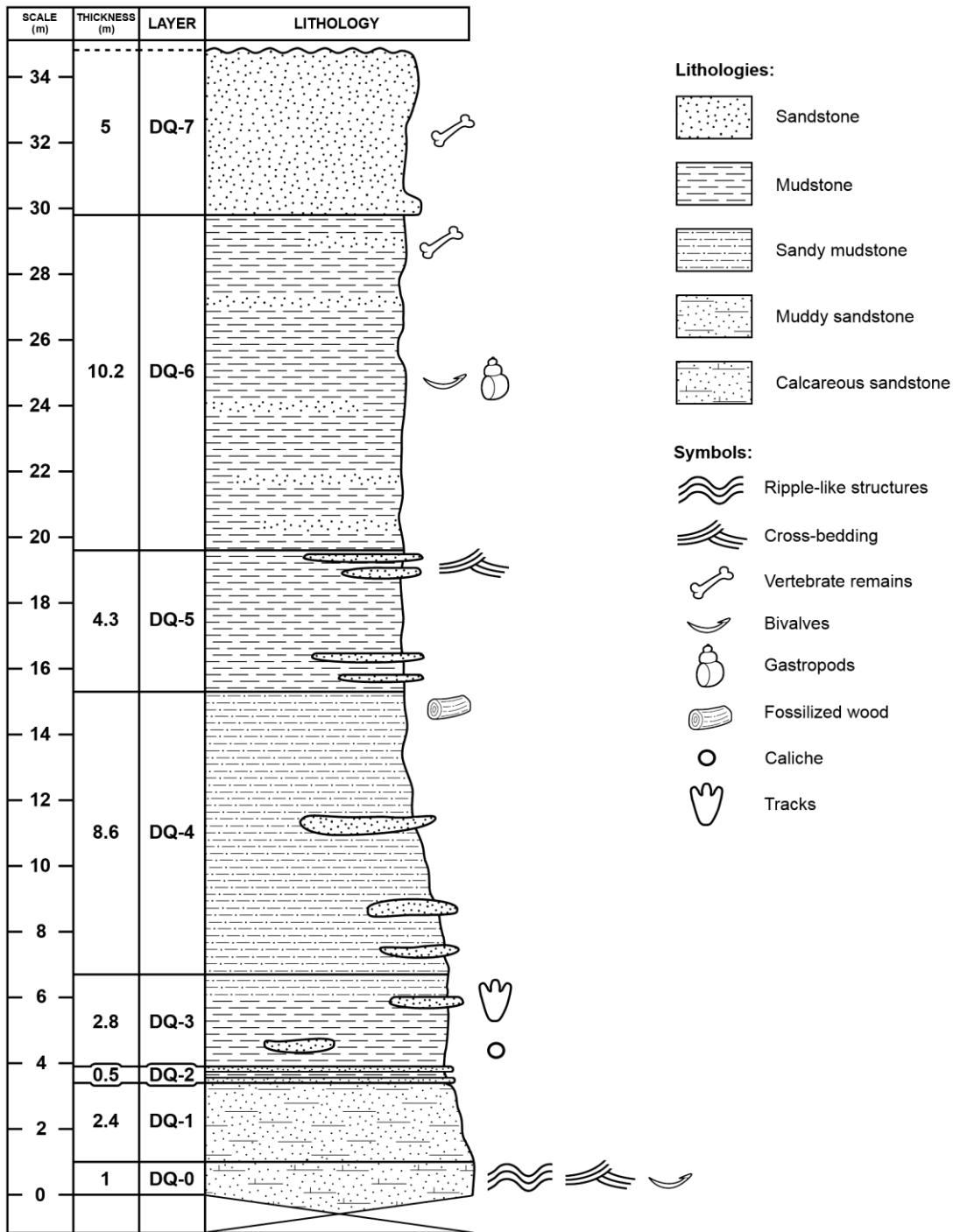


Figure 4.10: Stratigraphic log of Section 5 exposure at the North faced hills of Dana Quarry, Washakie County, Wyoming, USA.

4.2 Comparison and local correlation with previous works

For the area of Bobcat Hill, Saleiro and Mateus (2016) observed outcrops where around 78 meters of Morrison Fm. sediments were visible, while overlaying the upper part of the Sundance Fm. The contact between these two formations was placed at the base of a 15 meters greenish-grey sandstone layer (lower part of Morrison Fm.) and the top of a yellowish brown to grey carbonated sandstone layer bearing bivalves and belemnites (upper part of Sundance Fm.). The lowermost sandstone of the Morrison

Fm. is overlaid by 48 meters of reddish and gray-purple claystone and light grey sandstone, followed by 16 final meters of yellowish-grey sandstone. Atop the latter sediments, grey to orange sandstones of the Cloverly Fm. overlay disconformably. This transition from dark claystones to lighter sandstones is similar to description of Ostrom's Unit I and II (1970). At the Bobcat Hill exposure of Section 1, Unit I could comprise the layers L2 through L15, due the sequence being mainly represented by a dark colored claystone sequence overlaying marine sediments, with sandstone lenses sometimes showing crossbedding, while the sequence presenting light colored massive ledge-forming sandstones, with crossbedding, represented by layers L16 through L21 would be placed within Unit II.

The yellowish to tan sandstones of the Morrison Fm., where fieldwork was carried out at Cosm, were observed to alternate either with dark orange conglomerates (bearing bone fragments), or with greenish mudstones (bearing greyish mud clasts). Moreover, the dug area is also very rich of plant material, with several thin dark layers (up to few centimeters thick) preserving trunks, branches, cones, leaves, and amber, sometimes in direct contact with the bone surface, along with gypsum infills. This description of the Cosm layers is very similar to the one of Galiano and Albersdörfer (2010), where they report the fossiliferous layers of Dana Quarry's private side to be comprised mostly of soft sandstone, yellow-ochre in color, with lenses of grey mudstones, gypsum inclusions, and preserving plant and animal remains. In their work, these layers are approximately six to nine meters above the marine Upper Jurassic Sundance Fm., placing the contact between the two formations at the base of lenticular green shales or mudstones, visible on the eastern slope of the quarry.

Based on observations made while surveying the area around Dana Quarry, during the 2017 expedition, , the sandstone layers in which work had been focused were recorded as being underlain by approximately 19 meters of red and grey mudstone layers, occasionally intercalated by sandstone lenses; belonging to the Morrison Fm. with the greyish sandy limestone Windy Hill. Unlike what was previously reported for this area (Galiano & Albersdörfer, 2010), the Sundance is represented by a grey cross-bedded carbonated sandstone layer, with ripple marks observable at its exposed top limit (layer DQ 0), with outcrops observable through the washed overburden along the extension between Dana and Bobcat Hill, bearing rare bivalve fossils. This layer is much similar to the Sundance Fm. sandstone layers west of Ten Sleep described by Mirsky (1962) as grey, speckled, calcareous and glauconitic, moderately cemented, and thin-bed, with the lower layer preserving bivalve shells towards the bottom. Both descriptions of the topmost Sundance layers at the Ten Sleep area fit with Pipiringo's (1968) definition of the Windy Hill sandstone Member in central Wyoming as a ledge-forming sandstone, light to brownish grey, fine grained, oolitic, with a high content of lime, and sparsely fossiliferous. At the bottom of Bobcat Hill, DQ 0 is mostly covered by washed overburden, and overlaying layers of yellowish sandy limestone intercalated with sandstone, bearing belemnite remains, and ostreid-like bivalve shells, forming tightly packed, fine grained units, much like what was observed by Pipiringos (1968) for the Redwater shale Member, in central Wyoming. For the southeastern portion of the Big Horn Basin, Windy Hill and Redwater members have been correlated to the topmost stratigraphic units of Imlay's

(1956) “Upper Sundance” division, due to similarities in stratigraphical units, sedimentary structures, and similar fossil content, possibly being the last marine sediments deposited in Wyoming during the Jurassic, representing an Oxfordian regression (Wright, 1973). The J-5 Unconformity, placed either at the bottom or top limits of the Windy Hill sandstone Member (Pipiringos & O’Sullivan, 1978), was not observed at either Dana or Bobcat Hill, in great part due to the extent of the washed overburden coverage of the Sundance Fm. layers.

At Bobcat Hill, several other units overlie the sandstones of Cosm Quarry, however, it was difficult to discern their limits and extension along the hill due to their almost complete coverage by washed overburden sediments. In order to identify the contact between Jurassic and Cretaceous sediments, a cleaner cut close to the hilltop was used as a mean of comparison between Bobcat Hill and the cuts west of Ten Sleep. Moberly (1960) has described the lowest member of Cloverly fm, Pryor conglomerate member, as a conglomeratic layer of rounded black chert pebbles supported by a matrix made up of grey angular grains, with size varying between sand and grit, that unconformably overlies the Morrison sediments. Ostrom (1970) recognizes the presence of a Pryor-like conglomeratic sandstone, both in his observation of the Ten Sleep cut, as well as in Mirsky’s (1962) description of the same cut, agreeing on the placement of the Morrison-Cloverly limit. Two similar layers were observed at the top of Bobcat Hill, namely BH-2 and BH-5, as both present conglomeratic levels of rounded black clasts, supported by a grey, rather coarse grained, sandstone. As such, layer BH-5 (the lower of the two in the cut) is considered to mark the limit between the Morrison and Cloverly Fms. At Bobcat Hill.

4.3 Paleoenvironment

Galiano and Albersdörfer (2010) reported that the sandstone deposits of Dana represent a unique depositional event, and that the site was a seasonal body of water, such as an oxbow lake. Numerous small water-worn bone fragments found scattered throughout the fossil layers were assumed to result of moving water in that area. This however, may have been a misinterpretation of a rivers channel displacement along the years due to the constant erosion of the riverbank in a meandering fluvial system.

The least eroded of the yellowish brown to tan sandstone layers exposed at Cosm, and along Bobcat Hill preserve crossbedding, as well as several lenses of coal, mudstone, and small-grained conglomerate, and numerous fossil remains in different preservation conditions and degree of articulation. These massive sandstones appear to be imbricated with one another towards the northern exposure of the hill, possibly representing the migration towards north of a meandering river channel.

Mollusk remain have also been found both on these channel sandstones (Cosm) and on the mudstones that underlay them at Dana. Amongst the collected material, two fresh water species have been identified, following the work of Yen (1952) on the molluscan fauna of the Morrison Fm.: seven specimens *Amphovalvata scabrida* (Meek & Hayden, 1865), and several fragments of bivalve shells

belonging to *Unio* sp. Philipsson, 1788 (one thin shelled specimen found at Cosm, and all other specimens found in the grey mudstone underlying the fossiliferous layers of Dana).

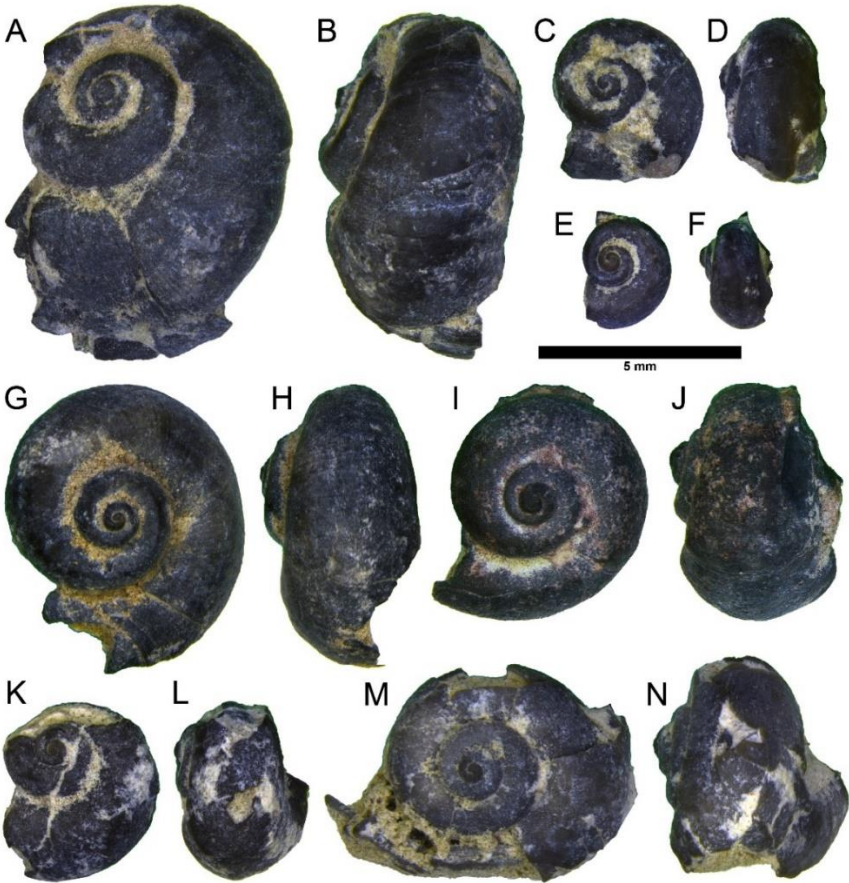


Figure 4.11: AMNH FI 113386 *Amplovalvata scabrida* specimens a (A, B), b (C, D), c (E, F), d (G, H), e (I, J), f (K, L), and g (M, N), in apical (A, C, E, I, K, M) and lateral views (B, D, F, H, J, L, N), collected at Dana Quarry.



Figure 4.12: AMNH FI 113385 *Unio* fragments collected at Dana Quarry.

4.4 *Age of Cosm and Dana quarries*

The sandstone layers of Dana Quarry have been previously described by Galiano and Albersdörfer (2010) as dating to the Oxfordian stage of the Upper Jurassic, about 156 Ma, which would place them within the Tidwell Member, according to the age range presented by Trujillo and Kowallis (2015) for the Morrison Fm. The attribution of this age was based on the presence of *Allosaurus "jimmadseni"* and *Hesperosaurus mjsosi*, which characterize Foster's (2007) biochronological Zone 1, based on the Dinosaur Zone 1 of Turner and Peterson (1999). This zone however, is also characterized by the presence of *Haplocanthosaurus* Hatcher, 1903, and the absence of diplodocid and macronarian faunas that would first appear during the duration of Dinosaur Zone 2, at the upper levels of the Salt Wash Member, and ecologically replace the haplocanthosaurid sauropods (Bakker, 1996; Carpenter, 1998; Turner & Peterson, 1999). Dana Quarry can therefore be excluded from Dinosaur Zone 1, due to the sauropod fauna recorded in its fossiliferous layers, as well as in Cosm Quarry, being dominated by diplodocids and macronarians, and to the recovery of ornithopod and theropod species that first appear in the Morrison's paleontological record along the duration of Dinosaur Zone 2 (Turner & Peterson, 1999).

Although the molluscan fauna of the Morrison Fm. is widespread both geographically and stratigraphically, allowing certain species of bivalves and gastropods to be used to ascertain the relative age of the strata in which they are preserved, such is not applicable to the specimens found at Cosm and Dana, due to both *Unio* sp. and *Amplovalvata scabrida* having a wide temporal range along the Morrison sediments, with the latter's distribution ranging from Lower Jurassic to Cretaceous rocks (Evanoff et al., 1998; Good, 2004).

However, the plant material collected may shed some light on the quarries' relative age. With several elements of *Araucaria delevoryasii* Gee, 2010 being recognized by C. Gee, and collected, at Cosm Quarry. So far, *A. delevoryasii* has only been documented based on specimens collected at Howe-Stevens Quarry on the northeastern edge of the Big Horn Basin (Gee & Tidwell, 2010). The presence of this species may point towards an approximate age between these two localities, placing the fossiliferous sandstone layers of Cosm Quarry, as well as the correlated sediments along Bobcat Hill and Dana, within the Brushy Basin Member, at the top layers of Morrison Fm., aged between 153 to 145 Ma (Kowallis et al., 1991).

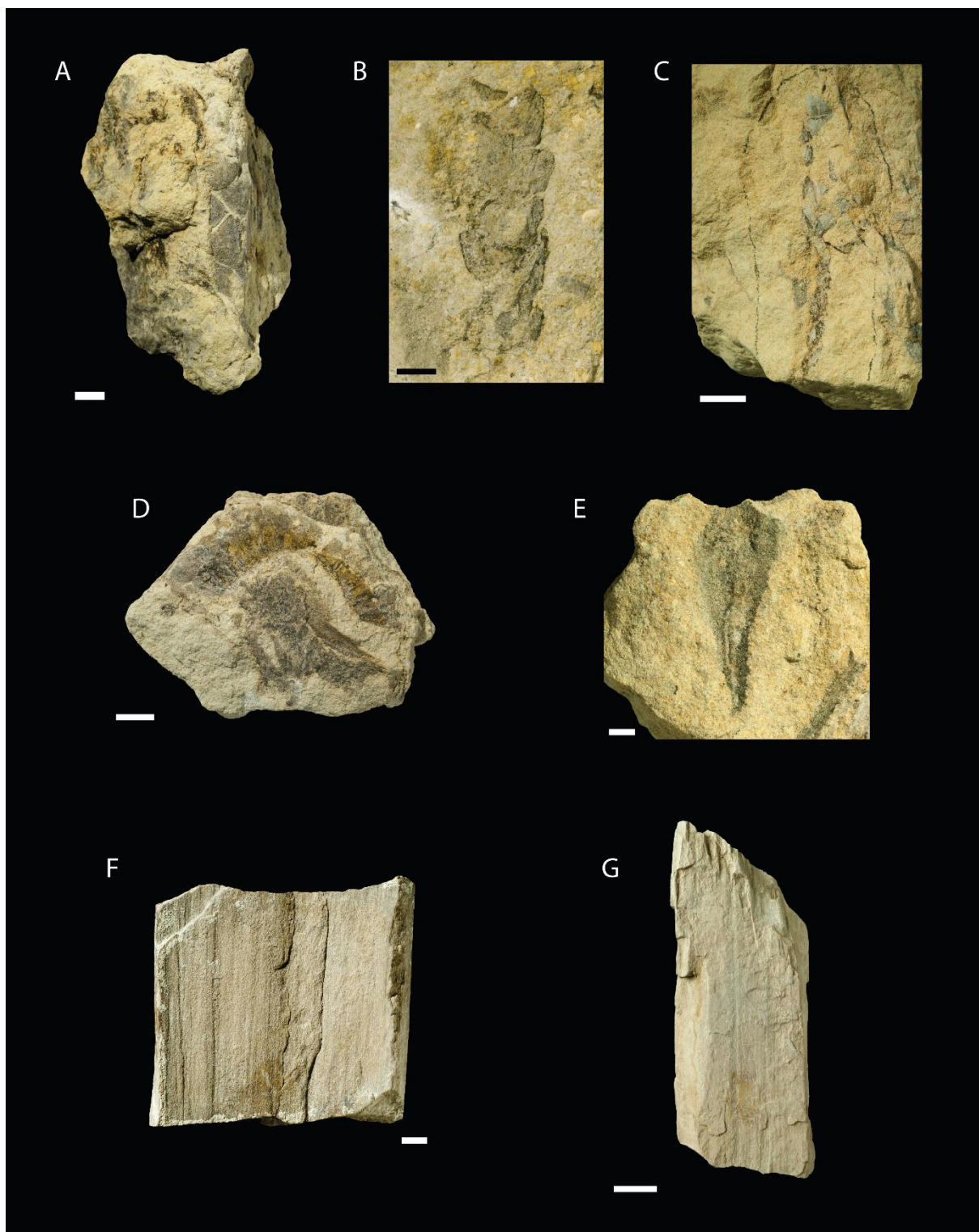


Figure 4.13: Assorted plant material collected at Cosm Quarry: AMNH FP 425, *Araucaria delevoryasii* branch with leaves (A; scale bar: 5 mm); AMNH FP 429, *Pagiophyllum* sp. Branch (B; scale bar: 3 mm); AMNH FP 430, *A. delevoryasii* branch with leaves (C; scale bar: 1 cm); AMNH FP 427 AMNH, *A. delevoryasii* seed cone (D; scale bar: 1 cm); AMNH FP 426 *A. delevoryasii* seed cone scale (E; scale bar: 3 mm); and two unnumbered wood fragments (F and G; scale bar, respectively 5mm, and 1 cm).

5. Taxonomical description

The material described in this work was collected during the 2016 expedition. The majority of the fossils collected during that year were taken by B. Sisson to be prepared at Fossilogic LLC in Utah (as pre-arranged with AMNH), while a few selected sauropod bones (including a block with a diplodocid skull) were taken to AMNH for preparation and study (see **Appendixes 5A** and **5B**). Originally, the material sent to Utah was to be studied and presented in this dissertation, however such did not happen due to a sudden cut in communication from the Fossilogic LLC preparation laboratory with both the AMNH and myself. As such, the bones hereby described represent a very small sample of the expedition's collected material lent to O. Mateus (see **Appendix 5C**) and taken to Portugal. All plant remains were taken to the AMNH, except for a few selected specimens that went to Bonn University, with C. Gee, for future studies. The full list of all collected material from the NOVA+AMNH Wyoming Paleontological Expedition, now part of the AMNH's repository can be consulted in **Appendix 5D**, for the 2016 expedition, and in **Appendix 5E**, for 2017.

5.1 Preparation

All specimens described in this work have been prepared at Museu da Lourinhã. In order to prepare the specimens, physical techniques were applied, mainly the use of air scribing tools, namely PaleoTools® Micro Jack 1 and 4, to remove the matrix surrounding the them. Wooden skewers, sometimes tipped with cotton, were used to expose the bone when the vibrations, inherent to the use of air scribing tools, were deemed as potentially to damaging for the specimen, or when the matrix was poorly consolidated. When using the skewers, either a solution of water and ethylic alcohol at 50%, or acetone, were used to moisten the matrix, making its removal easier, as well as to dissolve gypsum crystals or excess of Paraloid™ B-72 applied during excavation, respectively.

Paraloid™ B-72 is a versatile solution adhesive favored in fossil preparation, due to its stability, good aging properties, long shelf life, remaining resoluble overtime, and intermediate hardness and strength (Davidson & Alderson, 2009; Davidson & Brown, 2012). Paraloid™ B-72 diluted in acetone was used in lower concentrations (5%) to consolidate the prepared specimens and in higher concentrations (20% or 50%) as an adhesive for reattachment of fragmented elements.

All bones were marked following the method proposed by Davidson and colleagues (2006): applying a thin basecoat layer of Paraloid™ B-72 in acetone in order to seal and isolate the bone surface, write the catalog identification using crow quill pen and either black ink for technical pens or white acrylic paint, finishing by applying an overcoat layer of Paraloid™ B-72.

After prepared and marked, some of the fossils were used for photogrammetry, as requested to AMNH (see **Appendixes 5F**, **5G**, and **5H**). Mallison and Wings (2014) describe this technique as “the process involves taking a series of photographs of an object from different angles to computationally

generate a 3D model by comparing features across the photographs”. All 3D models were generated using AgiSoft Photoscan, under permit of the AMNH (see **Appendix 5F**)

5.2 Specimens description

5.2.1. AMNH FARB 33055

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Vertebral elements including one cervical, four sacral and one caudal vertebra, three metatarsals, two pedal phalanges, articulated tibia, fibula, and (possibly) astragalus, and unidentified cranial elements

Quarry: Cosm (North Section)

Layer: CQ-N 3

Associated field numbers: COSM 001, COSM 002, COSM 010, and COSM 011

Material described in this work: Left metatarsals II and III (condyles), and phalanges IV-1 and IV-2

Description:

Left Metatarsal II Condyle:

Only the distalmost portion of metatarsal (Figure 5.1) is preserved, being broken at the base of the condyle, and bearing large fractures, as well as signs of erosion. It measures 9 cm in length, from the distal articular face to the break surface, where the bone is sub-circular in cross-section, while the articular face of the condyle is U-shaped in distal view.

The middle of the dorsal face of the distal condyle bears a horizontal depression, forming two small ridges, where pits are observed. A longitudinal sulcus on the plantar face expanding distally to the articular surface divides the condyle in two hemicondyles, with the medial one being approximately half the size of the lateral hemicondyle. Round concave distal articular surface limit on the dorsal face of the condyle

The lateral collateral ligament fossa is oval-shaped, broader, and deeper than the medial collateral ligament fossa, which is spear shaped, tapers distally to the articular surface of the condyle, and very superficial.

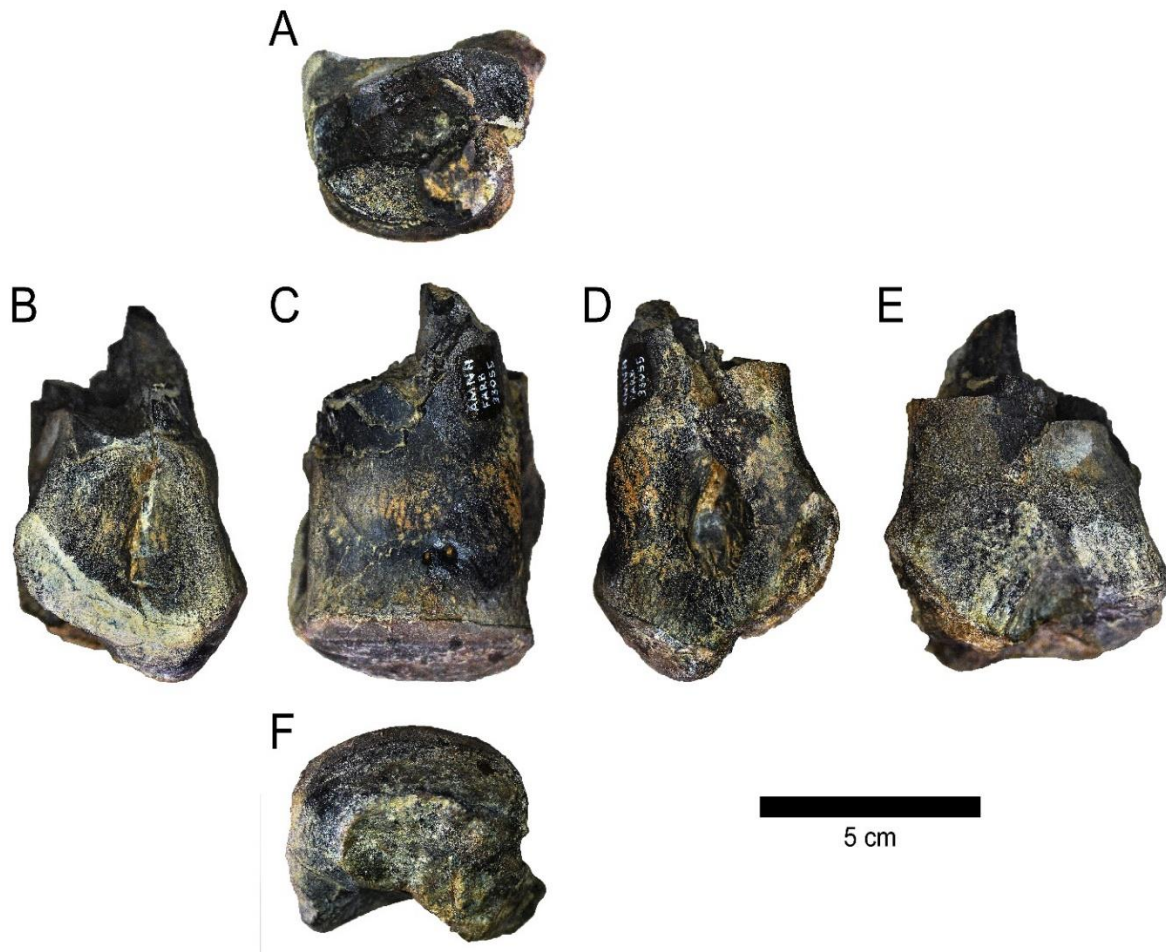


Figure 5.1: *Allosaurus* sp. AMNH FARB 33055 left metatarsal II condyle in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Metatarsal III Condyle:

Only the distalmost portion of metatarsal (Figure 5.2) is preserved, being broken at the base of the condyle, and bearing marks of wearing caused by the growth of gypsum crystals. It measures 8.90 cm in length from the distal articular face to the break surface where the bone is bean-shaped in cross-section, while the distal articular condyle has a rectangular shape in distal view, with the medial plantar edge being bulkier than the lateral edge, and projecting mediodorsally. The proximal end of the condyle is approximately one third wider than its distal end.

The plantar face of the condyle is slightly concave right before the articular surface, while on the dorsal face a V-shaped depression is observed close to its mid-point, with pits close to the articular surface, and forming two small ridges.

Large collateral ligament fossae are located in the middle lateral and medial faces of the condyle, the previous being elliptical, and the latter oval shaped. The surface of the bone around these fossae is gently tipping to the center of the condyle. The edges of the articular surface are convex laterally, triangular pointing upwards on the dorsal face, and triangular pointing downwards on the plantar face.

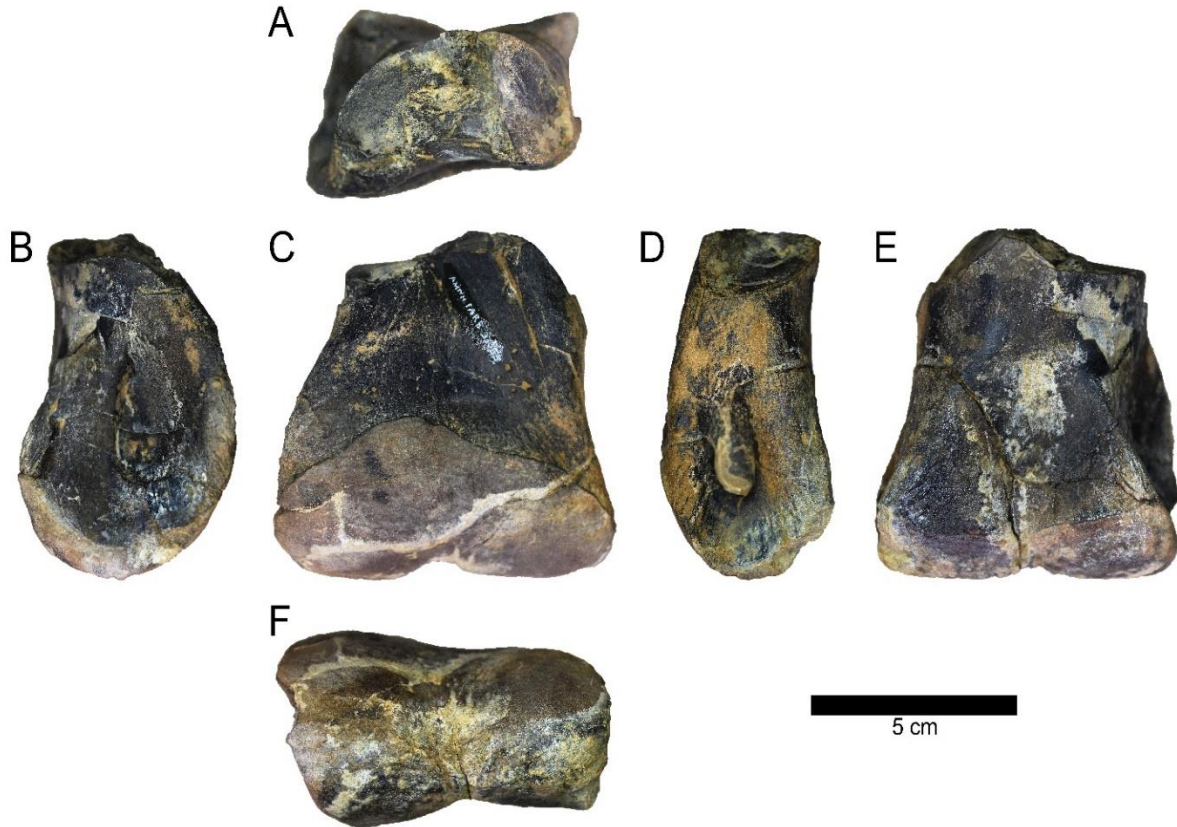


Figure 5.2: *Allosaurus* sp. AMNH FARB 33055 left metatarsal III condyle in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Phalanx IV-1:

This phalanx (Figure 5.3) measures 6.50 cm in length and is distally broken, missing the lateral hemicondyle, and partially preserving the medial hemicondyle. The proximal articular surface is U-shaped, concave, and projecting medially on the dorsal face, while the proximal end is slightly convex and rugose on the plantar face, and irregular with thin ridges on the dorsal face. A slight torsion of the phalanx makes the dorsal face tilt laterally.

Both medial and lateral faces have a depression towards the proximal articular surface close to the margin of the plantar face. The distal end of the shaft looks pinched on the dorsal face right above the distal condyle, and concave and smooth on the plantar face. The medial hemicondyle expands distally and ventrally, with a poorly preserved elliptical collateral ligament fossa.

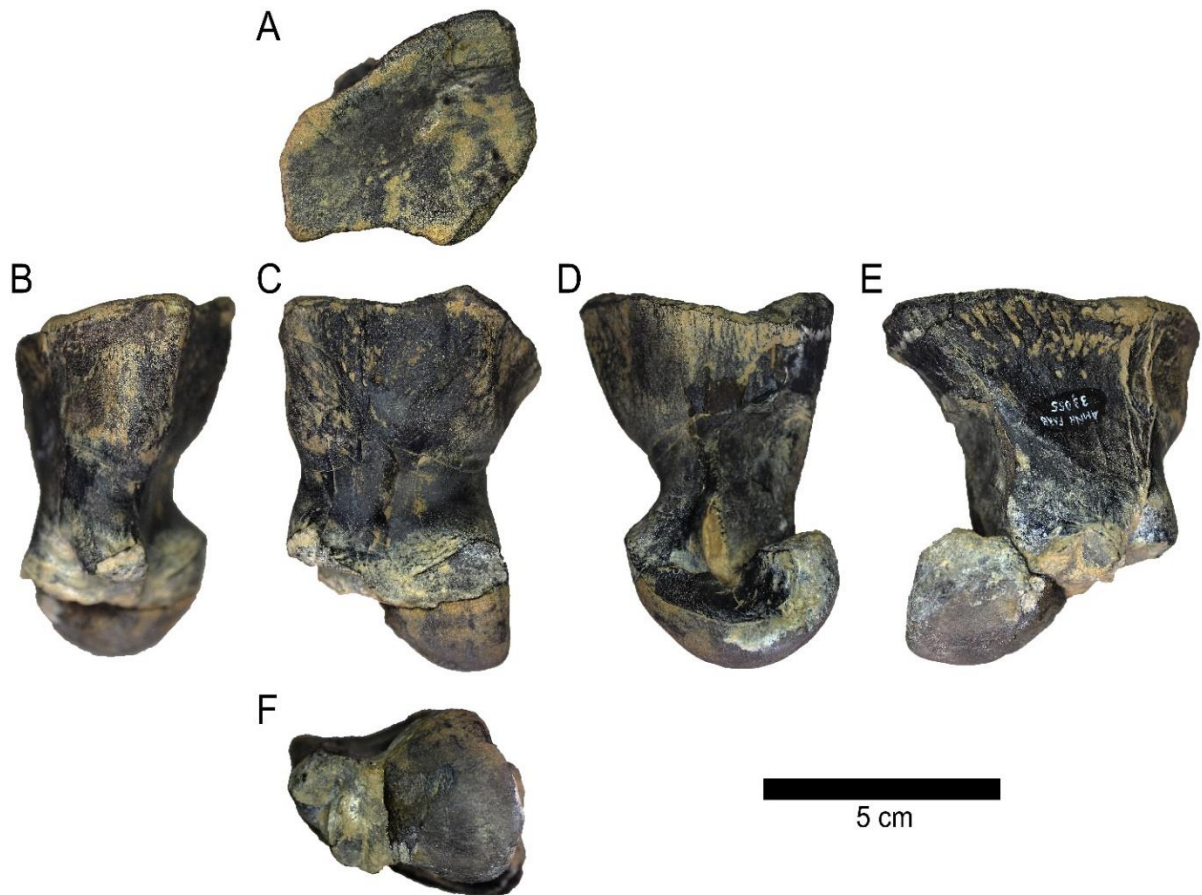


Figure 5.3: *Allosaurus* sp. AMNH FARB 33055 phalanx IV-1 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Phalanx IV-2:

The phalanx (Figure 5.4) measures 6.30 cm in length, and similar thickness and width at the distal and proximal with constriction of the shaft. The proximal articular surface is sub-circular, expanding medially on the plantar face, and dorsoventrally keeled with the medial depression broader than the lateral. The plantar face is slightly concave and smooth at the proximal end, having two rugose tubercles close of the proximal articular surface, one on each side of the phalanx, and separated from the hemicondyles by a horizontal sulcus.

At its mid-length is bean-shaped in cross-section, expanding medially on the plantar face. The distal end of the shaft right before the distal condyle is slightly concave on the plantar face, while on the dorsal face a small sub-circular depression is observed forming two small rounded ridges laterally and medially.

The distal condyle is very asymmetrical, with a pronounced sulcus separating the two hemicondyles, giving the condyle's articular surface an inverted triangular look in dorsal and plantar views. The medial hemicondyle is broad and round, with its plantar edge projecting medially, while the lateral hemicondyle is smaller and its dorsal edge is flat. The medial collateral ligament fossa is sub-circular and deeper than the elliptical lateral collateral ligament fossa.

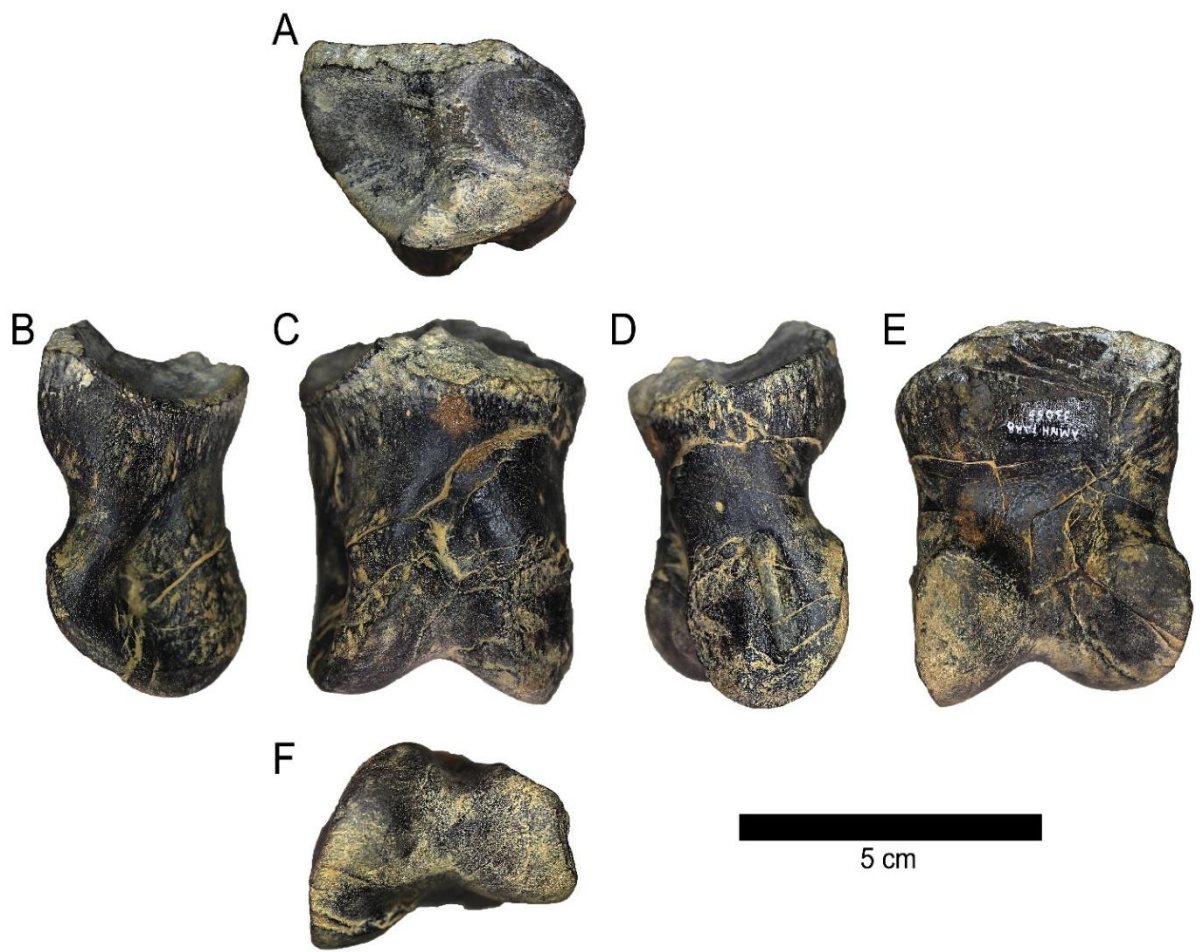


Figure 5.4: *Allosaurus* sp. AMNH FARB 33055 phalanx IV-2 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

5.2.2. AMNH FARB 33058

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Sauropoda Marsh, 1878

Camarasauridae Cope, 1877

Camarasaurus sp. Cope, 1877

Specimen material: Premaxilla with at least three teeth *in situ*, maxilla, and six loose teeth

Quarry: Cosm (North Section)

Layer: CQ-N 3

Associated field numbers: COSM 005, COSM 006, and COSM 073.17N

Material described in this work: Loose premaxillary/maxillary tooth, and a loose dentary tooth

Description:

Loose Pre-max/maxillary tooth:

The tooth (Figure 5.5) measures 9.80 cm in total length, being almost fully preserved, with only the apex of the root missing. The surface of the root is generally smooth, bearing a longitudinal depression on its labial face, and a ridge on the lingual face. In cross-section, the root is elliptical

The crown is 5.40 cm high and 2.70 cm wide, broad spatula shaped, and has wrinkle marks covering the surface. In cross-section is D-shaped at its mid-length. The margins are smooth towards the apex and distal/caudal edge, and a bit wrinkled at the base. The lingual surface of the crown is convex at the apex, with a medial ridge going from it to the base, and bordered by a groove on each side, while the labial surface is concave with a medial bulge bordered by a mesial/rostral groove. At its apex, the crown has a thin occlusal V-shaped wear facet.

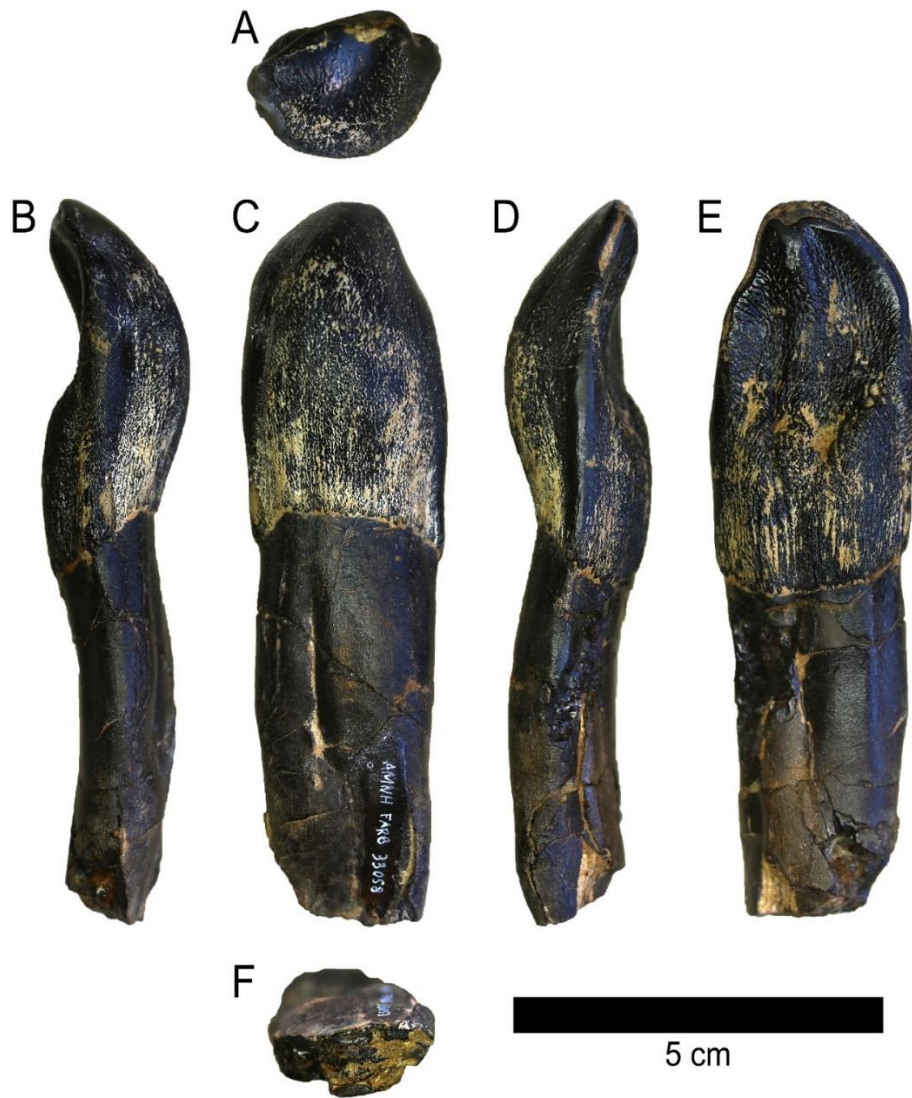


Figure 5.5: *Camarasaurus* sp. AMNH FARB 33058 loose pre-max/maxillary tooth in apical (A), mesial (B), labial (C), distal (D), lingual (E), and basal (F) views.

Loose Dentary tooth:

The tooth (Figure 5.6) measures 7.4. The surface of the root is generally smooth, bearing a longitudinal depression on its labial face, with several fractures along the crown and root, the latter being broken close to its base distal ledge. In cross-section, the root is circular.

The crown is 5.30 cm high and 2.90 cm wide, broad spatula shaped, and has wrinkle marks covering the surface. In cross-section, the crown is D-shaped at its mid-length. The margins are smooth towards the apex and distal/caudal ledge, and a bit wrinkled at the base. The lingual surface of the crown is convex at the apex, with a medial ridge going from it to the base, and bordered by a groove on each side while the labial surface is concave with a medial bulge bordered by a mesial/rostral groove. At its apex, the crown has a broad occlusal V-shaped wear facet, showing the homogenous enamel.

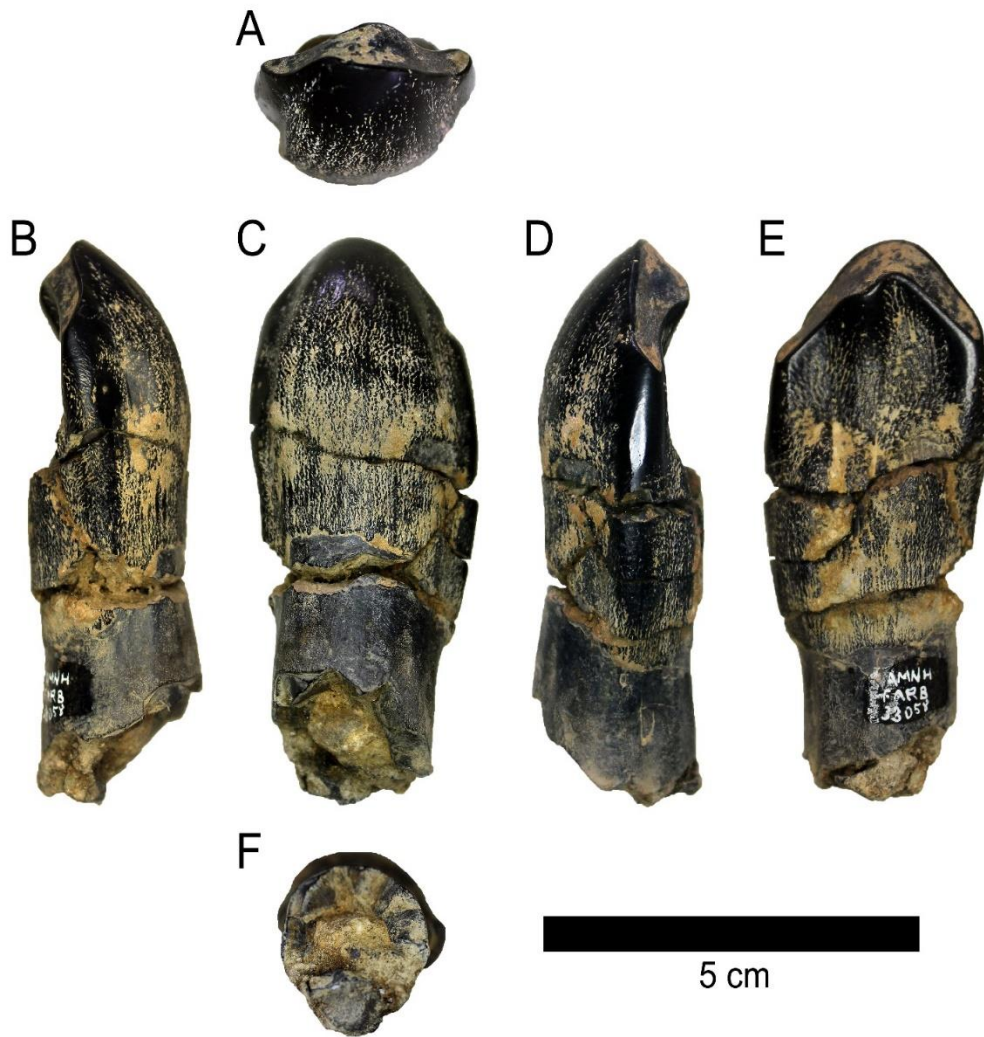


Figure 5.6: *Camarasaurus* sp. AMNH FARB 33058 loose dentary tooth in apical (A), mesial (B), labial (C), distal (D), lingual (E), and basal (F) views.

5.2.3. AMNH FARB 33061

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Premaxilar with 4 teeth in situ, basicranium, possible occipital condyle, loose left maxillary teeth, left humerus, left radius, right metatarsals II, III, and IV, left tarsal, left metatarsals I, II, III, IV, and V, left pedal phalanges I-1, III-1, III-2, III-3, and three unguals.

Quarry: Cosm (South Section)

Layer: CQ-S 5

Associated field numbers: COSM 021, COSM 025, COSM 026, COSM 030, COSM 054

Material described in this work: Maxillary tooth, right metatarsals II, III (condyles) and left pes elements mentioned above.

Description:

Left Metatarsal I (Halux):

The shortest of the five metatarsals, it measures 8.60 cm in length, and is very asymmetrical (Figure 5.7). The shaft is ellipsoid in cross-section, at least two times wider laterally than dorsoventrally, and tapers proximally at the mid-length giving it an inverted V blade-like shape (Hattori, 2016). Two structures are observed in the shaft right above the distal condyle: a concave prominence on the dorsal face, and a plantar tubercle

The distal articular condyle is V-shaped, with a sulcus on the plantar face dividing it into two hemicondyles similar in width. While the lateral hemicondyle is in line with the bone's axis and projects distally, the medial hemicondyle stands more proximally to the shaft on the medial face of the metatarsal, making the condyle articular surface stick out dorsomedially in the foot. The lateral collateral ligament fossa is oval, approximately twice as long as, and deeper than the sub-circular medial collateral ligament fossa. A small tubercle (~0.20 cm) is observed on the distal edge of the medial collateral ligament fossa. Few small pits are observed spread out inconsistently on the plantar and dorsal faces.

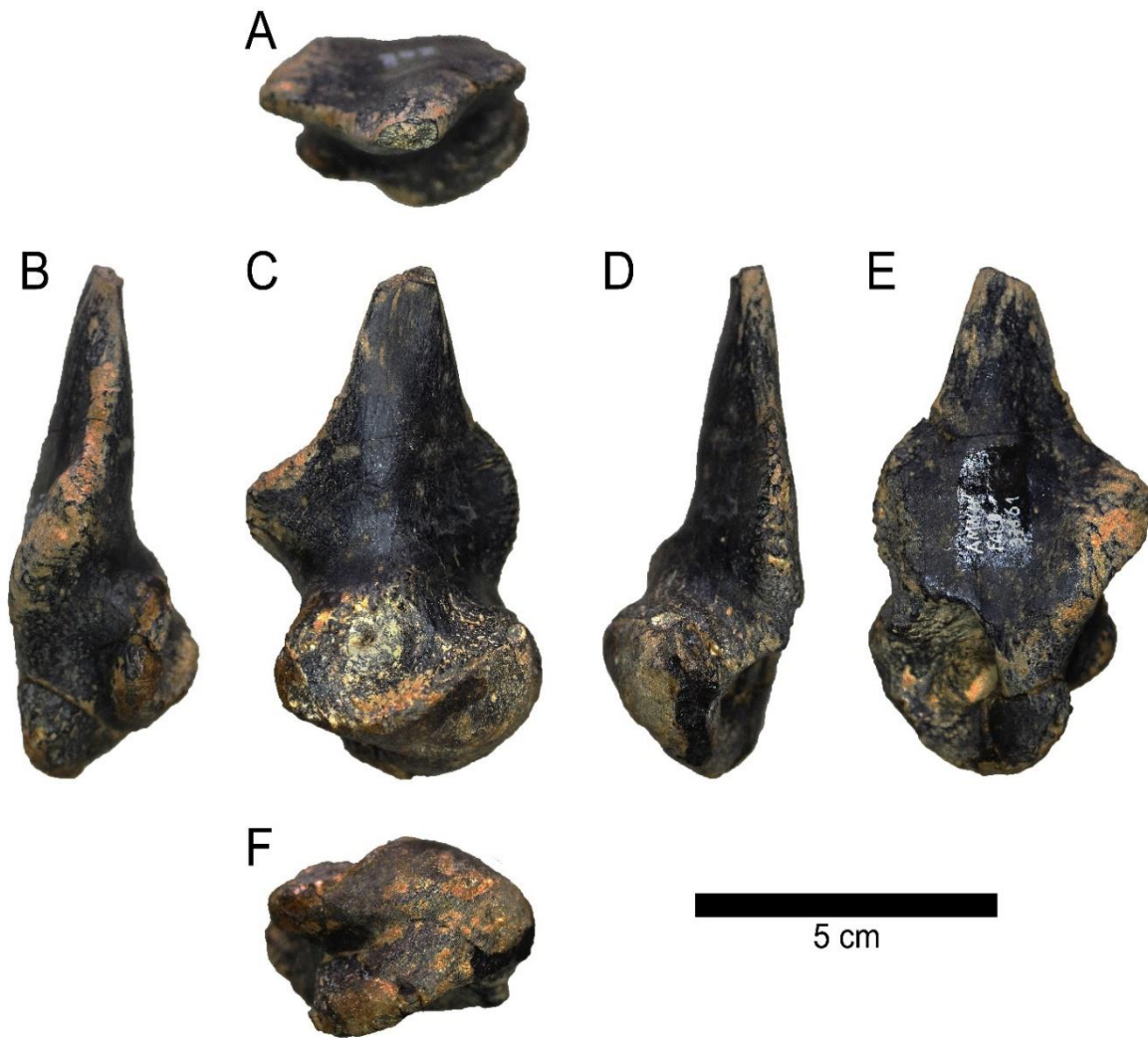


Figure 5.7: *Allosaurus* sp. AMNH FARB 33061 left metatarsal I in proximolateral (A), proximomedial (B), dorsal (C), distolateral (D), plantar (E), and distomedial (F) views.

Left Metatarsals II, III, IV:

The three metatarsals articulated (Figure 5.8), with yellowish-brown sandstone matrix connecting them, although due to taphonomy, metatarsals II and IV are displaced, such that the former projects proximally and the later distally in medial view. Metatarsals II and IV are sub-equal in length and both shorter than metatarsal III.



Figure 5.8: *Allosaurus* sp. AMNH FARB 33061 articulated left metatarsals II, III, and IV in proximal (A: current articulation; B: reconstructed articulation), medial (C), dorsal (D), lateral (E), plantar (F), and distal (G) views.

Metatarsal II is 34.5 cm in length and slightly concave laterally. The shaft is sub-squared. The proximal articular surface is triangular in proximal view, 7 cm wide and 8.5 cm long, with rounded dorsal and lateral edges that expand medially towards the plantar face forming the lateral articular surface that connects to the metatarsal III, and forming a convex structure with the proximal end of the shaft. The proximal thickness of the shaft is approximately $\frac{1}{2}$ of the proximal articular surface thickness, which increases at mid-length, due to the presence of a ridge, maintaining its thickness until the distal portion of the shaft. On the dorsal shaft surface, a tubercle-like structure (3.30cm) can be observed on the edge of the dorsal face at $\frac{1}{4}$ of the total length from the proximal end, as well as an oval-shaped ridge (6x2cm) on the plantar face distally located at the mid-point of the total length of the metatarsal, where the proximal end of MT I would contact.

The distal condyle is u-shaped in distal view, measuring approximately $\frac{1}{4}$ of the total length of the metatarsal, with width and thickness similar to the proximal articular surface. It bears a horizontal depression on the middle of the dorsal face, forming two small ridges, where pits are observed. A longitudinal sulcus on the posterior face expanding proximally divides the condyle in two hemicondyles, with the medial one being approximately $\frac{1}{3}$ smaller than the lateral hemicondyle, and slightly more eroded. The distal articular surface has a round and concave limit on the dorsal face, being convex around the collateral ligament fossae and posterior groove of the condyle. The medial collateral ligament fossa is spear shaped, tapering distally to the articular surface of the condyle, with its length being half of the total length of the condyle. The lateral collateral ligament fossa is not visible due to the matrix being preserved in order to maintain the metatarsals II and III articulated.

Metatarsal III measures 37.70 cm in length, and is generally straight, curving slightly laterally right after the mid-length of the shaft. Slightly sigmoidal-shaped proximal articular surface 13.10 cm long and 5.50 cm wide at the anterior side, gradually thinning towards the plantar face. Right before the proximal end of the shaft, the articular surface flattens on all sides of the shaft, forming a concave surface on the plantar and dorsal faces ($\frac{1}{3}$ of the articular surface thickness on the plantar face, and $\frac{1}{2}$ on the dorsal face).

The dorsal face of shaft starts thin and rounded at the proximal end, becoming broader ($\sim 2x$ larger) and flatter towards the distal end, and bearing a small ridge (~ 3 cm) located at $\frac{1}{4}$ of its total length. The plantar face of shaft starts flat and slightly broad at the proximal end, thinning slightly at the middle and becoming concave towards the distal end. Lateral and medial faces are generally straight

The distal articular condyle has a general rectangular shape, with the medial plantar edge being bulkier than the lateral edge, and the lateral plantar edge making a slightly thinner and more noticeable projection than its medial counterpart. Its width is $\sim \frac{1}{5}$ of the total length of the metatarsal, and thickness close to $\frac{1}{6}$. A horizontal depression close to the middle of the dorsal face of the distal condyle forms two small ridges, where pits are observed, with a ridge (3x2 cm) above and around its right side, reaching the edge of the condyle. Two large collateral ligament fossae are observed in the middle of the condyle lateral and medial faces, both having a shape similar to a tear, tapering distally to the articular surface of the condyle. The surface of the bone around these fossae is gently tipping to the center of the condyle, while the edges of the condyle articular surface are convex laterally, and triangular pointing upwards on the dorsal face, and pointing downwards on the plantar face.

Metatarsal IV as a length of 33.80 cm, with its shaft visibly curving laterally. Comma shaped proximal articular surface 9.50 cm long, broader on the dorsal face (5 cm wide) and gradually thinning towards the plantar face, reaching less of a $\frac{1}{5}$ of the anterior width---NOTE: proportion similar to the observed for metatarsal III. The proximal end of the metatarsal is generally flat, with the plantar face and the medial articular surface that articulates with metatarsal III being both twice as broader as the dorsal face

The dorsal face of the shaft is rounded for $\sim 2/3$ of its length, before thinning and forming a ridge at the distalmost portion of the shaft. The plantar face of the shaft is generally flat, with the most distal $1/5$ portion becoming rounder right above the distal condyle. A ridge is observed starting on the lateral plantar edge of the proximal end of the metatarsal and continuing along the lateral margin for $\sim 2/3$ of the metatarsal's total length. At $1/3$ of the total length of the bone the ridge starts to broaden to 2x its original width (at the broadest point), forming two smaller ridges separated by an almost unnoticeable depression, reconnecting right before the distal end of the shaft. Another ridge is observed on the medial plantar edge of the proximal end of the metatarsal with $\sim 1/2$ of the length of the distal end, being as broad as the ridge on the outside of the bone in its widest point, but with a rougher surface that abruptly ends.

The plantar face bears a sigmoid-shaped ridge that starts proximally at $1/4$ of the shaft length along the margin with the medial face, curving towards the center of the plantar face until it reaches the base of the distal condyle. Small, round, and rugose tubercle distally at $\sim 1/6$ of the shaft length observed on the plantar face.

The distal articular condyle is triangular with a longitudinal sulcus on the plantar face that divides it in two hemicondyles making the width of the condyle slightly less than $1/2$ of the proximal articular facet width. The medial hemicondyle expands distally, while the lateral hemicondyle expands laterally. The plantar face of the condyle tilts laterally with a horizontal depression and pits on its middle point, forming a ridge on the contact with the medial face, with the width being $\sim 1/2$ of the width of the condyle plantar face. No distinct collateral ligament fossae are observable with only a small depression on the lateral face (the medial face is not completely visible). Distal articular face poorly preserved, convex on the outer face of the condyle, concave on the dorsal face, and covering at least half of the surface of the two hemicondyles.

Left Metatarsal V:

This metatarsal (Figure 5.9) is 16.50 cm long, tapers distally; forming a curved and blunt distal end, and presents several fractures.

The proximal face is convex while the plantar face is convex proximally down to the mid-length of the shaft where it becomes concave down to the distal end, with a small nob being formed at its mid-length. At the proximal end, its margin is triangular, with the tip pointing upwards, and the dorsal edge slightly longer than the plantar.

Generally flat lateral face, with the edges of the distal end becoming more rounded. The medial face looks the same as the lateral side on the distal half of the metatarsal, with the proximal bearing a vertical ridge at its mid-thickness and forming two surfaces, one facing the dorsally and the other facing laterally while being in contact with the lateral face of the distal end of metatarsal IV

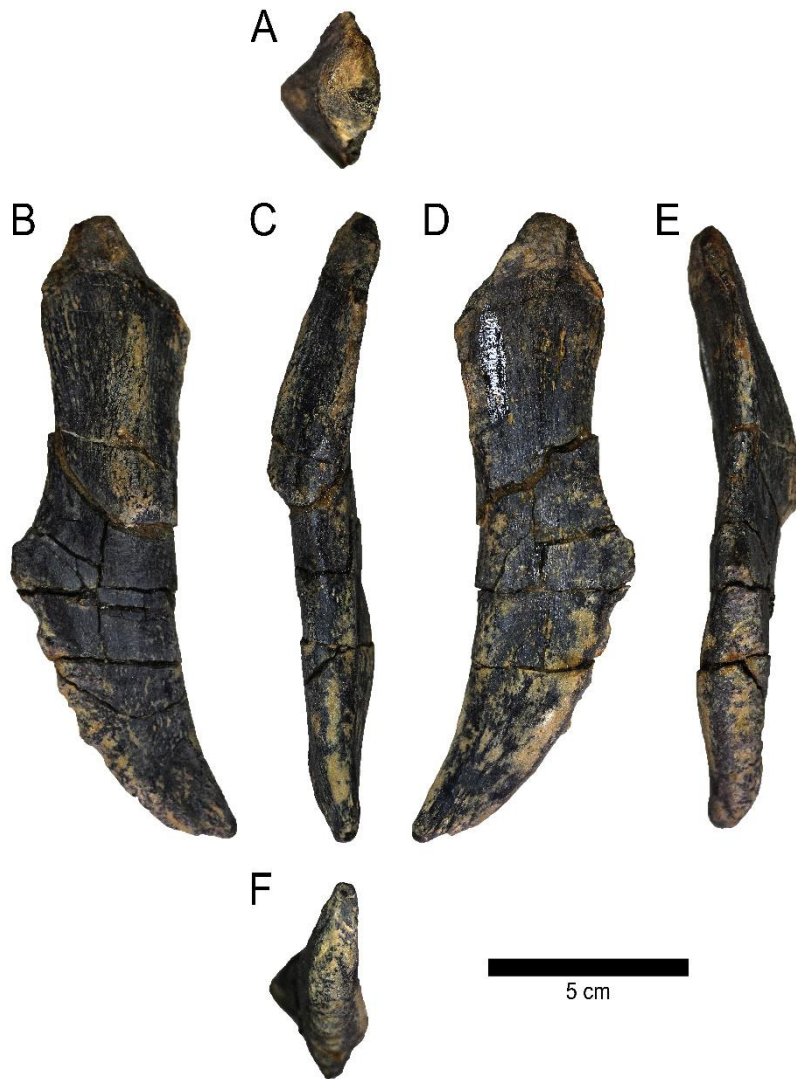


Figure 5.9: *Allosaurus* sp. AMNH FARB 33061 left metatarsal V in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Phalanx I-1 (halucal):

The phalanx is 7.10 cm in length (close to correspondent metatarsal's length), with the shaft having a pinched look (Figure 5.10). The proximal articular surface is sub-circular, with the medial ledge almost straight, making it D-shaped when observed in proximal view, and is slightly tilting dorsally.

The distal condyle is divided in two hemicondyles, with the lateral hemicondyle being larger than the medial, and slightly projecting posteriorly. Both collateral ligament fossae are sub-circular, but the lateral one is deeper than the medial.

A proximal tubercle-like prominence is observed on the lateral face and expanding into the plantar face, contacting distally with an almost unnoticeable ridge, and a single pit is observed on the medial face, close to the proximal articular face.

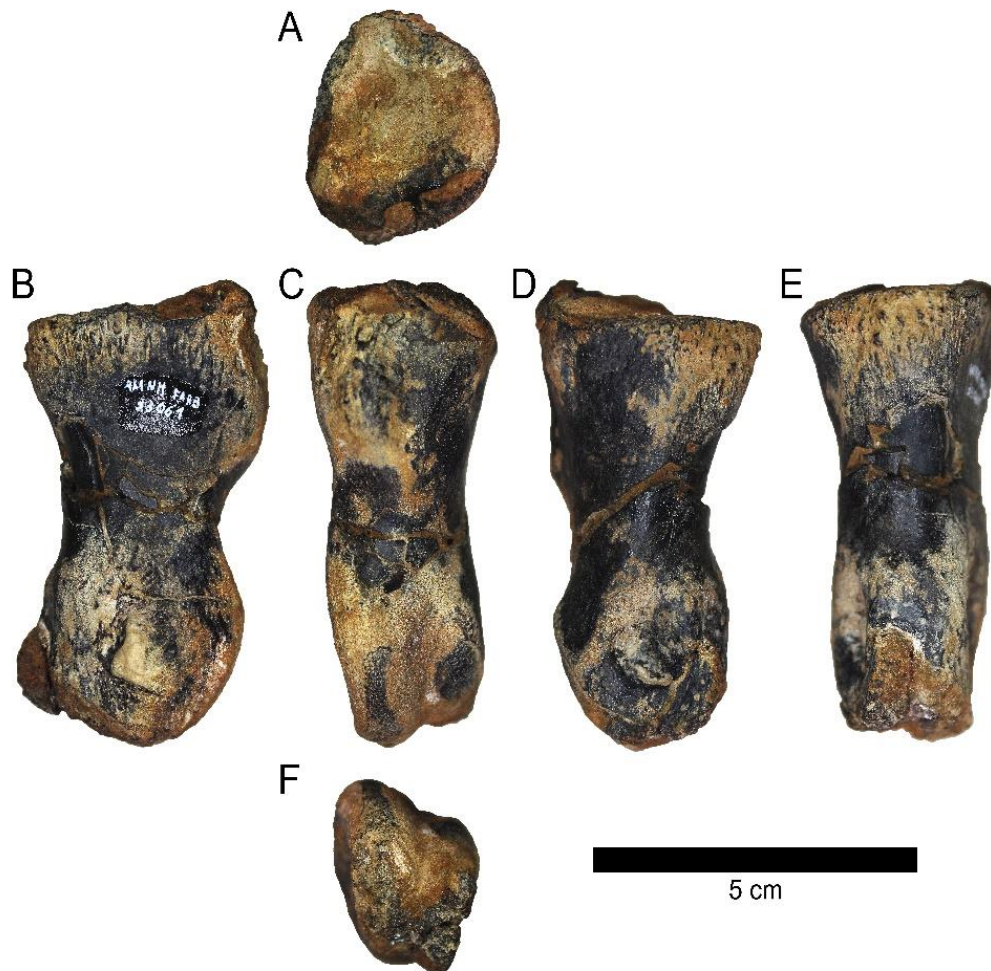


Figure 5.10: *Allosaurus* sp. AMNH FARB 33061 left phalanx I-1 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Phalanx III-1:

The phalanx (Figure 5.11) is 13.46 cm in length, with a sub-circular and convex proximal articular surface. The proximal end of plantar face is slightly concave and rugose, while the medial and lateral faces both have a small depression proximal to the proximal articular surface close to the margin of the plantar face.

At its mid-length, the shaft is sub-circular in cross-section, with the lateral face pinched, and its width and thickness are half of the proximal articular surface dimensions. The shaft has a bean-like depression on the dorsal face proximately to the distal condyle articular surface, forming ridges laterally and medially, with the medial ridge having a small and round rugose surface proximally to the mid length of the shaft. The distal end of the shaft, right before the distal condyle of the plantar face, is slightly concave and rugose.

The distal condyle is sub-rectangular in cross-section, as wide as the proximal articular surface, and has a convex articular surface forming two hemicondyles. The collateral ligament fossae are tear-shaped

tapering distally to the articular surface of the condyle, the medial being broader and deeper than the lateral. The dorsal and distal margins of the medial hemicondyle are very rugose and expand medially.

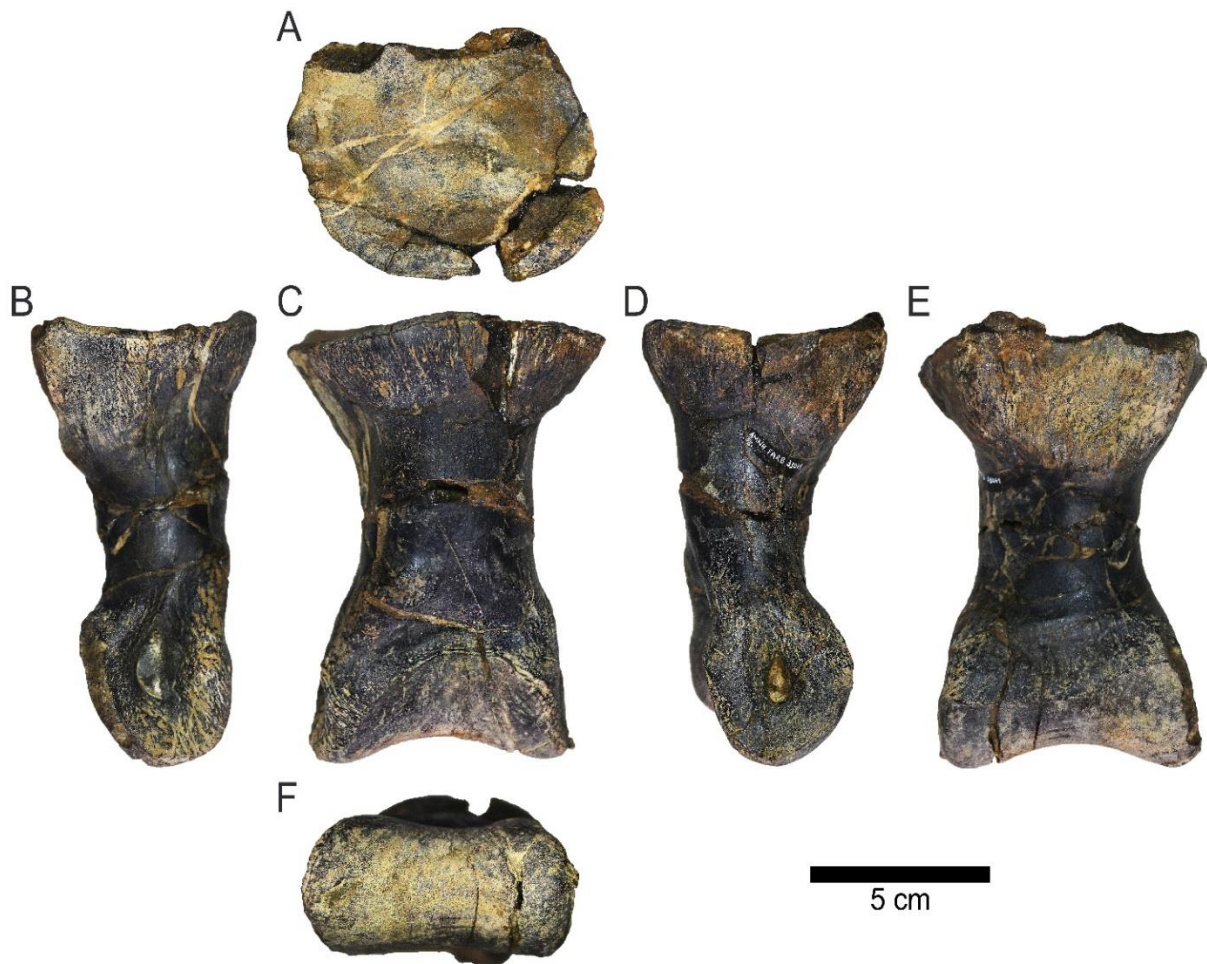


Figure 5.11: *Allosaurus* sp. AMNH FARB 33061 left phalanx III-1 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Phalanx III-2:

The phalanx (Figure 5.12) is 10 cm in length, with a bean-shaped proximal articular surface (dorsally concave margin and convex plantar margin), concave mediolaterally, and convex dorsoventrally. The proximal end projects lateroventrally, and has a slightly concave and very rugose plantar face.

The lateral face has a small depression proximal to the proximal articular surface close to the margin of the plantar face, where a circular rugose tubercle is observed close to its margin, and separated by a small sulcus from an elliptical rugose tubercle that extends to the lateral face.

At its mid-length, the shaft has a close to oval shape in cross-section, with the lateral face pinched, with its width a third smaller than the width of the proximal articular surface and half of the thickness. It has an elliptical depression on the dorsal face, proximately to the distal condyle articular

surface, forming ridges laterally and medially. The distal end of the shaft, right before the distal condyle of plantar face, is slightly concave and smooth

The distal condyle is sub-rectangular in cross-section, approximately as wide as the proximal articular surface, and has a convex articular surface forming two hemicondyles. The lateral hemicondyle is broader the medial and expands ventrolaterally. The collateral ligament fossae are oval-shaped, the medial being broader and slightly deeper than the lateral



Figure 5.12: *Allosaurus* sp. AMNH FARB 33061 left phalanx III-2 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Phalanx III-3:

The phalanx (Figure 5.13) is 7 cm in length, with a bean-shaped proximal articular surface (dorsally concave margin and convex plantar margin), concave mediolaterally, and slightly dorsoventrally keeled. The proximal end slightly projects laterodistally, and has a slightly concave and very rugose plantar face. At its mid-length, the shaft is D-shaped in cross-section, with its width and thickness approximately a third smaller than the proximal articular surface dimensions.

The lateral and medial faces have a small depression each on the margin with the dorsal face, proximal to the proximal articular surface close to the margin of the plantar face. A circular rugose tubercle is observed on the plantar face close to the margin of the proximal articular surface separated

by a small sulcus from an elliptical rugose tubercle that extends to the lateral face. The dorsal and plantar faces, proximally to the distal condyle articular surface, are both smooth and slightly concave.

The distal condyle is sub-rectangular in cross-section, with approximately a quarter of the proximal articular surface's width, and has a convex articular surface forming two hemicondyles. Both hemicondyles are similar in size, but the plantar face of the lateral hemicondyle and expands laterodistally. The collateral ligament fossae are elliptical, the medial being broader and slightly deeper than the lateral.



Figure 5.13: *Allosaurus* sp. AMNH FARB 33061 left phalanx III-3 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Ungual Phalanges:

Unguals III and IV are complete (Figures 5.15 and 5.16 respectively), while the unguale I is broken at two thirds of its length proximally to the apex (Figure 5.14). The U-III is the biggest being 8.40 cm in length, followed by U-IV with 7.80 cm, and the shortest being U-I with 6.10.

The three phalanges are curved and tapering distally towards the apex, and D-shaped in cross-section at their mid-length. The articular surface is convex, keeled, and the shape is elliptical on U-I and

sub-circular on U-III and U-IV. All have single lateral and medial grooves along the length of the ungual process with the same curvature as the claw.

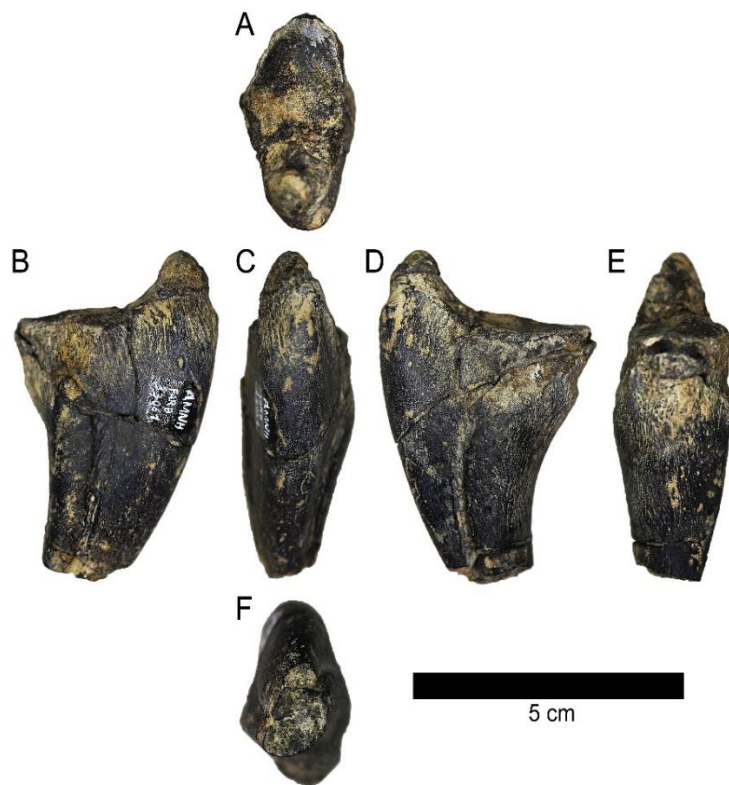


Figure 5.14: *Allosaurus* sp. AMNH FARB 33061 left ungual phalanx I in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

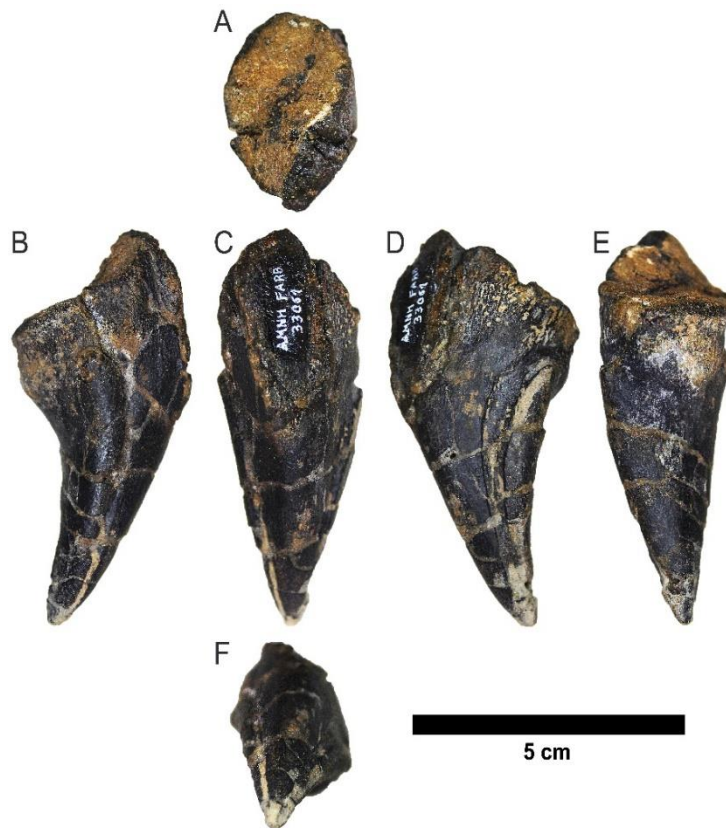


Figure 5.15: *Allosaurus* sp. AMNH FARB 33061 left unguis phalanx III in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

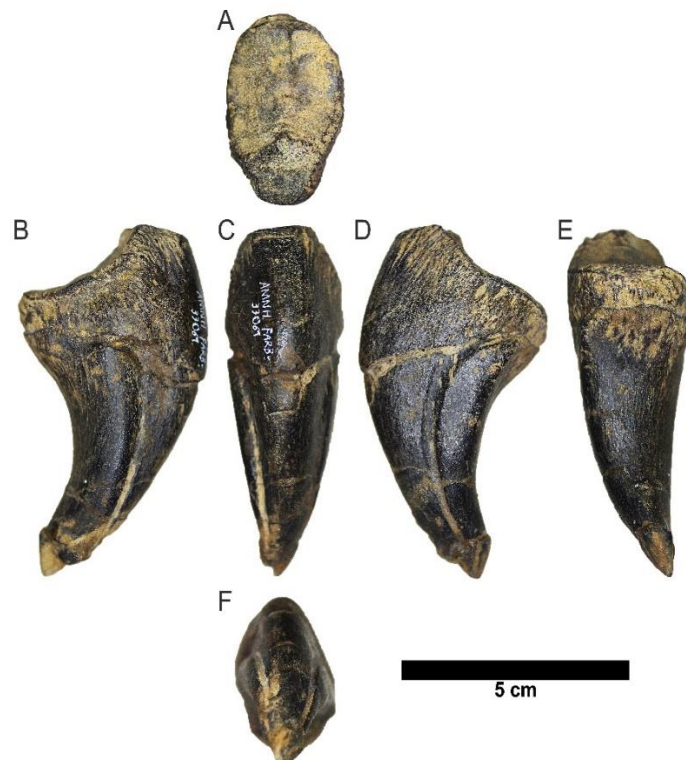


Figure 5.16: *Allosaurus* sp. AMNH FARB 33061 left unguis phalanx IV in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Right Metatarsal II Condyle:

Only the distalmost portion of metatarsal is preserved (Figure 5.17), being broken at the base of the condyle, as well as being heavily fractured. It measures 7.80 cm in length from the distal articular face to the break surface, where the bone is sub-circular in cross-section, while the distal articular condyle looks U-shaped in distal view. On the dorsal face, the distal articular surface limit is rounded and concave.

An horizontal depression on the middle of the dorsal face of the distal condyle forms two small ridges, while a longitudinal sulcus on the plantar face expanding distally to the articular surface, and dividing the condyle in two partially preserved hemicondyles. The medial collateral ligament fossa is oval-shaped and very eroded, while the lateral collateral ligament fossa is no preserved.

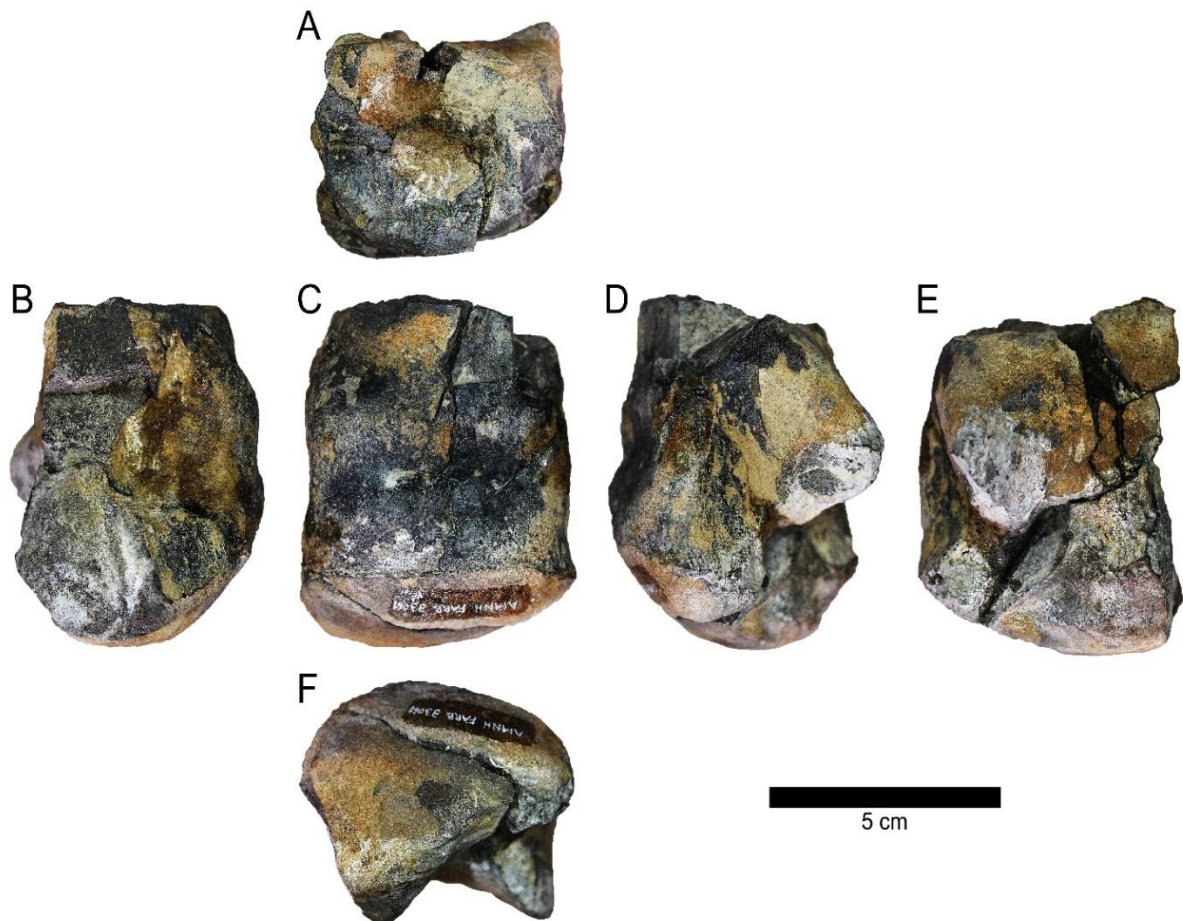


Figure 5.17: *Allosaurus* sp. AMNH FARB 33061 right metatarsal II condyle in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Right Metatarsal III Condyle:

Only the distalmost portion of metatarsal is preserved (Figure 5.18), being broken at the base of the condyle, as well as bear a deep transversal fracture. It measures 8.10 cm in length from the distal articular face to the break surface, while the distal

articular condyle is sub-rectangular in distal view, with two large hemicondyles, concave on the plantar face, and tilting laterally on the dorsal face.

The medial hemicondyle expands dorsomedially and is the larger of the two, while the lateral hemicondyle is not fully preserved due to the abovementioned fracture. Two large collateral ligament fossae are observed in the middle of the condyle lateral and medial faces, both having a shape similar to a tear, tapering distally to the articular surface of the condyle. The condyle articular surface is very eroded, triangular pointing upwards on the dorsal face and concave on the plantar, lateral, and medial faces.

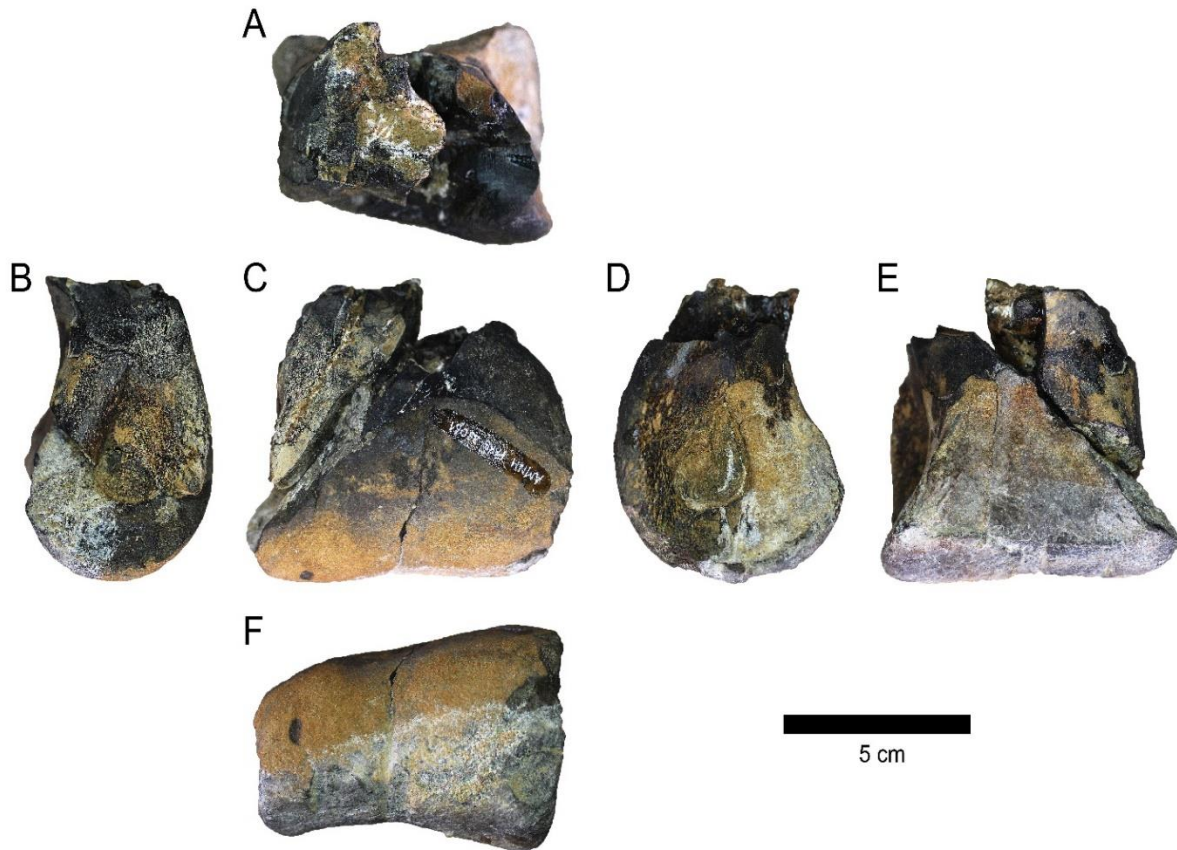


Figure 5.18: *Allosaurus* sp. AMNH FARB 33061 right metatarsal III condyle in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Maxillary Tooth (loose)

Elongated medium sized zipodont tooth (CH of 43 mm) with complete crown and root (Figure 5.19). The crown is compressed labiolingually, with mesial and distal margins distally curved, both presenting serrated carinae, and broader mesiodistally (CBL of 22 mm) than labiolingually (CBW of 10 mm). In cross-section the tooth it is lanceolate at the base (CBR of 0.45), becoming more lenticular towards the apex. The distal carina is medially positioned and slightly curved lingually with the crown, bearing denticles along the preserved margin (from the base to the apex of the crown). The mesial carina is medially positioned at the apex, curving gently towards the lingual face the closer it gets to the crown base, with smaller denticles than the distal ones that only appear approximately 6.5 mm from the base,

due to the crown having a shallow break surface. A transverse undulation is present above the cingulum and several others from the mid length of the crown towards the apex, becoming more frequent apically. Marginal undulations are also present along the distal carina close to the base of the crown.



Figure 5.19: *Allosaurus* sp. AMNH FARB 33061 left maxillary tooth in apical (A), labial (B), mesial (C), lingual (D), ldistal (E), and basal (F) views.

The root curves distally and lingually towards the root apex, contrasting in color with the crown (the previous being black, and the later brown), and eight-shaped in cross-section at its mid-length. Both lingual and labial faces have a longitudinal depression ranging from the cervix to the mid-length of the root. However, the lingual face of the root is mostly concave towards the apex of the root due to the

presence of a large resorption pit making up for two thirds of the total length of the root. This pit is broad at the apex of the root and tapers towards the base, its margin becoming triangular.

The mesial carina bears 13 denticles per 5 mm at the apex and 17 at the mid-crown, with no denticles at the base. The distal carina bears around 13 denticles per 5 mm at the apex, 14 at the mid-crown, and 23 at the base. The distal denticles appear to be more elongated than the mesial ones, both becoming minute the closer they are to the base of the crown, but the distal becoming larger towards the mid-crown, and the mesial towards the apical region of the crown. In general, the denticles are symmetrical labiolingually and basoapically, in lateral view at the external margin are subquadrangular to round, becoming basoapically thinner at their center where an interdenticular space is formed. The enamel layer is distinguishable on the larger distal denticles as a darker band on the external margin. The central distal denticles bear relatively well-defined cauda that pend towards the base, giving them a slightly curved look, while the apical and basal (closest to the cervix) denticles have a more squared look. The mesial denticles have in general a squared look. The interdenticular space is generally elliptical between the denticles of the distal carina (more noticeable between the bigger ones), rounded on the bigger denticles of the mesial carina, and straight on the smaller mesial denticles and on the distal denticles close to the cervix.

The crown's surface appears to be generally smooth, bearing several thin longitudinal fissures and transverse cracks observed through the surface of the tooth. The enamel has a braided structure throughout the crown. The root bears several cracks, most of which are located at its apex.

5.2.4. AMNH FARB 33062

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: At least eight vertebrae (two caudal, four articulated, and two smaller ones), an isolated chevron, left metatarsal IV, and left pedal phalanx IV-1

Quarry: Cosm (North Section)

Layer: CQ-N 4

Associated field numbers: COSM 023 and COSM 032

Material described in this work: The pes material above mentioned

Description:

Left Metatarsal IV:

The metatarsal (Figure 5.20) is approximately 33.60 cm in length, with the shaft slightly curving laterally, and several fractures filled by a yellowish brown matrix, sometimes very thin roots, and gypsum. The proximal articular surface is partially preserved (~6.40 cm, but incomplete), bean-shaped, broader on the dorsal face (4.80 cm), and gradually thinning towards the plantar face. The proximal end of the metatarsal is convex on the medial, and concave on the dorsal face where a ridge marks the contact with the lateral face. In cross-section the shaft at its mid-length, appears to be D-shaped, becoming slightly more oval towards the distal condyle.

On the plantar face, at three quarters of the length of the shaft from its proximal end, an elliptical structure is observed, formed by two small ridges separated by an almost unnoticeable depression, connecting both proximally and distally. A ridge is also present on the plantar face of the metatarsal beginning proximally at one third of the shaft length, from its distal end, curving laterally on the center of the plantar face, and reaching the beginning of the distal condyle. The plantar face bears a small, round, and rugose tubercle distally at ~1/6 of the shaft length.

The distal articular condyle is triangular with a longitudinal sulcus on the plantar face that divides it in two hemicondyles making the width of the condyle approximately the same as the proximal articular facet width. The medial hemicondyle expands distally, while the lateral hemicondyle expands laterally. The dorsal face of the condyle tilts laterally with round depression and pit on its middle point, forming a ridge on the contact with the medial face, with the width being ~1/2 of the width of the condyle plantar face. No distinct collateral ligament fossa is observable on the lateral face, with only a small depression being present, while the medial collateral ligament fossa is elliptical and situated at the middle of the

medial face. Distal articular face eroded, convex on the plantar, lateral, and medial faces of the condyle, and concave on the dorsal face.



Figure 5.20: *Allosaurus* sp. AMNH FARB 33062 left metatarsal IV in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

Left Phalanx IV-1:

The phalanx (Figure 5.21) is 7.70 cm in length, with a concave U-shaped proximal articular surface. The proximal end of plantar face is slightly convex and rugose, while the medial and lateral

face both have a depression proximal to the proximal articular surface close to the margin of the plantar face.

At its mid-length, the shaft is sub-triangular in cross-section, with the lateral face pinched, and its width and thickness are approximately a quarter of the proximal articular surface dimensions. The shaft has a sub-circular depression on the dorsal face proximately to the distal condyle articular surface, forming two tubercles on the lateral and medial contact with the condyles articular surface. The distal end of the shaft right before the distal condyle of plantar face is concave and smooth.

The distal condyle is triangular in cross-section, approximately as wide as the proximal articular surface, and has a convex articular surface forming two hemicondyles, the medial hemicondyle being bigger and expanding distally. The medial collateral ligament fossa is elliptical and deep, while the lateral looks more oval and superficial.

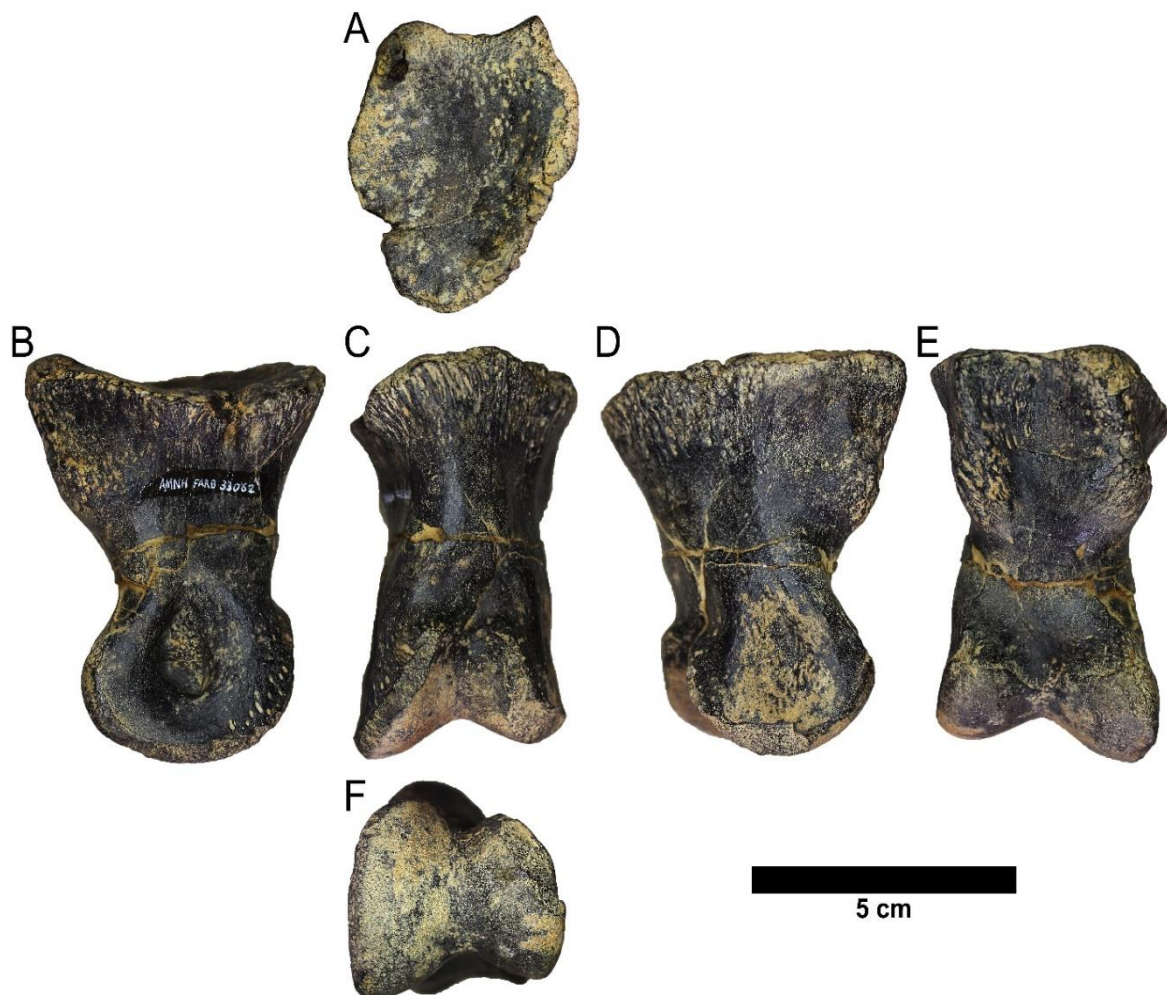


Figure 5.21: *Allosaurus* sp. AMNH FARB 33062 left phalanx IV-1 in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

5.2.5. AMNH FARB 33072

Systematic paleontology:

Dinosauria Owen, 1842

Ornithischia Seeley, 1888

Ornithopoda *indet.* Marsh, 1881

Specimen material: Isolated pedal phalanx

Quarry: Cosm (South Section)

Layer: CQ-S 5

Associated field numbers: COSM 038

Material described in this work: Mentioned above

Description:

The phalanx (Figure 5.22) is 2.80 cm in length, fractured on the medial hemicondyle, missing the dorsal face of the proximal articular surface, and with constant thickness and width. The proximal articular surface is sub-circular expanding medially on the plantar face, and dorsoventrally keeled with the medial depression broader than the lateral. The proximal end of the plantar face is flat and rugose, while the dorsal face is pinched, forming a ridge slightly positioned to the medial side.

The distal end of the phalanx right before the distal condyle of the plantar face has a small depression. The distal condyle is divided by a vertical depression on the plantar face, forming two hemicondyles that make approximately half of the phalanx's length, each having a shallow collateral ligament fossa.

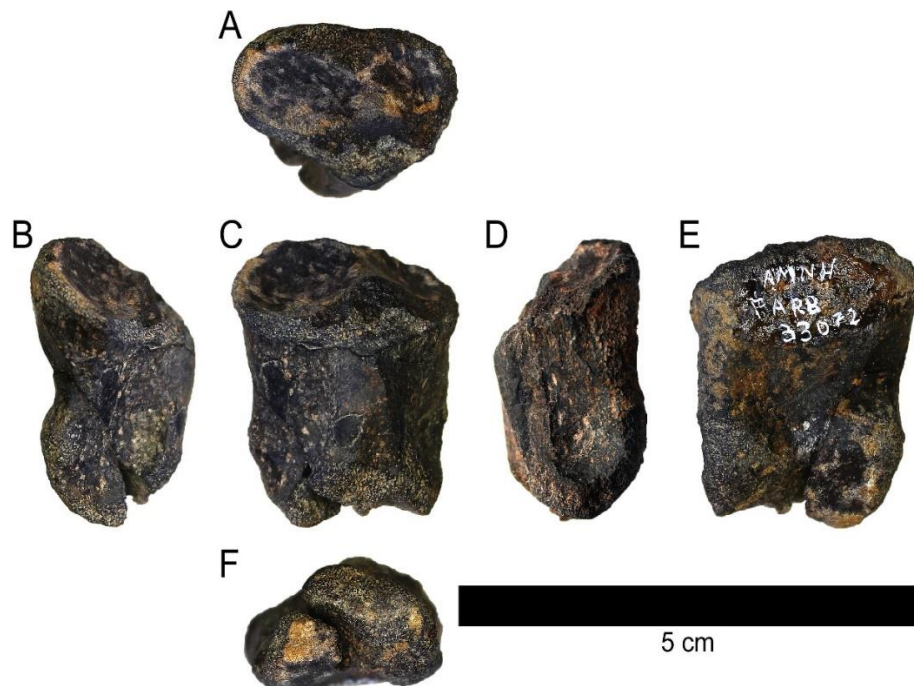


Figure 5.22: Unidentified ornithopod AMNH FARB 33072 isolated pedal phalanx in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views

5.2.6. AMNH FARB 33077

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Isolated tooth

Quarry: Cosm (South Section)

Layer: CQ-S 5

Associated field numbers: COSM 053

Material described in this work: Mentioned above

Description:

Elongated small sized ziphodont tooth (CH of 15 mm) tooth, with the crown cracked and slightly displaced at the base, and without its root preserved (Figure 5.23). The crown is compressed labiolingually, with distally curved mesial and distal margins, both presenting serrated carinae, broader mesiodistally (CBL of 5.5 mm) than labiolingually (CBW of 5 mm). In cross-section, the tooth is lanceolate (CBR of 1.1). The distal carina is medially positioned and slightly curved lingually with the crown, bearing denticles along the preserved margin (from the apex to the displaced crown fragment). The mesial carina has a medial position at the apex, curving gently towards the lingual face the closer it gets to the crown base, and still preserved on the displaced fragment. The surface of the crown appears to be generally smooth, bearing several thin longitudinal fissures and two transverse cracks. The enamel has a braided structure throughout the crown.

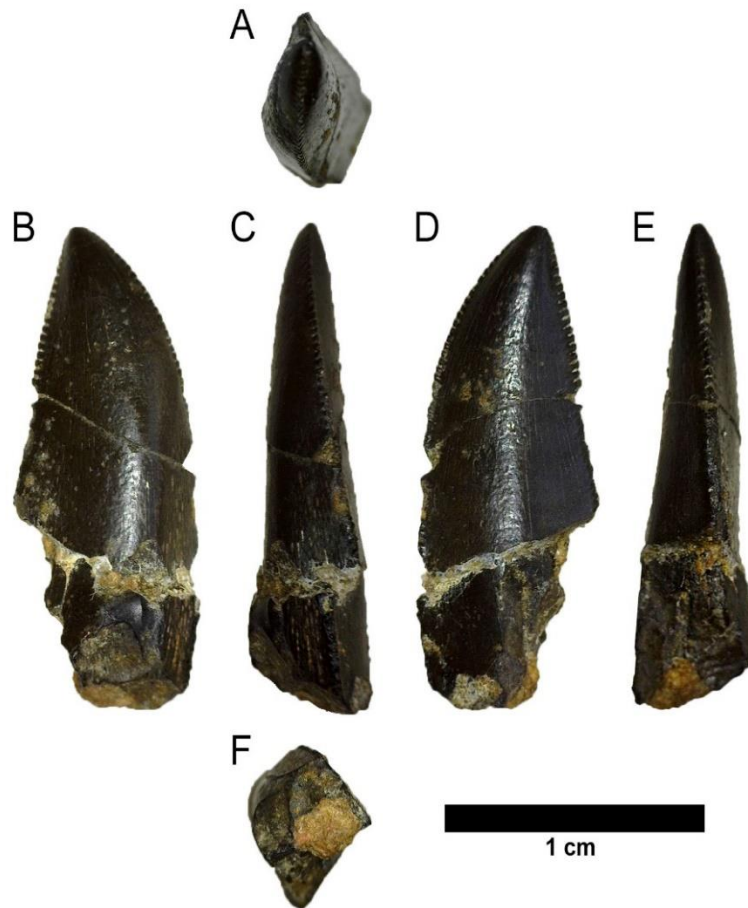


Figure 5.23: *Allosaurus* sp. AMNH FARB 33077 isolated tooth in apical (A), labial (B), mesial (C), lingual (D), distal (E), and basal (F) views.

The mesial carina bears 17 denticles per 5 mm at the apex and seven preserved central denticles. The distal carina bears around 18 denticles per 5 mm at the apex, and 13 central denticles. No basal denticles are preserved in the crown. The distal denticles are slightly more elongated than the mesial ones, both becoming minute the closer they are to the apex of the crown. In general, the denticles are symmetrical labiolingually and apicobasally, in lateral view at the external margin are subquadrangular to round, the distal denticles center becoming more basoapically thinner than the mesial ones, where a small interdenticular space is formed. The enamel layer is not distinguishable on the external margin of the denticles. In general, the denticles have a squared look on both carinae. The interdenticular space is generally elliptical between the denticles of the distal carina (more noticeable between the bigger ones), and rounded on the denticles of the mesial carina

5.2.7. AMNH FARB 33078

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Isolated tooth

Quarry: Cosm (North Section)

Layer: CQ-N 4

Associated field numbers: COSM 055

Material described in this work: Mentioned above

Description:

Slightly pachydont small sized tooth (CH of 4.5 mm) missing most of the apical portion of the crown, with parts of the carina eroded, and broken below the cervix preserving the most basal end of the root (Figure 5.24). Crown with a slightly straight lingual face bearing a ridge along its mid-point and a more concave face expanding labially, mesial and distal margins curving towards the center of the tooth, with serrated carinae, and broader mesiodistally (CBL approximately of 4.5 mm) than labiolingually (CBW approximately of 4.1 mm). In cross-section the crown is asymmetrically D-shaped at the base (CBR of 9.1), and at the apical breaking surface. The distal carina is medially positioned, slightly curving lingually with the crown, bearing denticles along the preserved margin (from the base of the crown, up to the distal break surface). The mesial carina faces towards the lingual face of the crown, curving just like the distal carina, with denticles only appearing approximately 1 mm from the base of the crown. The surface is smooth with thin longitudinal fissures, and, apart from its irregular texture, the enamel bears no distinctive structure observable throughout the crown.

The root is broken close to the base, contrasting in color with the crown (the previous being black, and the later brown), and asymmetrically D-shaped in cross-section at the basal breaking surface

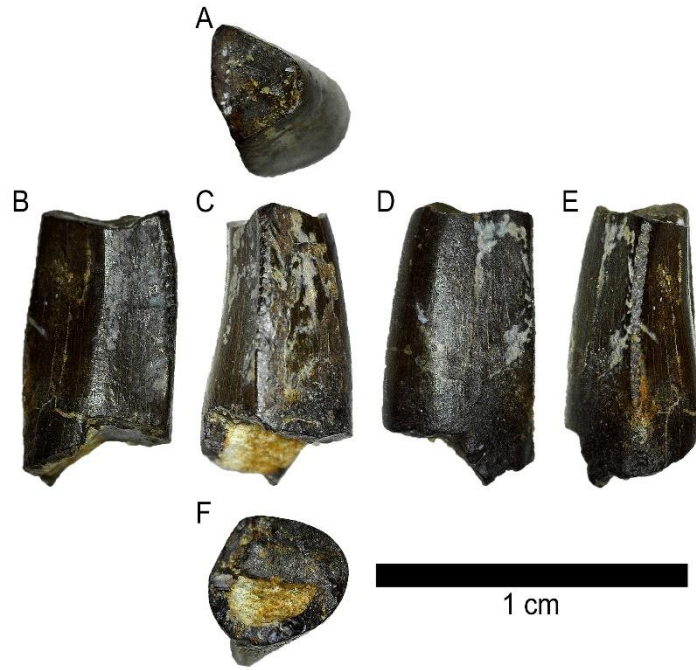


Figure 5.24: *Allosaurus* sp. AMNH FARB 33078 isolated tooth in apical (A), lingual (B), mesial (C), labial (D), lmesial (E), and basal (F) views.

The mesial carina bears six central denticles per 2 mm at, and no denticles at the base. The distal carina bears six denticles per 2 mm at the center of the crown, and 8 basal denticles. No apical denticles preserved in the crown. Both mesial and distal denticles are rounded at the base, poorly preserved, and without observable external margin or interdenticular space.

5.2.8. AMNH FARB 33079

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Isolated phalanx condyle

Quarry: Cosm (North Section)

Layer: CQ-N 4

Associated field numbers: COSM 056

Material described in this work: Mentioned above

Description:

The preserve portion of the phalanx (Figure 5.25) is 3.60 cm in length, broken at the distal end of the shaft, elliptical at the distal end of the shaft in cross-section, and with the dorsal face bearing more wear than the plantar face.

The distal end of the shaft, right before the distal condyle of plantar face, is slightly concave and smooth, while on the dorsal face a small rounded depression is observed. The distal condyle is sub-rectangular in cross-section, slightly wider than the preserved end of the shaft, and has a convex articular surface forming two hemicondyles, very similar in shape. The collateral ligament fossae are sub-circular with similar dimensions.

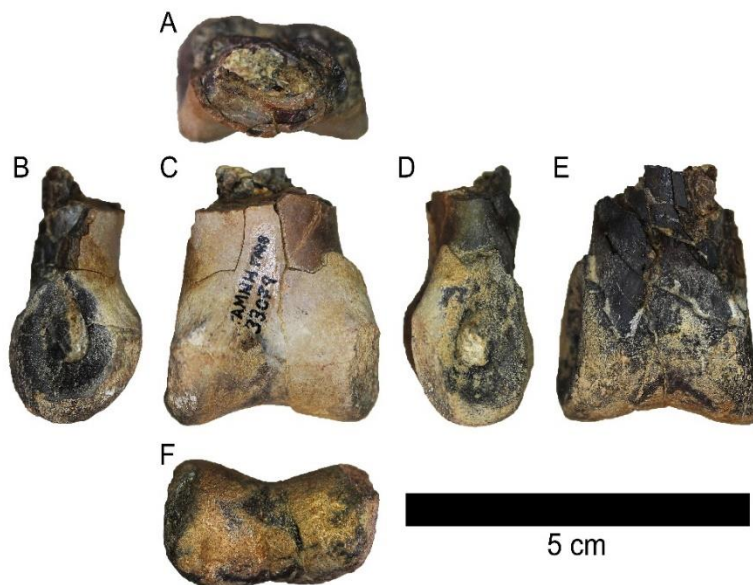


Figure 5.25: *Allosaurus* sp. AMNH FARB 33079 isolated phalanx condyle in proximal (A), medial (B), dorsal (C), lateral (D), plantar (E), and distal (F) views.

5.2.9. AMNH FARB 33081

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Isolated tooth

Quarry: Cosm (South Section)

Layer: CQ-S 5

Associated field numbers: COSM 058

Material described in this work: Mentioned above

Description:

Short and small ziphodont tooth (CH of 11 mm) missing the crown apex and parts of the carina, and broken below the cervix preserving the most basal end of the root (Figure 5.26). The crown is compressed labiolingually, with distally curved mesial and distal margins, serrated carinae, and broader mesiodistally (CBL of 9 mm) than labiolingually (CBW of 4 mm). In cross-section the crown is lanceolate at the base (CBR approximately 0.44) and lanceolate at the apical breaking surface. The distal carina is medially positioned and curves laterally with the crown, bearing denticles along the preserved margin (from the base of the crown, up to the distal break surface). The mesial carina curves laterally as well, but its margin bears no denticles due to the presence of a wear facet on the labial face ranging from the distal break surface to the basal area of the crown. The surface is smooth with thin longitudinal fissures on one side, while the other has several thin cracks. No distinctive structure is observable on the enamel throughout the crown.

The root is broken distally and parallel to the crown base, contrasting in color with the crown (the previous being black, and the later brown), and eight-shaped in cross-section at the basal breaking surface, due to the apical ends of the lingual and labial depression, where the dentin appears to be thicker mesiodistally than labiolingually.

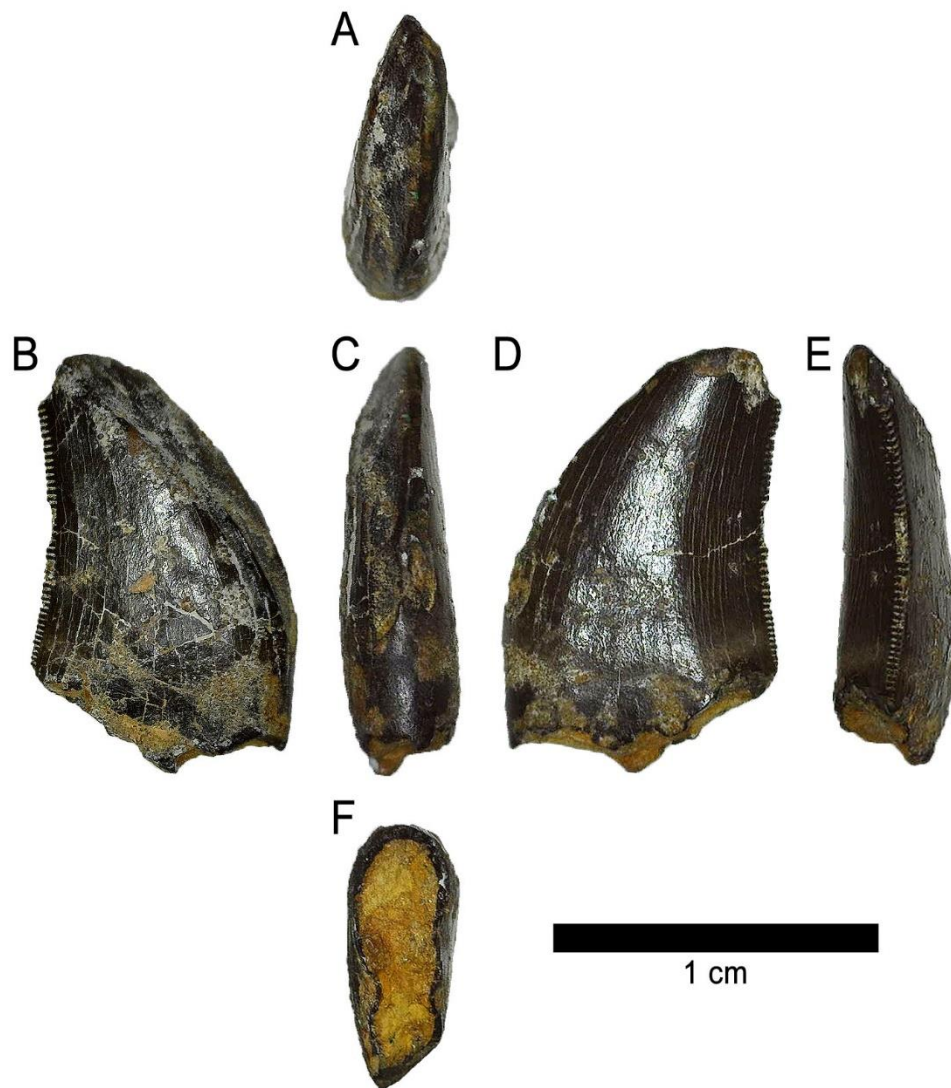


Figure 5.26: *Allosaurus* sp. AMNH FARB 33081 isolated tooth in apical (A), labial (B), mesial (C), lingual (D), distal (E), and basal (F) views.

The distal carina bears around 15 denticles per 5 mm at the mid-crown, and 20 at the base. No apical and mesial denticles are preserved. The distal denticles are elongated, larger at the mid-crown than the most basal denticles, but the distal. In general, the denticles are symmetrical labiolingually and basoapically, in lateral view at the external margin are subquadrangular to round, becoming basoapically thinner at their center where an interdenticular space is formed. The enamel layer is distinguishable on some denticles as a darker band on the external margin, although with some difficulty. The central distal denticles bear poorly defined cauda. The interdenticular space is generally elliptical between the denticles of the distal carina (more noticeable between the bigger ones).

5.2.10.AMNH FARB 33083

Systematic paleontology:

Dinosauria Owen, 1842

Saurischia Seeley, 1888

Theropoda Marsh, 1881

Allosauridae Marsh, 1878

Allosaurus sp. Marsh, 1877

Specimen material: Isolated tooth

Quarry: Cosm (North Section)

Layer: CQ-N 3

Associated field numbers: COSM 060

Material described in this work: Mentioned above

Description:

Elongated small sized ziphodont tooth (CH of 18 mm) missing the crown apex and parts of the carina, and broken below the cervix preserving the most basal end of the root (Figure 5.27). The crown is compressed labiolingually, with distally curved mesial and distal margins, serrated carinae, and broader mesioistally (CBL of 13.5 mm) than labiolingually (CBW of 6 mm). Is lanceolate in cross-section at the base (CBR approximately 0.44), and ovaloid to lenticular shaped at the apical breaking surface. The distal carina is medially positioned and straight, with denticles along the preserved margin (from the base of the crown up to the distal break surface). The mesial carina is medially positioned, gently curving laterally, with smaller denticles than the distal ones that only appear approximately 13 mm from the base of the crown, making the distal face without denticles rounded and smooth. The surface appears to be generally smooth, apart from three transverse undulations, almost equidistant from each other, along the crown. The surface also bears several thin longitudinal fissures and a fracture at the tooth's total mid-length. The enamel has a braided structure throughout the crown.

The root is broken distally and parallel to the crown base, contrasting in color with the crown (the previous being black, and the later brown), and eight-shaped in cross-section at the basal breaking surface, due to the apical ends of the lingual and labial depression, where the dentin appears to be thicker.

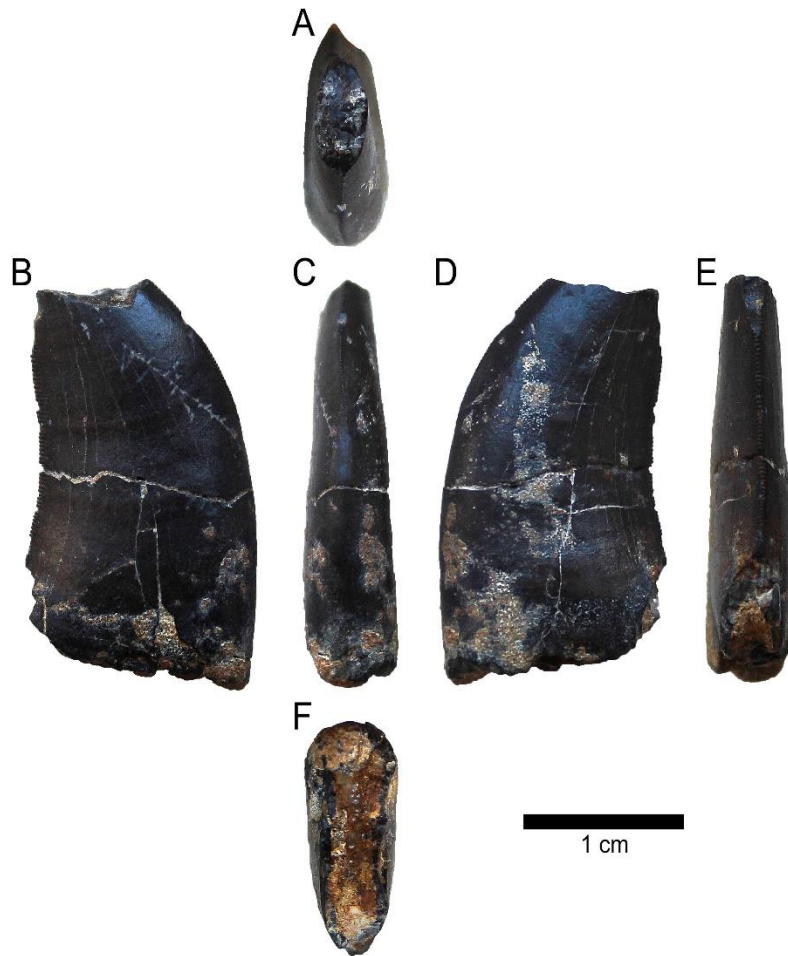


Figure 5.27: *Allosaurus* sp. AMNH FARB 33083 isolated tooth in apical (A), labial (B), mesial (C), lingual (D), distal (E), and basal (F) views.

The mesial carina bears 14 denticles per 5 mm at the mid-crown, with no denticles at the base. The distal carina bears around 19 denticles per 5 mm at the mid-crown, and 10 preserved basal denticles. The distal denticles are more elongated than the mesial ones, with the former becoming slightly smaller towards the base of the crown, while the latter become minute to the basal end of the mesial carina. In general, the denticles are symmetrical labiolingually and basoapically, in lateral view at the external margin are subquadrangular to round, becoming basoapically thinner at their center where the interdenticular space is formed. The enamel layer is distinguishable on the larger distal denticles as a darker band on the external margin. The central distal denticles close to the apical break surface bear cauda that pend towards the base, giving them a slightly curved look, while the other distal denticles don't exhibit this type of structure. The mesial denticles have in general a squared look. The interdenticular space is generally elliptical between the denticles of the distal carina (more noticeable between the bigger ones), rounded on the bigger denticles of the mesial carina, and straight on the smaller mesial denticles.

5.3 Taxonomical discussion

A great portion of the material described in this work is made up of pedal bones of theropod dinosaurs, with great morphological similarity observed between the specimens **AMNH FARB 33055**, **33061**, **33062**, and **33079**, enough to place them within the same clade. The only pedal element not identified as theropodian is **AMNH FARB 33072**, a broad and strongly dorsoventrally compressed phalanx, with unconstricted shaft, and bearing the marks of a potentially well developed dorsal sagittal ridge, possibly belonging to an ornithopod (Norman, 2004; Moreno, 2007).

In the latest phylogenetical analysis of Tetanurae, Carrano and colleagues (2012) present twelve characters observable for the pes. As the specimen preserving more pedal elements of the specimens described above, **AMNH FARB 33061** presents a good subject for identification, following the characters of Carrano and colleagues (2012), with eleven characters observed. Three synapomorphies of Neotheropoda are observable on the metatarsals: length of Mt I is less than half of the length of Mt II [Carrano et al., 2012: 340(1)], Mt IV slightly taller than broad at its distal end [Carrano et al., 2012: 344(1)], and the non-articular distal end of Mt I [Carrano et al., 2012: 345(1)]. The length of Mt V being approximately 48% of Mt IV's length [Carrano et al., 2012: 345(1)], and the combined length of phalanges I-1 and I-2 (ungual), in articulation (~13 centimeters), being slightly less than the total length of phalanx III-1 (13.46 centimeters) [Carrano et al., 2012: 351(1)] are shared characters between Averostra (ACTRAN) and Tetanurae (DELTRAN). The deeply notched shape of Mt III's proximal end [Carrano et al., 2012: 341(2)], and the elliptical shape of ungual phalanges III and IV in cross-section [Carrano et al., 2012: 349(1)] are synapomorphies of Avetheropoda, with one synapomorphy of Allosauroidea being observed in the Mt III as its plantar face is less broad than the dorsal face, giving it a pinched look

[Carrano et al., 2012: 342(1)]. The other three characters observable are the short and thick metatarsals with a length:transverse width ratio of approximately 5% [Carrano et al., 2012: 343(0)], the absence of antartometatarsals [Carrano et al., 2012: 347(0)], and single grooved lateral and medial faces of the ungual phalanges [Carrano et al., 2012: 348(0)], whose states of character are not considered synapomorphies, accelerated transformations (ACTRAN), or delayed transformations (DELTRAN).

Allosauroidea is divided into two clades, Metriacanthosauridae and Allosauria, the latter including the clades Allosauridae and Carcharodontosauria (Carrano et al., 2012), with Allosauridae being the only one represented in the Morrison Fm. Within this clade, three species occur in this geological formation: *Allosaurus fragillis*, Marsh, 1877b, *A. "jimmadseni"*, and *Saurophaganax maximus* Chure, 1995. *Saurophaganax*, the only Morrison Fm theropod specimen reported for Oklahoma, differs from other allosaurids based on the morphology of the neural spine and chevrons (Chure, 1995), however, its main distinction from *Allosaurus* are its bigger proportions, approximately 25% larger. This very restrictive geographical distribution, along with a dubious systematic character such as size, makes it safer to place **AMNH FARB 33055**, **33061**, **33062**, and **33079**, within *Allosaurus* sp., due to the bones preserved appearing to be more similar to the same bones described in other works

(Gilmore, 1920; Madsen, 1976; Chure, 2000; Hattori, 2016), and due to the lack of significant differences between the metatarsals of *A. fragillius* and *A. "jimmadseni"* (Chure, 2000).

This identification is also supported by the differences between the preserved metatarsals, and the the same bones belonging to specimens of the other two large theropod clades of the Morrison Fm.: *Ceratosaurus* and *Torvosaurus*. Gilmore (1920) described the metatarsals of *Ceratosaurus* as being shorter than those of adult *Allosaurus* ("*Antrodemus*" Leidy, 1870 in his work, later assigned to *Allosaurus fragillius*), and proposed that the coossification observed by Marsh (1884b) in these bones was a normal, non-pathological occurrence in older individuals. Although neither such fusion, nor traces of it, are observed in **AMNH FARB 330061** and 33062, this feature cannot be considered fundamental differences between the two genera, due to the uncertainty of its origin, as the features observed for metatarsals III and IV. While the proximal articular surfaces of metatarsals III and IV are, respectively, sub quadrangular and trapezoidal in *Ceratosaurus* (Gilmore, 1920), the same structures have more elongated and slender, almost triangular, look in **AMNH FARB 330061** and **33062**. The third metatarsal of *Ceratosaurus* has been described (Gilmore, 1920) as having a wider plantar face than dorsal face at its proximal end, being the widest of the three metatarsal in plantar view, while in **AMNH FARB 330061**, the proximal end has a wider dorsal face, narrowing towards the plantar face, giving it an elongated look. It should also be noted that the antarctometatarsal morphology, not observable in **AMNH FARB 330061**, is a synapomorphy of Ceratosauria [Carrano et al., 2012: 347(1)].

The metatarsals of *Torvosaurus* were described by Britt (1991) as being straight and stockier than the metatarsals of other large Morrison theropods, and having broad and concave distal collateral ligament fossae, absent of pits, while Hanson and Makovicky (2012) describe this pits as being very broad and shallow. **AMNH FARB 330061** and **33062** however, have slender and slightly curved metatarsals (III and IV), with collateral ligament fossae bearing deep and well-defined collateral pits, the exception being the indistinct and shallow lateral ligament fossae of metatarsal IV observed in both specimens. *Torvosaurus* also lacks the deep longitudinal sulcus present on the distal condyle of metatarsus IV, observable **AMNH FARB 330061** and **33062**, instead being lower in height, broader, and a more obtuse ventral surface (Britt, 1991).

All five theropod teeth in this work show characteristics described for the teeth of *Allosaurus*. Teeth ascribed to this genus have been reported to show different morphologies depending on their placement. The mesial teeth (premaxillary) are described as being uniform in size and morphology, D-shaped in cross section at the base of the crown, and with the medial carina extending to and sometimes past, the cervix and twisting towards the lingual face (Madsen, 1976; Hendricks et al., 2014), however, this D-shaped cross-section of the crown is not unique to *Allosaurus*, as it is also characteristic of Tyrannosauridae (Holtz Jr, 2007). The lateral teeth (maxillary and dentary), closer to the mesial dentition have been described as robust, compact, or pachydont, becoming progressively flat and curving distally (Gilmore, 1920; Madsen, 1976; Hendrickx et al., 2015). The lateral dentition of *Allosaurus* is ziphodont, with serrated, and slightly offset of the tooth's axis (Holtz Jr et al., 2007), mesial and distal carinae, the

latter being strongly displaced labially (Hendrickx et al., 2014), and having a longer extension of serration than the mesial carina (Madsen, 1976). To better identify the placement of the teeth described in this work, crown/base ratio (CBR=CBW:CBL; Smith et al., 2005;) can be applied using the values proposed by Hendrickx and colleagues (2014): 0.3-0.6 for the most posterior lateral teeth, 0.6-0.7 for the first eight maxillary teeth, and 0.7-1.2 for the other mesial teeth.

AMNH FARB 33061, 33077, 33081, and 33083 all show the general characteristics of the lateral dentition of *Allosaurus* above described (with **33061** already ascribed above to *Allosaurus* based on the specimen's pedal remains), with the CBR values (Table 5.1) confirming this placement. The labially displacement of the distal carina observable in **AMNH FARB 33061, 33077, and 33081** is considered an ambiguous synapomorphy of *Allosaurus* [Hendrickx & Mateus, 2014: 83(1)], along with the 8-shaped outline of the mid-root in cross section [Hendrickx & Mateus, 2014: 139(1)] clearly visible in **33061**, and partially visible in **33081** and **33083**, with the first hint of the labiolingual constriction that characterizes the 8-shaped outline. **AMNH FARB 33061** and **33083** also have the transversal undulations characteristic of the crown of Allosauroidea [Hendrickx & Mateus, 2014: 109(2)]. As for **AMNH FARB 33078**, its D-shaped cross section and slight pachydonty are characteristics shared by several theropod clades, being most commonly observed in Tyrannosauroidae and in the mesial dentition of *Allosaurus* (as previously stated), however it lacks the lingually or linguodistally facing distal carina, an unambiguous synapomorphy of Tyrannosauroidae [Hendrickx & Mateus, 2014: 48(2)], instead having a labially displaced, and facing distally, mesial carina [Hendrickx & Mateus, 2014: 48(1)], characteristic of the mesial dentition of *Allosaurus*. The placement of **AMNH FARB 33078** using the CBR value is not taken into account, as more than a half of the tooth's crown is missing.

Regarding AMNH FARB 33058, the ascription of the specimen as *Camarasaurus* can easily be made using the teeth described in this work, as it falls in line with previous descriptions of this clade's dental elements, distinguishing them from diplodocids, as well as other contemporary macronarians: broadly spatulate high crown, lack of denticles rugose texture, strongly convex labial face with two small apicobasal grooves toward the medial and distal side of the crown, strongly concave lingual face with an apicobasal ridge, and clear wearing facets at apex of the crown, sometimes with a slight polish of the distal and mesial edges due to the imbricated nature of the teeth battery (Calvo, 1994; Chatterjee & Zheng, 2005; Gilmore, 1925; McIntosh et al., 1996; Mocho et al., 2017; Osborn, 1905; Tschopp et al., 2015; Upchurch et al., 2004; Wilson & Sereno, 2010; White, 1958; Wiersma & Sander, 2016)

6. Conclusion

As a result of the NOVA+AMNH Wyoming Paleontological Expedition, two new quarries for the Morrison Fm. are added to already long list of productive outcrops across this formation. The two sites proved to be incredibly rich, preserving abundant material of Allosaurus, Apatosaurus, Camarasaurus, diplodocids, and some less well represented stegosaur, small onithopod, and Ornitholestes.

Invertebrate and plant material, along with stratigraphical data collected from five new sections for the Ten Sleep-Hyattville are of the Big Horn Basin, allows us to place the fossiliferous sandstone layers, where the expedition efforts were focused, top Morrison, in the higher divisions of the Morrison Fm, dating from the Tithonian, and representing a meandering fluvial system developing towards North.

This thesis also fulfills its original objective of being an important record of this expedition's beginning, as it documents the pre requisites needed for project like this to start , as well as it gives a detailed description of the work developed by the team through two years of expedition, and records all collected, and yet to collect, material, giving an insight on things to come.

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Appendixes

3A. Permit PA16-WY-245



United States Department of the Interior

BUREAU OF LAND MANAGEMENT

Wyoming State Office
P.O. Box 1828
Cheyenne, WY 82003-1828
www.blm.gov/wy



AUG 17 2017

In Reply Refer To:
8270 (930)
PA16-WY-245

Prof. Octávio Mateus
Dept. Earth Sciences
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa,
2829516
Caparica, Portugal

Dear Dr. Mateus:

We are pleased to extend your Bureau of Land Management (BLM) Paleontological Resources Use Permit PA16-WY-245 for paleontological excavation on BLM administered land at the Dana Quarry (). The expiration date of your permit is December 31, 2017. We hope that your work may not only contribute to the advancement of science, but also provide important information that will help us to better manage the public lands and resources.

Attached is your permit, as well as some additional materials explaining permit procedures. Please read the included material and become familiar with it. Please carry a copy of the permit while you are in the field.

Permittees are required to meet with the Field Manager in each Field Office where fieldwork will be done. You should arrange well in advance to meet with the manager before starting work each field season. If there will be a significant break in your time in the field, please contact the Field Manager prior to resuming work. Telephone numbers and addresses of all Wyoming Field Offices are attached.

Annual reports are required on or before December 31 of any year in which you have a permit in effect; if you did no fieldwork, a letter will be sufficient. Also, in any written documents or oral presentations where work done on BLM-administered lands is included, you should acknowledge this agency's part in your research. Should you want to change any details in the permit, you must notify the BLM Wyoming State Office in writing. Detailed instructions on all requirements are attached to your permit.

When you meet with the Field Manager prior to beginning fieldwork, please provide a list of all people in your party.

This will enable BLM to be of assistance in locating members of your group if there is an accident or other emergency.

Areas with special management guidelines, such as Areas of Critical Environmental Concern (ACECs) or historic trails, may be located within your permit area. Your Field Office contact will inform you of any specific management concerns and environmental requirements when you contact the Field Office prior to field work.

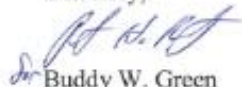
BLM rangers are available to help in emergencies and can be contacted through the Field Offices or the 24-hour Wyoming law enforcement hotline at 1-800-442-2767. Rangers must complete accident forms for any collisions or mishaps that occur on public lands. The Rangers are there for your benefit and assistance.

If you or anyone in your party is aware of possible unauthorized removal of fossil resources from the public lands, the Ranger or Field Manager should be notified immediately. For your own safety, please do not make contact with any individuals you may observe engaged in such activities.

Remember that your permit is valid only on lands administered by the BLM in Wyoming and authorizes only the collection of paleontological resources. A separate permit is required for the collection of cultural (archaeological) resources. Other Federal agencies such as the National Park Service, Bureau of Reclamation, and U.S. Forest Service require permits issued by each agency for paleontological work on lands they administer. Collecting on Indian lands is by permission of the Indian landowner or the tribe. If you wish to work on private or State lands, you must obtain permission from landowners or the Wyoming Board of Land Commissioners before beginning fieldwork.

We welcome the opportunity to work with you. Please contact Brent Breithaupt at (307) 775-6052 if you have any questions concerning your permit or any of the attached material.

Sincerely,



Buddy W. Green
Deputy State Director
Resources Policy and Management

Attachments

Form 8270-2 (Temporary)
(December 1994)

United States
Department of the Interior
Bureau of Land Management

Permit number:

PA16 – WY – 245
(Extended)

Paleontological Resources Use Permit

*A copy of this permit must be carried by the individual(s)
named in Line 8 whenever fieldwork is in progress.*

1a. Permittee: Prof. Octávio Mateus	1b. Affiliation: Faculty of Science and Technology, Nova University Lisbon
2. Mailing address: Dept. Earth Sciences Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, 2829516 Caparica, Portugal Email: omateus@fct.unl.pt	3. Telephone number: Office1: +351.212.948.573 Email1: omateus@fct.unl.pt Fax1: +351.212.948.556 Field number: +351.918.38.15.01
4. Nature of authorized paleontological fieldwork: Allow a professional excavation at the unexcavated, fossiliferous Dana Quarry on BLM-administered land, where recovery of new exceptional dinosaurian material is expected. a. Survey and limited surface collection OR b. Excavation X	
5. Location of authorized paleontological fieldwork: Dana Quarry, _____, – BLM-administered land	
6. Authorized start date: July 25, 2017	7. Expiration Date: December 31, 2017
8. Name(s) of individual(s) responsible for planning, supervising, and carrying out fieldwork: Prof. Octávio Mateus; Prof. Mark A. Norell; Dr. Emanuel Tschopp	
9. Repository name and address: American Museum of Natural History, New York, USA	
10. Special conditions are attached and must be adhered to: See Standard Terms and Conditions (attached), as well as those to be added later by the Worland Field Office.	

Field Manager

Date

Field Manager

Date



Deputy State Director



Date

3B. Permit PA16-WY-255 – 2016



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Wyoming State Office
P.O. Box 1828
Cheyenne, WY 82003-1828
www.blm.gov/wy



In Reply Refer To:
8270 (930)
PA16-WY-255

AUG 01 2016

Prof. Octávio Mateus
Dept. Earth Sciences
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa,
2829516
Caparica, Portugal

Dear Dr. Mateus:

We are pleased to forward your new Bureau of Land Management (BLM) Paleontological Resources Use Permit PA16-WY-255 for paleontological excavations on BLM-administered land for Jurassic dinosaur remains at two nearby localities (

) outside of Tensleep, Washakie County, Wyoming. The expiration date of your permit is December 31, 2016. We hope that your work may not only contribute to the advancement of science, but also provide important information that will help us to better manage the public lands and resources.

Attached is your permit, as well as some additional materials explaining permit procedures. Please read the included material and become familiar with it. Please carry a copy of the permit while you are in the field.

Permittees are required to meet with the Field Manager in each Field Office where fieldwork will be done. You should arrange well in advance to meet with the manager before starting work each field season. If there will be a significant break in your time in the field, please contact the Field Manager prior to resuming work. Telephone numbers and addresses of all Wyoming Field Offices are attached.

Annual reports are required on or before December 31 of any year in which you have a permit in effect; if you did no fieldwork, a letter will be sufficient. Also, in any written documents or oral presentations where work done on BLM-administered lands is included, you should acknowledge this agency's part in your research. Should you want to change any details in the permit, you must notify the BLM Wyoming State Office in writing. Detailed instructions on all requirements are attached to your permit.

When you meet with the Field Manager prior to beginning fieldwork, please provide a list of all people in your party. This will enable BLM to be of assistance in locating members of your group if there is an accident or other emergency.

Areas with special management guidelines, such as Areas of Critical Environmental Concern (ACECs) or historic trails, may be located within your permit area. Your Field Office contact will inform you of any specific management concerns and environmental requirements when you contact the Field Office prior to field work.

BLM rangers are available to help in emergencies and can be contacted through the Field Offices or the 24-hour Wyoming law enforcement hotline at 1-800-442-2767. Rangers must complete accident forms for any collisions or mishaps that occur on public lands. The Rangers are there for your benefit and assistance.

If you or anyone in your party is aware of possible unauthorized removal of fossil resources from the public lands, the Ranger or Field Manager should be notified immediately. For your own safety, please do not make contact with any individuals you may observe engaged in such activities.

Remember that your permit is valid only on lands administered by the BLM in Wyoming and authorizes only the collection of paleontological resources. A separate permit is required for the collection of cultural (archaeological) resources. Other Federal agencies such as the National Park Service, Bureau of Reclamation, and U.S. Forest Service require permits issued by each agency for paleontological work on lands they administer. Collecting on Indian lands is by permission of the Indian landowner or the tribe. If you wish to work on private or State lands, you must obtain permission from landowners or the Wyoming Board of Land Commissioners before beginning fieldwork.

We welcome the opportunity to work with you. Please contact Brent Breithaupt at (307) 775-6052 if you have any questions concerning your permit or any of the attached material.

Sincerely,


Buddy W. Green
Deputy State Director
Resources Policy and Management

Attachments:

- 1 - Permit
- 2 - Standard Terms and Conditions for Excavation Permits
- 3 - Reports for Research Permits
- 4 - Permitting Procedures
- 5 - Field Office Contacts and Map
- 6 - Paleontological Locality Form and Instructions
- 7 - Annual Report Cover Sheet
- 8 - Worland Field Office Stipulations

Form 8270-2 (Temporary)
(December 1994)

United States
Department of the Interior
Bureau of Land Management

Permit number:

PA16 - WY - 255

Paleontological Resources Use Permit

*A copy of this permit must be carried by the individual(s)
named in Line 8 whenever fieldwork is in progress.*


1a. Permittee: Prof. Octávio Mateus	1b. Affiliation: Faculty of Science and Technology, Nova University Lisbon
2. Mailing address: Dept. Earth Sciences Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, 2829516 Caparica, Portugal Email: omateus@fct.unl.pt	3. Telephone number: Office1: +351.212.948.573 Email1: omateus@fct.unl.pt Fax1: +351.212.948.556 Field number: +351.918.38.15.01
4. Nature of authorized paleontological fieldwork: Allow for professional paleontological excavations on BLM-administered land for Jurassic dinosaur remains at two nearby localities () outside of Tensleep, Washakie County, Wyoming. a. Survey and limited surface collection OR b. Excavation X	
5. Location of authorized paleontological fieldwork: BLM-administered land at two nearby localities (i.e.,) outside of Tensleep, Washakie County, Wyoming.	
6. Authorized start date: August 5, 2016	7. Expiration Date: December 31, 2016
8. Name(s) of individual(s) responsible for planning, supervising, and carrying out fieldwork: Prof. Octávio Mateus; Prof. Mark A. Norell; Dr. Emanuel Tschopp; Mr. Carl Mehling	
9. Repository name and address: American Museum of Natural History, New York, USA	
10. Special conditions are attached and must be adhered to: See Standard Terms and Conditions (attached), as well stipulations added by the Worland Field Office.	

Field Manager

Date

Field Manager

Date


Deputy State Director

Date

3C. Permit PA16-WY-255 – 2017



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Wyoming State Office
P.O. Box 1828
Cheyenne, WY 82003-1828
www.blm.gov/wy



In Reply Refer To:
8270 (930)
PA16-WY-255

JUN 06 2017

Prof. Octávio Mateus
Dept. Earth Sciences
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa,
2829516
Caparica, Portugal

Dear Dr. Mateus:

We are pleased to forward your new Bureau of Land Management (BLM) Paleontological Resources Use Permit PA16-WY-255 for paleontological excavations on BLM-administered land for Jurassic dinosaur remains at two nearby localities (

) outside of Tensleep, Washakie County, Wyoming. The expiration date of your permit is December 31, 2017. We hope that your work may not only contribute to the advancement of science, but also provide important information that will help us to better manage the public lands and resources.

Attached is your permit, as well as some additional materials explaining permit procedures. Please read the included material and become familiar with it. Please carry a copy of the permit while you are in the field.

Permittees are required to meet with the Field Manager in each Field Office where fieldwork will be done. You should arrange well in advance to meet with the manager before starting work each field season. If there will be a significant break in your time in the field, please contact the Field Manager prior to resuming work. Telephone numbers and addresses of all Wyoming Field Offices are attached.

Annual reports are required on or before December 31 of any year in which you have a permit in effect; if you did no fieldwork, a letter will be sufficient. Also, in any written documents or oral presentations where work done on BLM-administered lands is included, you should acknowledge this agency's part in your research. Should you want to change any details in the permit, you must notify the BLM Wyoming State Office in writing. Detailed instructions on all requirements are attached to your permit.

When you meet with the Field Manager prior to beginning fieldwork, please provide a list of all people in your party. This will enable the BLM to be of assistance in locating members of your group if there is an accident or other emergency.

Areas with special management guidelines, such as Areas of Critical Environmental Concern (ACECs) or historic trails, may be located within your permit area. Your Field Office contact will inform you of any specific management concerns and environmental requirements when you contact the Field Office prior to field work.

The BLM rangers are available to help in emergencies and can be contacted through the Field Offices or the 24-hour Wyoming law enforcement hotline at 1-800-442-2767. Rangers must complete accident forms for any collisions or mishaps that occur on public lands. The Rangers are there for your benefit and assistance.

If you or anyone in your party is aware of possible unauthorized removal of fossil resources from the public lands, the Ranger or Field Manager should be notified immediately. For your own safety, please do not make contact with any individuals you may observe engaged in such activities.

Remember that your permit is valid only on lands administered by the BLM in Wyoming and authorizes only the collection of paleontological resources. A separate permit is required for the collection of cultural (archaeological) resources. Other Federal agencies such as the National Park Service, Bureau of Reclamation, and U.S. Forest Service require permits issued by each agency for paleontological work on lands they administer. Collecting on Indian lands is by permission of the Indian landowner or the tribe. If you wish to work on private or State lands, you must obtain permission from landowners or the Wyoming Board of Land Commissioners before beginning fieldwork.

We welcome the opportunity to work with you. Please contact Brent Breithaupt at (307) 775-6052 if you have any questions concerning your permit or any of the attached material.

Sincerely,



Buddy W. Green
Deputy State Director
Resources Policy and Management

Attachments:

- 1 - Permit
- 2 - Standard Terms and Conditions for Excavation Permits
- 3 - Reports for Research Permits
- 4 - Permitting Procedures
- 5 - Field Office Contacts and Map
- 6 - Paleontological Locality Form and Instructions
- 7 - Annual Report Cover Sheet
- 8 - Worland Field Office Stipulations

Form 8270-2 (Temporary)
(December 1994)

United States
Department of the Interior
Bureau of Land Management

Permit number:

PA16 – WY – 255

Paleontological Resources Use Permit

*A copy of this permit must be carried by the individual(s)
named in Line 8 whenever fieldwork is in progress.*

1a. Permittee: Prof. Octávio Mateus	1b. Affiliation: Faculty of Science and Technology, Nova University Lisbon
2. Mailing address: Dept. Earth Sciences Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, 2829516 Caparica, Portugal Email: omateus@fct.unl.pt	3. Telephone number: Office1: +351.212.948.573 Email1: omateus@fct.unl.pt Fax1: +351.212.948.556 Field number: +351.918.38.15.01
4. Nature of authorized paleontological fieldwork: Allow for professional paleontological excavations on BLM-administered land for Jurassic dinosaur remains at two nearby localities () outside of Tensleep, Washakie County, Wyoming. a. Survey and limited surface collection OR b. Excavation X	
5. Location of authorized paleontological fieldwork: BLM-administered land at two nearby localities (i.e.,) outside of Tensleep, Washakie County, Wyoming.	
6. Authorized start date: June 5, 2017	7. Expiration Date: December 31, 2017
8. Name(s) of individual(s) responsible for planning, supervising, and carrying out fieldwork: Prof. Octávio Mateus; Prof. Mark A. Norell; Dr. Emanuel Tschopp; Mr. Carl Mehling	
9. Repository name and address: American Museum of Natural History, New York, USA	
10. Special conditions are attached and must be adhered to: See Standard Terms and Conditions (attached), as well stipulations added by the Worland Field Office.	

Field Manager

Date

Field Manager

Date


Deputy State Director


Date

3D. Permit PA16-WY-256 – 2016



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Wyoming State Office
P.O. Box 1828
Cheyenne, WY 82003-1828
www.blm.gov/wy



AUG 01 2016

In Reply Refer To:
8270 (930)
PA16-WY-256

Prof. Octávio Mateus
Dept. Earth Sciences
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa,
2829516
Caparica, Portugal

Dear Dr. Mateus:

We are pleased to forward your new Bureau of Land Management (BLM) Paleontological Resources Use Permit PA16-WY-256 for scientific survey, documentation, and limited surface collection of paleontological resources in Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY. The expiration date of your permit is December 31, 2016. We hope that your work may not only contribute to the advancement of science, but also provide important information that will help us to better manage the public lands and resources.

Attached is your permit, as well as some additional materials explaining permit procedures. Please read the included material and become familiar with it. Please carry a copy of the permit while you are in the field.

Permittees are required to meet with the Field Manager in each Field Office where fieldwork will be done. You should arrange well in advance to meet with the manager before starting work each field season. If there will be a significant break in your time in the field, please contact the Field Manager prior to resuming work. Telephone numbers and addresses of all Wyoming Field Offices are attached.

Annual reports are required on or before December 31 of any year in which you have a permit in effect; if you did no fieldwork, a letter will be sufficient. Also, in any written documents or oral presentations where work done on BLM-administered lands is included, you should acknowledge this agency's part in your research. Should you want to change any details in the permit, you must notify the BLM Wyoming State Office in writing. Detailed instructions on all requirements are attached to your permit.

When you meet with the Field Manager prior to beginning fieldwork, please provide a list of all people in your party. This will enable BLM to be of assistance in locating members of your group if there is an

accident or other emergency.

Areas with special management guidelines, such as Areas of Critical Environmental Concern (ACECs) or historic trails, may be located within your permit area. Your Field Office contact will inform you of any specific management concerns and environmental requirements when you contact the Field Office prior to field work.

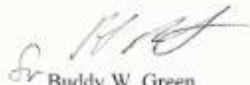
BLM rangers are available to help in emergencies and can be contacted through the Field Offices or the 24-hour Wyoming law enforcement hotline at 1-800-442-2767. Rangers must complete accident forms for any collisions or mishaps that occur on public lands. The Rangers are there for your benefit and assistance.

If you or anyone in your party is aware of possible unauthorized removal of fossil resources from the public lands, the Ranger or Field Manager should be notified immediately. For your own safety, please do not make contact with any individuals you may observe engaged in such activities.

Remember that your permit is valid only on lands administered by the BLM in Wyoming and authorizes only the collection of paleontological resources. A separate permit is required for the collection of cultural (archaeological) resources. Other Federal agencies such as the National Park Service, Bureau of Reclamation, and U.S. Forest Service require permits issued by each agency for paleontological work on lands they administer. Collecting on Indian lands is by permission of the Indian landowner or the tribe. If you wish to work on private or State lands, you must obtain permission from landowners or the Wyoming Board of Land Commissioners before beginning fieldwork.

We welcome the opportunity to work with you. Please contact Brent Breithaupt at (307) 775-6052, if you have any questions concerning your permit or any of the attached material.

Sincerely,



Buddy W. Green
Deputy State Director
Resources Policy and Management

Attachments:

- 1 - Permit
- 2 - Standard Terms and Conditions for Excavation Permits
- 3 - Reports for Research Permits
- 4 - Permitting Procedures
- 5 - Field Office Contacts and Map
- 6 - Paleontological Locality Form and Instructions
- 7 - Annual Report Cover Sheet
- 8 - Ichnology Stipulations

Form 8270-2 (Temporary)
(December 1994)

United States
Department of the Interior
Bureau of Land Management

Permit number:

PA16 – WY – 256

Paleontological Resources Use Permit

*A copy of this permit must be carried by the individual(s)
named in Line 8 whenever fieldwork is in progress.*

1a. Permittee: Prof. Octávio Mateus	1b. Affiliation: Faculty of Science and Technology, Nova University Lisbon
2. Mailing address: Dept. Earth Sciences Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, 2829516 Caparica, Portugal Email: omateus@fct.unl.pt	3. Telephone number: Office1: +351.212.948.573 Email1: omateus@fct.unl.pt Fax1: +351.212.948.556 Field number: +351.918.38.15.01
4. Nature of authorized paleontological fieldwork: Scientific survey, documentation, and limited surface collection of paleontological resources in Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY. a. Survey and limited surface collection <input checked="" type="checkbox"/> OR b. Excavation <input type="checkbox"/>	
5. Location of authorized paleontological fieldwork: Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY.	
6. Authorized start date: August 5, 2016	7. Expiration Date: December 31, 2016
8. Name(s) of individual(s) responsible for planning, supervising, and carrying out fieldwork: Prof. Octávio Mateus; Prof. Mark A. Norell; Dr. Emanuel Tschopp; Mr. Carl Mehling	
9. Repository name and address: American Museum of Natural History, New York, USA	
10. Special conditions are attached and must be adhered to: See Standard Terms and Conditions (attached).	

Field Manager

Date

Field Manager

Date



Deputy State Director

Date

3E. Permit PA16-WY-256 – 2017



United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Wyoming State Office
P.O. Box 1828
Cheyenne, WY 82003-1828
www.blm.gov/wy



In Reply Refer To:
8270 (930)
PA16-WY-256

MAY 16 2017

Prof. Octávio Mateus
Dept. Earth Sciences
Faculdade de Ciências e Tecnologia, FCT,
Universidade Nova de Lisboa,
2829516
Caparica, Portugal

Dear Dr. Mateus:

We are pleased to extend your Bureau of Land Management (BLM) Paleontological Resources Use Permit PA16-WY-256 for scientific survey, documentation, and limited surface collection of paleontological resources in Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY. The expiration date of your permit is December 31, 2017. We hope that your work may not only contribute to the advancement of science, but also provide important information that will help us to better manage the public lands and resources.

Attached is your permit, as well as some additional materials explaining permit procedures. Please read the included material and become familiar with it. Please carry a copy of the permit while you are in the field.

Permittees are required to meet with the Field Manager in each Field Office where fieldwork will be done. You should arrange well in advance to meet with the manager before starting work each field season. If there will be a significant break in your time in the field, please contact the Field Manager prior to resuming work. Telephone numbers and addresses of all Wyoming Field Offices are attached.

Annual reports are required on or before December 31 of any year in which you have a permit in effect; if you did no fieldwork, a letter will be sufficient. Also, in any written documents or oral presentations where work done on BLM-administered lands is included, you should acknowledge this agency's part in your research. Should you want to change any details in the permit, you must notify the BLM Wyoming State Office in writing. Detailed instructions on all requirements are attached to your permit.

When you meet with the Field Manager prior to beginning fieldwork, please provide a list of all people in your party. This will enable the BLM to be of assistance in locating members of your group if there is an accident or other emergency.

Areas with special management guidelines, such as Areas of Critical Environmental Concern (ACECs) or historic trails, may be located within your permit area. Your Field Office contact will inform you of any specific management concerns and environmental requirements when you contact the Field Office prior to field work.

The BLM rangers are available to help in emergencies and can be contacted through the Field Offices or

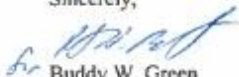
the 24-hour Wyoming law enforcement hotline at 1-800-442-2767. Rangers must complete accident forms for any collisions or mishaps that occur on public lands. The Rangers are there for your benefit and assistance.

If you or anyone in your party is aware of possible unauthorized removal of fossil resources from the public lands, the Ranger or Field Manager should be notified immediately. For your own safety, please do not make contact with any individuals you may observe engaged in such activities.

Remember that your permit is valid only on lands administered by the BLM in Wyoming and authorizes only the collection of paleontological resources. A separate permit is required for the collection of cultural (archaeological) resources. Other Federal agencies such as the National Park Service, Bureau of Reclamation, and U.S. Forest Service require permits issued by each agency for paleontological work on lands they administer. Collecting on Indian lands is by permission of the Indian landowner or the tribe. If you wish to work on private or State lands, you must obtain permission from landowners or the Wyoming Board of Land Commissioners before beginning fieldwork.

We welcome the opportunity to work with you. Please contact Brent Breithaupt at (307) 775-6052 if you have any questions concerning your permit or any of the attached material.

Sincerely,



Buddy W. Green
Deputy State Director
Resources Policy and Management

Attachments:

- 1 - Permit
- 2 - Standard Terms and Conditions for Excavation Permits
- 3 - Reports for Research Permits
- 4 - Permitting Procedures
- 5 - Field Office Contacts and Map
- 6 - Paleontological Locality Form and Instructions
- 7 - Annual Report Cover Sheet
- 8 - Ichnology Stipulations

Form 8270-2 (Temporary)
(December 1994)

United States
Department of the Interior
Bureau of Land Management

Permit number:

PA16 – WY – 256

Paleontological Resources Use Permit

*A copy of this permit must be carried by the individual(s)
named in Line 8 whenever fieldwork is in progress.*

1a. Permittee: Prof. Octávio Mateus	1b. Affiliation: Faculty of Science and Technology, Nova University Lisbon
2. Mailing address: Dept. Earth Sciences Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa, 2829516 Caparica, Portugal Email: omateus@fct.unl.pt	3. Telephone number: Office1: +351.212.948.573 Email1: omateus@fct.unl.pt Fax1: +351.212.948.556 Field number: +351.918.38.15.01
4. Nature of authorized paleontological fieldwork: Scientific survey, documentation, and limited surface collection of paleontological resources in Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY. a. Survey and limited surface collection <input checked="" type="checkbox"/> OR b. Excavation <input type="checkbox"/>	
5. Location of authorized paleontological fieldwork: Mesozoic units on BLM-administered land near Tensleep, Washakie County, WY.	
6. Authorized start date: June 5, 2017	7. Expiration Date: December 31, 2017
8. Name(s) of individual(s) responsible for planning, supervising, and carrying out fieldwork: Prof. Octávio Mateus; Prof. Mark A. Norell; Dr. Emanuel Tschopp; Mr. Carl Mehling	
9. Repository name and address: American Museum of Natural History, New York, USA	
10. Special conditions are attached and must be adhered to: See Standard Terms and Conditions (attached).	

Field Manager

Date

Field Manager

Date


Deputy State Director


Date

3F. Paleontological locality forms

Form 8270-3 (Temporary)
(May 1984)

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

-
1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
 2. Repository/Accn.#: AMNH
 3. Locality #: _____ Plant Vertebrate Invertebrate Other
 4. Formation (and subdivision, if known): Sundance Formation
 5. Age: Upper Jurassic
 6. County: Washakie
 7. BLM Field Office: Worland
 9. Map name: _____
 10. Map source: _____
 11. Map size: _____
 12. Map edition: _____
 13. Latitude (deg., min., sec., direction):
 14. Longitude (deg., min., sec., direction):
and UTM Grid: Zone _____ m E _____ m N NAD
 15. Survey (Twp, Rge, Sec, subdiv): _____
 16. Taxa Collected/observed: Pectinidae, Belemnitidae, Plesiosauria and Ichiosauria (observed)
 17. Collector: _____
 18. Date: _____
 19. Remarks: Found while looking for an advantage point over the Cosm Site for stratigraphy. The fossils are found loose on the ground and very fragmented. The invertebrate material can easily be collected as it is small and found in great quantities. On the other hand, the vertebrate material is a bit more difficult to be collected by other people since you need to know the exact location were the bones are in order to do so.

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

-
1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
 2. Repository/Accn.#: AMNH
 3. Locality #: _____ Plant Vertebrate Invertebrate Other
 4. Formation (and subdivision, if known): Morrison Formation
 5. Age: Upper Jurassic
 6. County: Washakie
 7. BLM Field Office: Worland
 9. Map name: _____
 10. Map source: _____
 11. Map size: _____
 12. Map edition: _____
 13. Latitude (deg., min., sec., direction):
 14. Longitude (deg., min., sec., direction):
and UTM Grid: Zone _____ m E _____ m N NAD
 15. Survey (Twp, Rge, Sec, subdiv): _____
 16. Taxa Collected/observed: Allosauridae (observed)
 17. Collector: _____
 18. Date: _____
 19. Remarks: Found while observing a yellowish sandstone layer that could be correlated with the layers dug by us in Dana Quarry and Cosm Site. The specimen was composed mainly of exposed vertebral material and maybe skull material as well, with part of it still being *in situ* on the cliff while the other part was part of a big boulder that rolled down the cliff. The chances of it being seen and collected by passerbies are slim due to being preserved in a not so easily accessible place and due to the hardness of the sandstone.

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

-
1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
 2. Repository/Accn.#: AMNH
 3. Locality #: _____ Plant Vertebrate Invertebrate Other
 4. Formation (and subdivision, if known): Morrison Formation
 5. Age: Upper Jurassic
 6. County: Washakie
 7. BLM Field Office: Worland
 9. Map name: _____
 10. Map source: _____
 11. Map size: _____
 12. Map edition: _____
 13. Latitude (deg., min., sec., direction):
 14. Longitude (deg., min., sec., direction):
and UTM Grid: Zone _____ m E _____ m N NAD
 15. Survey (Twp, Rge, Sec, subdiv): _____
 16. Taxa Collected/observed: Sauropoda (collected)
 17. Collector: Octávio Mateus
 18. Date: September 4th, 2016
 19. Remarks: Found while looking for Morrison Formation outcrops that could be correlated with the layers dug by us in Dana Quarry and Cosm Site. The material collect was composed by gastrolithes and opalized bone fragments found as Morrison material that was reworked into overlying Cloverly Fm. and then rolled back down to the Morrison sediments. This fossils are easily collected by ground picking, making them easy targets for collectors, but only if the exact location of the hill where they were found is known.

Form 5270-3 (Temporary)
(May 1994)

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
2. Repository/Accn.#: AMNH
3. Locality #: _____ Plant Vertebrate Invertebrate Other
4. Formation (and subdivision, if known): Cody Shale (presumably)
5. Age: Upper Cretaceous
6. County: Big Horn
7. BLM Field Office: Worland
9. Map name: _____
10. Map source: _____
11. Map size: _____
12. Map edition: _____
13. Latitude (deg., min., sec., direction): _____
14. Longitude (deg., min., sec., direction): _____
and UTM Grid: Zone _____ m E _____ m N NAD _____
15. Survey (Twp, Rge, Sec, subdiv): _____
16. Taxa Collected/observed: Batoidea, Crocodylomorpha, and Selachimorpha (all collected)
17. Collector: Carl Mehling and Octávio Mateus
18. Date: August 5th
19. Remarks: This site was found the road to Cosm Quarry, on a hill to the north, in a black shale layer, possibly belonging to the Cody Shale Fm. The material, comprised of three isolated teeth, was collected off the area surrounding an anthill by the roadside (surface collection). Collection of material from this site is very unlikely, due to being located by the side of an off-road.

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
2. Repository/Accn.#: AMNH
3. Locality #: _____ Plant Vertebrate Invertebrate Other
4. Formation (and subdivision, if known): Sundance Formation
5. Age: Upper Jurassic
6. County: Big Horn
7. BLM Field Office: Worland
9. Map name: _____
10. Map source: _____
11. Map size: _____
12. Map edition: _____
13. Latitude (deg., min., sec., direction): _____
14. Longitude (deg., min., sec., direction): _____
and UTM Grid: Zone _____ m E _____ m N NAD _____
15. Survey (Twp, Rge, Sec, subdiv): _____
16. Taxa Collected/observed: *Ophthalmosaurus natans* (Ichthyosauria)
17. Collector: Carl Mehling, Fiona Brady, Jessica Oreck, and Will Harcourt-Smith
18. Date: August 19th
19. Remarks: The specimen was found by Carl Mehling on September 3rd, 2016, while surveying the hill east of Bobcat Hill, under that year's BLM survey permit. Although the several bones belonging to the specimen were loose on the ground and very fragmented upon discovery, they were left on the field due to the permit only allowing the collection of fossils belonging to the Morrison Fm. (which was not the case of this specimen).
During the 2017 expedition, this specimen was again found, but this time missing some bones observed the previous year, with the ones remaining under a serious risk of loss during the following months. To prevent the loss of this material it was decided that such the bones should be collected.

Form 8270-3 (Temporary)
(May 1994)

United States
Department of the Interior
Bureau of Land Management

Paleontological Locality Form

-
1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
 2. Repository/Accn.#: AMNH
 3. Locality #: _____ Plant Vertebrate Invertebrate Other
 4. Formation (and subdivision, if known): Sundance Formation
 5. Age: Lower Cretaceous
 6. County: Big Horn
 7. BLM Field Office: Worland
 9. Map name: _____
 10. Map source: _____
 11. Map size: _____
 12. Map edition: _____
 13. Latitude (deg., min., sec., direction): _____
 14. Longitude (deg., min., sec., direction): _____
and UTM Grid: Zone _____ m E _____ m N NAD _____
 15. Survey (Twp, Rge, Sec, subdiv): _____
 16. Taxa Collected/observed: Crocodylomorpha, Sauropoda, Theropoda, and one unidentified taxon
 17. Collector: Alexandra Fernandes, André Saleiro, and Carl Mehling
 18. Date: August 18th
 19. Remarks: This site was found during a walk through a badland-like area North of Hyattville, while being guided by a local. The material here found is scarce and fragmentary. Collection of material from this site is very unlikely, due to being located far from any major roads and off-roads.

Form 8270-3 (Temporary)
(May 1994)

United States
Department of the Interior
Bureau of Land Management


Paleontological Locality Form

-
1. Permit #/Permittee: PA16-WY-256/Octávio Mateus
 2. Repository/Accn.#: AMNH
 3. Locality #: _____ Plant Vertebrate Invertebrate Other
 4. Formation (and subdivision, if known): Sundance Formation
 5. Age: Lower Cretaceous
 6. County: Big Horn
 7. BLM Field Office: Worland
 9. Map name: _____
 10. Map source: _____
 11. Map size: _____
 12. Map edition: _____
 13. Latitude (deg., min., sec., direction): _____
 14. Longitude (deg., min., sec., direction): _____
and UTM Grid: Zone _____ m E _____ m N NAD _____
 15. Survey (Twp, Rge, Sec, subdiv): _____
 16. Taxa Collected/observed: Sauropoda (?)
 17. Collector: Carl Mehling and Fiona Brady
 18. Date: August 18th
 19. Remarks: This site was found during a walk through a badland-like area North of Hyattville, while being guided by a local. The material here found is scarce and fragmentary. Collection of material from this site is very unlikely, due to being located far from any major roads and off-roads.

3G. Simplified inventory list of used materials throughout the expedition

Equipment	Consumables
Bags (for lunch and water transport)	Acetone
Basins	Aluminum foil
Bottles for adhesives (with and without nozzle)	Biodegradable stakes
Brooms	Burlap
Brushes (paint, whisk, and wire)	Butvar® B-76
Buckets	Cling Wrap
Bungee Cords	Cyanoacrylates
Chisels (large, medium, and small)	Dust Masks
Cooler	Erosion Net
Crates	Fence posts
Crowbar	Gloves (latex, rubber, and work)
Drill (Hammer Drill)	Grease (white lithium)
Dustpans	Markers (dry erase and sharpies)
Extension Cord	Nails
First Aid Kits	Paraloid B-72™ pellets
Generator	Pipettes
Gas Can	Plaster bandages
Grid (50x100 cm)	Plaster of Paris
Hammers (geological, and mallets)	Sandwich Containers (Rubbermaid)
Hoes (back, and draw)	Specimen Bags (large and small Ziplock®)
Jackhammer (with bit)	Spray Paint
Knives (large military, and small and flexible blade)	Survey Marker Rods
Measuring Tapes	Tape (masking, packing, and duct)
Net and Octopus	Toilet Paper
Pallets	
Pickaxes (Mattock)	
Rope (ribbon, string, and thick)	
Saws (hacksaw, and plaster)	
Scissors	
Screwdrivers (large and small)	
Shovels (small, and large)	
Sieves	
Tarps	
Trowels	
Water containers	
Writing Tablets (chalk, and dry erase)	

3H. Log of expenses for 2016

FORM #4
AMERICAN MUSEUM OF NATURAL HISTORY 
LOG OF EXPENSES

Traveler: Carl Mehling

Travel Form #: _____

Trip Dates: 24-Aug-16 — 18-Sep-16
FROM TO

Reimbursement Method: (Check One Box)

Destination: Ten Sleep, Wyoming

- Actual Receipts**
- Actual Lodging Expense + Per Diem Meals**
- Full Per Diem**

Currency Used: US Dollar (USD)

Exchange Rate: 1.00
USD = 1,000
[Currency Converter website](#)

[Domestic Per Diem Rates Look Up](#)
[Foreign Per Diem Rates Look Up](#)

Please use separate page for each currency used

DATE	PAID TO	AIRFARE	VEHICLE RENTAL	LODGING / MEALS	OTHER	REGISTRATION	PARTICIPANT SUPPORT
		418,4181	418,4182	418,4184	418,4183	461.4610	466,4665
07/10/16	AirBNB			8 120,00			
08/22/16	American Airlines/Iberia	972,00					
08/22/16	Home Depot				56,48		
08/23/16	AMNH				56,22		
08/24/16	Burger King			8,31			
08/24/16	Villa Fresh Italian Kitchen			11,50			
08/24/16	Avis		1 141,95				
08/24/16	Burger King			15,42			
08/24/16	Taste of Peru			70,01			
08/24/16	Sunoco				37,78		
08/24/16	Starbucks			9,54			
08/24/16	Citgo				29,57		
08/24/16	Greens			38,47			
08/24/16	Best Western			154,02			
08/24/16	Best Western			143,68			
08/25/16	Big D				24,00		
08/25/16	Altitude Chop House			95,00			
08/25/16	Firenze			117,05			
08/25/16	Pilot				22,57		
08/25/16	Graham's				36,73		
08/25/16	Shell				33,40		

08/25/16	BP				28,59		
08/25/16	Carr Valley Cheese			129,93			
08/25/16	Mobil				36,95		
08/25/16	Diner			32,79			
08/25/16	Comfort Inn			131,18			
08/25/16	Comfort Inn			131,18			
08/25/16	Comfort Inn			131,18			
08/26/16	Blair's			139,50			
08/26/16	Ranchito			90,00			
08/26/16	Bloedorn Lumber				20,99		
08/26/16	Kennedy Ace Hardware				52,98		
08/26/16	Cenex				16,75		
08/26/16	Arrow				37,63		
08/26/16	Slate Creek Grill			55,89			
08/27/16	Lake Lodge			17,42			
08/27/16	Lake Lodge			168,73			
08/27/16	Yellowstone General Store				41,18		
08/27/16	Albertson's				13,50		
08/27/16	Albertson's			83,24			
08/27/16	Albertson's				2,90		
08/27/16	YPSS				30,74		
08/27/16	Conoco				25,93		
08/28/16	Albertson's			766,15			
08/28/16	Log Cabin Cafe			169,44			
08/28/16	YPSS				36,01		
08/28/16	YPSS				22,01		
08/28/16	Lake Hotel			155,35			
08/30/16	Sinclair				40,02		
08/30/16	Blair's			131,56			
08/30/16	Bloedorn Lumber				15,53		
09/01/16	Dirty Sally's			51,00			
09/02/16	Dirty Sally's			22,91			
09/03/16	Dirty Sally's			51,25			
09/03/16	Pony Express				20,01		
09/03/16	Conoco				45,92		
09/04/16	Shopko				27,02		
09/04/16	Blair's			293,00			
09/04/16	Dirty Sally's			38,00			
09/04/16	Blair's			210,49			
09/04/16	Sinclair				33,68		
09/04/16	Bloedorn Lumber				106,83		
09/05/16	Avis				15,40		
09/06/16	The Paintrock Inn			162,00			
09/08/16	Conoco				51,00		
09/10/16	Pony Express				45,74		
09/10/16	Dirty Sally's			74,44			

09/12/16	Dirty Sally's			16,70			
09/12/16	Dirty Sally's			13,65			
09/12/16	Dirty Sally's			94,98			
09/13/16	Pony Express				40,71		
09/13/16	Bloedorn Lumber				12,06		
09/14/16	Red Reflet Ranch			1 804,50			
09/15/16	Pony Express				60,00		
09/16/16	Dirty Sally's			6,41			
09/16/16	Pony Express				35,28		
09/16/16	Krull's			12,77			
09/16/16	Conoco				32,14		
09/16/16	Johnny J's			90,80			
09/16/16	Black Bear Café			124,17			
09/16/16	Dirty Sally's			7,88			
09/17/16	Get-n-Go				26,67		
09/17/16	Amish Market Sq.				34,99		
09/17/16	Amish Market Sq.			29,52			
09/17/16	Petro Trav Cntr				19,14		
09/17/16	Rolling Prairie				36,06		
09/17/16	Diner			63,00			
09/17/16	Love's				60,00		
09/17/16	Best Western			119,89			
09/17/16	Best Western			119,89			
09/18/16	Garden Grille&Bar			28,38			
09/18/16	Lab Topaz				22,05		
09/18/16	Diner			26,73			
09/18/16	Ingrams				48,91		
09/18/16	DMNS Café			5,89			
09/18/16	Avis		4 860,26				
10/06/16	PayPal				62,02		
11/25/16	PayPal				255,38		
	Subtotals in currency used:	972,00	6 002,21	14 584,79	1 809,47	0,00	0,00
	Subtotals in US \$:	\$972,00	\$6 002,21	\$14 584,79	\$1 809,47	\$0,00	\$0,00

Total US \$: **\$23 368,47**

Traveler's Signature: _____

Date: __23 Nov
2016_____

3I. Log of expenses for 2017

FORM #4

AMERICAN MUSEUM OF NATURAL HISTORY 

LOG OF EXPENSES

Travel Form

: _____

Traveler: Carl Mehling

Trip Dates: 15-Aug-17 — 15-Sep-17
FROM TO

Destination: Ten Sleep, WY

Currency Used: US Dollar (USD)

Exchange Rate: 1.00
 USD = 1,000

[Currency Converter website](#)

Reimbursement Method: (Check One Box)

- Actual Receipts
- Actual Lodging Expense + Per Diem Meals
- Full Per Diem

[Domestic Per Diem Rates](#)

[Look Up](#)

[Foreign Per Diem Rates Look Up](#)

Please use separate page for each currency used

DATE	PAID TO	AIRFARE	VEHICLE RENTAL	LODGING / MEALS	OTHER	REGISTRATION	PARTICIPANT SUPPORT
		418,4181	418,4182	418,4184	418,4183	461.4610	466,4665
06/22/17	Big Agnes				100,00		Alex
07/13/17	Best Western			511,00			Alex
07/26/17	Amazon				70,41		Alex
08/10/17	REI				47,78		
08/12/17	Kwik Fill				40,95		Alex
08/12/17	Chipotle			12,35			Alex
08/12/17	Chestnut Mart				26,59		Alex
08/13/17	Hampton Inn & Suites			168,74			Alex
08/13/17	Granger Bell Mart				38,80		Alex
08/13/17	Erin's Snug Irish Pub			15,81			Alex
08/13/17	Circle K				27,37		Alex
08/13/17	Kwik Trip				36,42		Alex
08/13/17	Delta	1 181,90					Octavio
08/14/17	Duffy's BP				37,27		Alex
08/14/17	Sioux Fall Gas Station				29,10		Alex
08/14/17	Mousehouse Cheesehaus			138,03			Alex
08/14/17	I-80 Travel Plaza				43,49		Octavio
08/14/17	McDonald's			7,93			Alex
08/14/17	Big Top			120,21			Octavio
08/14/17	AMNH Gift Shop				30,00		
08/14/17	Arby's			43,07			Octavio
08/14/17	Best Western			178,02			Octavio

08/14/17	Best Western			166,54			Octavio
08/14/17	Best Western			166,54			Octavio
08/14/17	Fairfield Inn & Suites			147,71			Alex
08/15/17	Delta	388,20					
08/15/17	Country Pride Conven				25,67		Alex
08/15/17	Big D				36,29		Alex
08/15/17	Meadlow Lark Lake Lodge				20,00		Alex
08/15/17	Kennedy Ace Hardware				73,40		Octavio
08/15/17	Blair's			313,20			Octavio
08/15/17	Blair's			104,33			Octavio
08/15/17	Kum & Go				27,11		
08/15/17	Linda's Fry Bread			72,00			
08/15/17	Gas				17,00		
08/15/17	Veteran's				75,00		
08/15/17	Comfort Inn			179,85			Octavio
08/15/17	Comfort Inn			179,85			Octavio
08/15/17	Comfort Inn			179,85			Octavio
08/15/17	Holiday Inn			141,69			Alex
08/16/17	Pony Express Conoco				40,29		
08/16/17	Dirty Sally's			3,68			
08/16/17	Dirty Sally's				12,89		Joao
08/17/17	Bloedorn Lumber				86,61		
08/17/17	Dirty Sally's				6,15		
08/17/17	Blair's			1 435,27			
08/18/17	Pony Express Conoco				72,87		
08/18/17	Pony Express Conoco				40,17		
08/19/17	Pony Express Conoco				10,00		
08/19/17	Pony Express Conoco				9,78		
08/19/17	Dirty Sally's			52,00			
08/20/17	Pony Express Conoco				17,50		
08/20/17	Pony Express Conoco				37,62		
08/21/17	Dirty Sally's			37,44			
08/23/17	Pony Express Conoco				38,70		
08/23/17	Ten Sleep Saloon			199,68			
08/23/17	Dirty Sally's				53,30		
08/23/17	Pony Express Conoco				40,00		Octavio
08/23/17	Dirty Sally's				6,25		Octavio
08/24/17	Dirty Sally's			50,33			
08/25/17	Blair's			29,58			Alex
08/25/17	Wyoming Dinosaur Center				48,00		
08/25/17	Blair's			247,22			
08/25/17	Big Horn Coop				38,96		
08/25/17	Black Bear Café			78,93			
08/25/17	Ace Hardware				96,09		
08/25/17	The Metropolitan			28,35			Octavio

08/28/17	Stop N Go				26,05		
08/28/17	Pony Express Conoco				36,18		
08/28/17	Johnny J's Diner			70,37			
08/29/17	Dirty Sally's				19,40		
08/29/17	Pony Express Conoco				36,77		
08/29/17	Dirty Sally's				31,96		
08/30/17	Dirty Sally's				30,93		
08/31/17	Bradis Candies			54,73			
08/31/17	Napa Auto				15,74		
08/31/17	Greybull Bldg Center				12,58		
08/31/17	Cenex				137,33		
09/01/17	Dirty Sally's				50,99		
09/01/17	Pony Express Conoco				43,49		
09/02/17	Bozeman Trail Steak House			23,19			
09/02/17	Dirty Sally's				25,09		
09/03/17	Pony Express Conoco				7,54		Marco
09/03/17	Pony Express Conoco				32,41		
09/03/17	Pony Express Conoco				52,88		
09/03/17	Home Depot				59,19		Alex
09/04/17	Dirty Sally's				3,75		
09/05/17	Blair's			8,38			Alex
09/05/17	Eastside Sinclair				15,00		Alex
09/05/17	Blair's				226,99		Alex
09/05/17	Kennedy Ace Hardware				113,32		Alex
09/06/17	Dirty Sally's				15,00		
09/07/17	Bloedorn Lumber				115,74		
09/07/17	Pony Express Conoco				40,96		
09/07/17	Pony Express Conoco				51,49		
09/08/17	Dirty Sally's				174,34		
09/08/17	Kennedy Ace Hardware				56,67		
09/08/17	Bloedorn Lumber				74,29		
09/09/17	Pony Express Conoco				42,06		
09/10/17	Shopko				38,36		
09/10/17	Kennedy Ace Hardware				4,18		
09/10/17	Blair's			5,79			
09/10/17	Pony Express Conoco				30,64		
09/10/17	Pony Express Conoco				29,22		
09/11/17	Pony Express Conoco				35,31		Octavio
09/11/17	Cenex				24,16		
09/11/17	Pilot				40,00		
09/11/17	Ditty's				40,16		
09/11/17	Cubby's				39,02		
09/11/17	Great Harvest Bread Co.			47,07			Octavio

09/11/17	Great Harvest Bread Co.			12,75			Octavio
09/11/17	Gas Express II				40,00		Octavio
09/11/17	Dirty Sally's				5,50		Octavio
09/12/17	5280 Burger Bar			115,47			
09/12/17	Sinclair				32,00		
09/12/17	Kyoto			244,86			
09/12/17	Rochelle Travel				46,66		
09/12/17	5280 Burger Bar						
09/13/17	Best Western			326,18			Alex
09/13/17	Best Western			326,18			Alex
09/13/17	Best Western			326,18			Alex
09/13/17	Sunoco				30,00		
09/13/17	Richard Walker's			61,18			
09/13/17	Avis		3 131,47				Octavio
09/14/17	Sunoco				44,56		
09/14/17	Shell				54,48		
09/14/17	Hampton Inn & Suites			214,04			
09/25/17	Red Reflet Ranch			13 372,63			
09/28/17	Les Daugherty Storage				600,00		
09/29/17	Sky Aviation Corp.				1 265,00		
10/02/17	Westside Highway Car Wash				75,00		
10/26/17	Wes Linster				600,00		Wes
10/30/17	PayPal				0,69		
10/30/17	PayPal				0,78		
10/30/17	PayPal				89,13		
10/30/17	PayPal				236,75		
	Subtotals in currency used:	1 570,10	3 131,47	20 218,20	6 407,57	0,00	0,00
	Subtotals in US \$:	\$1 570,10	\$3 131,47	\$20 218,20	\$6 407,57	\$0,00	\$0,00

Total US \$: \$31 327,34

Traveler's Signature: _____

Date: _____

3J. Team members' presence sheet

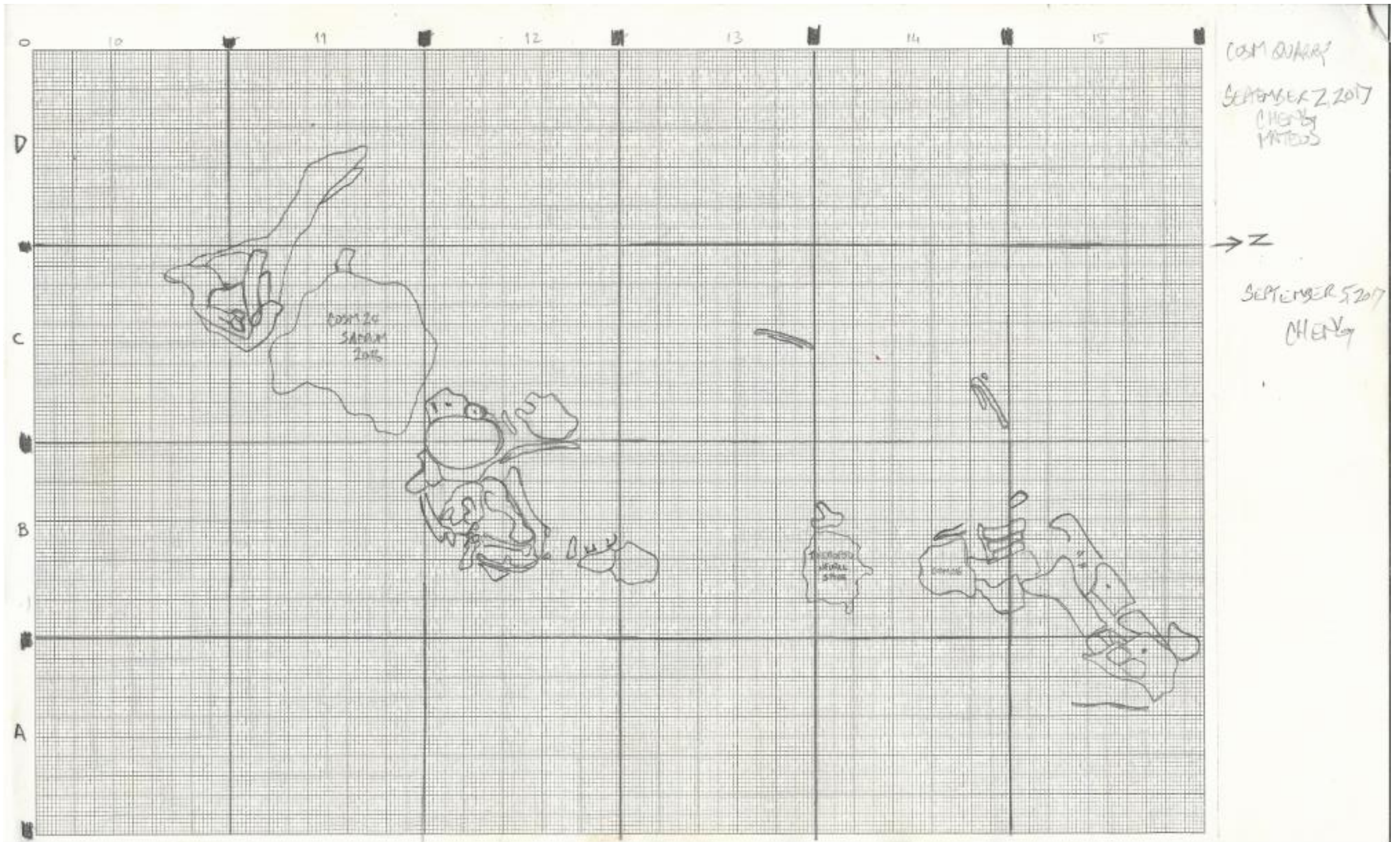
Presence sheet 1: Team members' presence on the field during the expedition of 2016 (on site: ✓, away: -).

Team	August			September														
	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Octávio Mateus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Carl Mehling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Alexandra Fernandes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Alexandre Guillaume	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	✓
André Saleiro	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓
Emanuel Tschopp	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-
João Marinheiro	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
Marco Marzola	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Simão Mateus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
Total of hours of Work	118																	

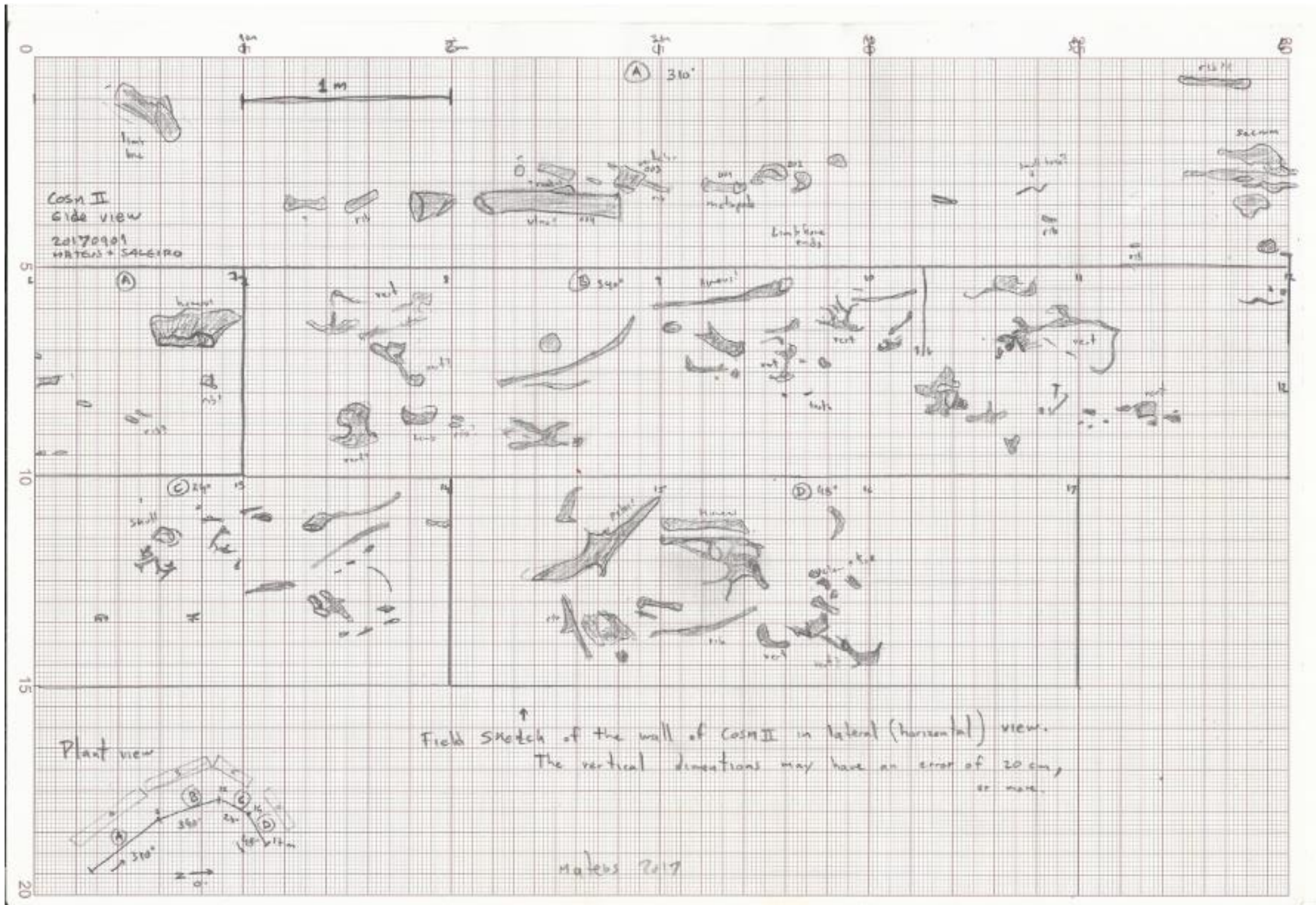
Presence sheet 2: Team members' presence on the field during the expedition of 2017 (on site: ✓; away: -; solar eclipse: ○; attending the Society ofmVertebrate Paleontology 77th Annual Meeting in Calgary, Alberta, Canada: **SVP**).

		AF	AG	AS	CM	ET	JR	MM	MN	OM	VC
August	16	✓	✓	✓	✓	✓	✓	✓	-	✓	-
	17	✓	✓	✓	✓	✓	✓	✓	-	✓	-
	18	✓	✓	✓	✓	✓	✓	✓	-	✓	-
	19	✓	-	✓	✓	✓	✓	✓	-	✓	-
	20	✓	✓	✓	✓	✓	✓	✓	-	✓	-
	21	○	○	○	○	○	○	○	○	○	○
	22	✓	✓	✓	✓	✓	✓	✓	-	✓	-
	23	✓	✓	✓	✓	✓	✓	✓	-	-	-
	24	✓	✓	✓	✓	SVP	✓	SVP	-	SVP	SVP
	25	-	-	-	-	SVP	-	SVP	-	SVP	SVP
	26	✓	✓	✓	✓	SVP	✓	SVP	-	SVP	SVP
	27	✓	✓	✓	✓	-	✓	-	-	✓	-
	28	-	-	-	-	-	-	-	-	-	-
	29	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
30	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	
31	-	-	-	-	-	-	-	-	-	-	
September	1	✓	✓	✓	✓	✓	✓	✓	-	✓	✓
	2	✓	✓	✓	✓	-	✓	✓	-	✓	✓
	3	✓	✓	✓	✓	-	✓	✓	-	✓	✓
	4	✓	✓	✓	-	-	-	✓	-	✓	✓
	5	-	✓	-	✓	-	✓	✓	-	✓	✓
	6	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
	7	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
	8	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
	9	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
Total hours of work: 147											

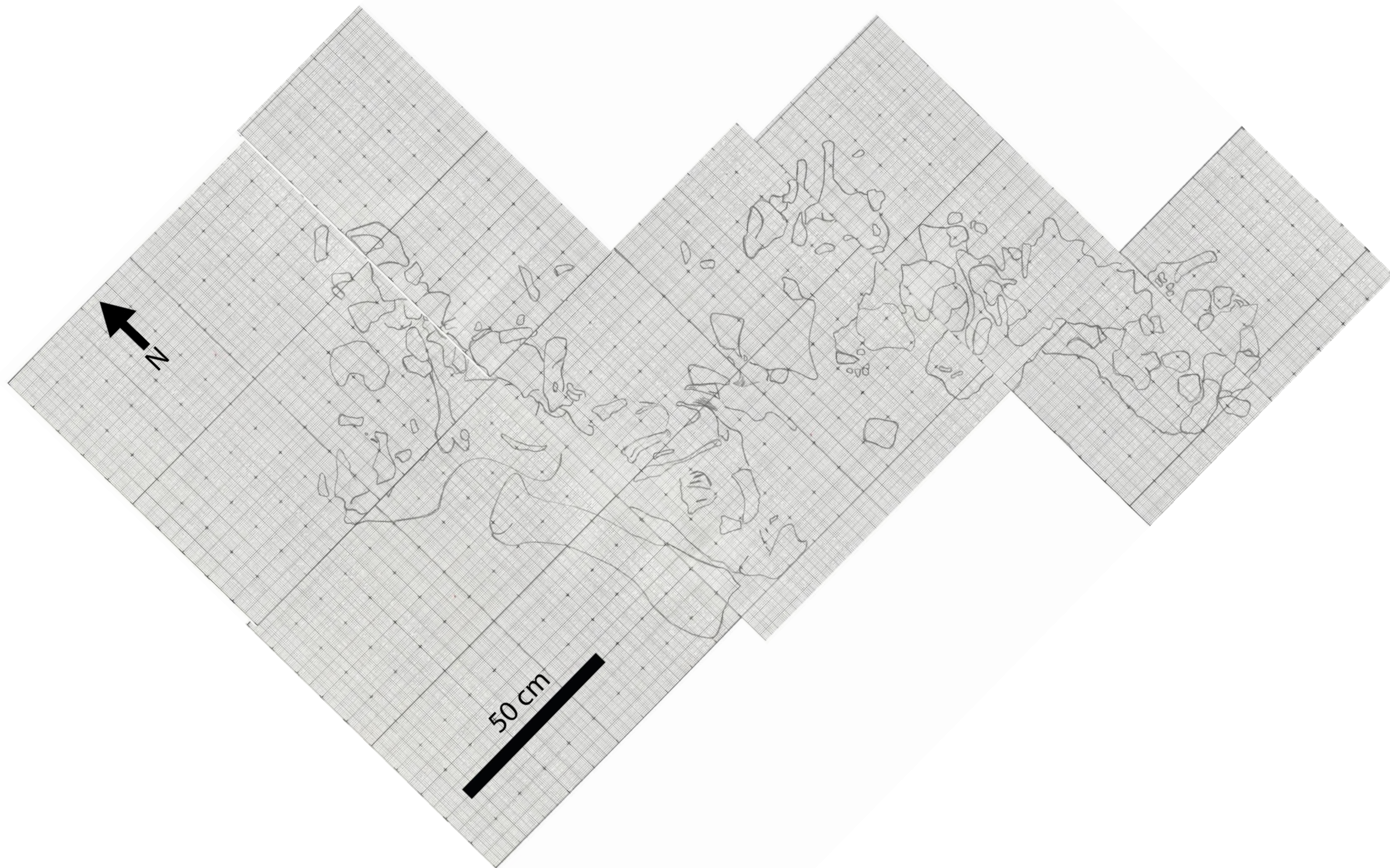
3K. Cosm Quarry map by Vincent Cheng (2017)



3L. Cosm-II map by Octávio Mateus (2017)



3M. Dana Quarry map of theropod assemblage by Vincent Cheng (2017)



3N. Dana Quarry map of the Apatosaurus specimen by Vincent Cheng (2017)



5A. Specimen Transfer Form for the material collected during 2016

American Museum of Natural History
Central Park West at 79th Street
New York, NY 10024-5192

SPECIMEN TRANSFER FORM

The objects described below have been sold/given to AMNH by:

Name Octávio Mateus Tel: +351 212 948 573

Institution of Affiliation, if relevant: Universidade Nova de Lisboa

Address: Dept. Earth Sciences
28 295 16
Caparica, Portugal

Fax: _____

email: omateus@fcf.unl.pt

To the American Museum of Natural History, Department of Vertebrate Paleontology. These specimens are hereby transferred with no limiting conditions or restrictions. I hereby represent that I have full right and title to the objects hereby transmitted and authority to dispose there of.

Specimen # or Number of Specimens with Description.

Dinosaur fossils (AMNH FARB 33053-33089) and plant fossils (AMNH FP 383-419, 423, 425-431) collected south of Hyattville, WY during the summer field season of 2016.

I collected/obtained the material through legal means from:

These specimens were collected under a 2016 BLM permit. PA16-WY-245

If the material was obtained from outside the United States of America, I verify that it was imported into the US by legal means. Where possible, I have provided copies of all relevant documentation (permits, sales receipts, etc.)

If these specimens were collected on United States State or Federal Lands, please specify below where and when. Please include copies of all permits or receipts of purchase.

Date of Delivery of object(s) to the AMNH: 09 / 01 / 2016

Seller's/ Donor's Signature: [Signature]

Date: / /

Curator's Signature: _____

Date: / /

Gift

Exchange

Purchase

Other

Permanent loan of Federal Specimens

5B. Specimen Transfer Form for the material collected during 2016

American Museum of Natural History
Central Park West at 79th Street
New York, NY 10024-5192

SPECIMEN TRANSFER FORM

The objects described below have been sold/given to AMNH by:

Name Octávio Mateus Tel: +351 918351809

Institution of Affiliation, if relevant: Universidade Nova de Lisboa

Address: Dept. Earth Sciences
2829516
Caparica, Portugal

Fax: _____

email: omateus@fct.unl.pt

To the American Museum of Natural History, Department of Vertebrate Paleontology. These specimens are hereby transferred with no limiting conditions or restrictions. I hereby represent that I have full right and title to the objects hereby transmitted and authority to dispose thereof.

Specimen # or Number of Specimens with Description.

Dinosaur fossils (AMNH FARB 33093, 33094, 33095), a fish fossil (AMNH FF 21138), and plant fossils (AMNH FP 412, 422)

I collected/obtained the material through legal means from:

These specimens were collected under a 2016 BLM permit: PA16-WY-245

If the material was obtained from outside the United States of America, I verify that it was imported into the US by legal means. Where possible, I have provided copies of all relevant documentation (permits, sales receipts, etc.)

If these specimens were collected on United States State or Federal Lands, please specify below where and when. Please include copies of all permits or receipts of purchase.

Date of Delivery of object(s) to the AMNH: / /

Seller's/ Donor's Signature: 

Date: 5 / April / 2017

Curator's Signature: _____

Date: / /

Gift

Exchange

Purchase

Other

Permanent loan of Federal specimens

1/99 rev'd 12/99

5C. Loan document regarding the Cosm Quarry material prepared at Museum of Lourinhã

AMNH Loan # <div style="border: 1px solid black; padding: 2px; display: inline-block;">2016-12-4</div> Old Loan #'s	American Museum of Natural History Division of Paleontology Department of Vertebrate Paleontology Fossil Amphibian, Reptile, and Bird Collections (FR)	Date of Loan <div style="border: 1px solid black; padding: 2px; display: inline-block;">9/16/2016</div> Due Date 9/16/2017
<h3 style="margin: 0;">Outgoing Loan Invoice</h3>		
Generator Institution: American Museum of Natural History Department: Dept of Vertebrate Paleontology Address: Central Park West @ 79th St. New York, NY 10024 Contact: Carl Mehling Title: Scientific Assistant Phone: 212-769-5849 e-mail: cosm@amnh.org	Recipient In Care Of: Dr. Octávio Mateus Institution: Universidade Nova de Lisboa Department: Departamento de Ciências da Terra Address: 2829-526 Caparica, Portugal Phone: +351.918381501 e-mail: omateus@gmail.com For Use By: Mateus	

Specimen Number	Taxon	Description	Status
FR 33055 <small>Loaned to Mateus.</small>	Allosaurid	Phalanges & metatarsals	Out
FR 33058 <small>Loaned to Mateus.</small>	<i>Camarasaurus</i> sp.	2 teeth	Out
FR 33061 <small>Loaned to Mateus.</small>	Allosaurid	Pedal bones, tooth, & skull material	Out
FR 33062 <small>Loaned to Mateus.</small>	Allosaurid	Pedal bones	Out
FR 33072 <small>Loaned to Mateus.</small>	?Ornithopod	Phalanx	Out
FR 33077 <small>Loaned to Mateus.</small>	Theropod	Tooth	Out

Invoice notes: Permission granted to prepare any of the specimens

Loan Period: 1 year Approved by: Dr. Mark A. Norell Due Date: 9/16/2017	Please Return all AMNH Boxes to the American Museum of Natural History	Shipment Date: Carrier: Hand Carried # of packages: Airbill number:
---	--	--

A Paleontology loan is for one year, renewable for two more years. Type specimens are not loaned. A loan is to the institution under the care of the borrower. No transfers to a third party -- all loans must be returned to AMNH and we will issue a new loan. Preparation of material is prohibited unless permission is specifically granted by AMNH on this loan form, including making of peels and casts. All products of preparation, e.g. material samples, acid preparation residues, SEM stubs, thin sections are regarded as part of the specimen and must also be returned. 3D scanning of specimens (by CT or other technologies) is prohibited unless prior, written permission is granted by AMNH. This loan can be terminated or otherwise recalled at any time by the Museum for any reason.

AMNH Loan #

2016-12-4

Loan Invoice
(continued)

Specimen Number	Taxon	Description	
FR 33077 Loaned to Mateus.	Theropod	Small phalanx and vertebra	Out
FR 33078 Loaned to Mateus.	? <i>Stokesosaurus clevelandi</i>	Tooth	Out
FR 33079 Loaned to Mateus.	Theropod	Phalanx	Out
FR 33080 Loaned to Mateus.	Theropod	Skull bone fragments	Out
FR 33081 Loaned to Mateus.	Theropod	Tooth	Out
FR 33082 Loaned to Mateus.	Diplodocid	Tooth	Out
FR 33083 Loaned to Mateus.	Allosaurid	Tooth	Out

Total Specimen Count: 13

Please return signed and dated copy of invoice upon receipt and inspection of loan.

Signature: _____

Date: _____

5D. AMNH inventory sheet for the collected fossils of the 2016 expedition

Institution prefix	Collection prefix	Catalog number	Field Number	Taxon Identification	Element(s)	Specimen nickname	Country	State	County	Town or geographic area	Era	Period	Stage	Formation	Remarks
AMNH	FP	383	—	Plant material	?algal concretion	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	384	—	Plant material	?fungal	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	385	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	386	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	387	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	388	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	389	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	390	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	391	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	392	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	393	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	394	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	395	—	Plant material	assorted (2 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	396	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	397	—	<i>Araucaria delevoryasii</i>	?branch	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	398	—	Plant material	assorted (3 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	399	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	400	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	401	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	402	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	403	—	Plant material	oval charcoal clast	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	404	—	<i>Araucaria delevoryasii</i>	branch and scale leaves (3 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	405	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	406	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	

AMNH	FP	407	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	408	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	409	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	410	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	411	—	Plant material	oval charcoal clast	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	412	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	413	—	Plant material	assorted (2 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	414	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	415	—	Plant material	assorted (2 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	416	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	417	—	Plant material	assorted (3 pieces)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	418	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered under Cosm 032
AMNH	FP	419	—	Plant material	assorted	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	423	—	<i>Brachyphyllum</i> sp.	shoot with leaves	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FP	425	Cosm 039	<i>Araucaria delevoryasii</i>	branch with leaves	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Taken by Carole Gee for further study
AMNH	FP	426	Cosm 040	<i>Araucaria delevoryasii</i>	seed cone scale	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Taken by Carole Gee for further study
AMNH	FP	427	Cosm 041	<i>Araucaria delevoryasii</i>	seed cone	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Taken by Carole Gee for further study
AMNH	FP	428	Cosm 042	Plant material	unknown	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Taken by Carole Gee for further study
AMNH	FP	429	Cosm 043	<i>Pagiophyllum</i> sp.	branch	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Possibly a new species of <i>Araucaria</i> . Taken by Carole Gee for further study
AMNH	FP	430	Cosm 044	<i>Araucaria delevoryasii</i>	branch with leaves (part and counterpart)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Not at AMNH. Taken by Carole Gee?
AMNH	FP	431	Cosm 045	<i>Pagiophyllum</i> sp.	branch	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Possibly a new species of <i>Araucaria</i> . Taken by Carole Gee for further study
AMNH	FARB	33053	Cosm 022	Sauropod	Left metatarsal II, Ungual phalanx, 2 phalanges (left I-1, and indet.)	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Ungual found "floating" nearby. André Saleiro emailed on 4 Nov 2016: Based on the photos you sent, AMNH FARB 33053 might actually be COSM 013.
AMNH	FARB	33054	Cosm 008 & 014	Diplodocid	Skull: Maxillae (left and right), premaxillae (left and right), orbital, postorbital,	Xana	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Majority of skull at AMNH (Cosm 008), the rest may be with Brock (Cosm 014)

					quadratojugal, 15+ teeth (most <i>in situ</i>)										
AMNH	FARB	33055	Cosm 001, Cosm 002	Allosaurid	Cosm 001=Sacrum (4 sacral vertebrae + 1 ?caudal), 3 metatarsals, 2 phalanges ; Cosm 002=Skull fragments	Wes	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33056	Cosm 003	Sauropod	ungual phalanx	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33057	Cosm 004	?Ornithopod	Limb bone	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 blocks
AMNH	FARB	33058	Cosm 005, Cosm 006	<i>Camarasaurus</i> sp.	Premaxilla with (at least) 3 teeth in situ, maxilla, 5 loose teeth that were collected nearby	André	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33059	Cosm 009	Diplodocid	8 caudal vertebrae	Marco	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 vertebra (Block B) collected in the same block as COSM 017
AMNH	FARB	33060	Cosm 017	<i>Camarasaurus</i> sp.	Caudal vertebra	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Collected with 2 Cosm 009 (AMNH FARB 33059) vertebrae
AMNH	FARB	33061	Cosm 021, Cosm 025, Cosm 026, Cosm 030, Cosm 054	Allosaurid	Cosm 021=Skull: Premaxilla (4 teeth <i>in situ</i>), basicranium and occipital ?condyle; Cosm 025= phalanx III, medial phalanx II2/IV2, 3 unguual phalanges; Cosm 026=3 metatarsals a phalanx plus skull material; Cosm 030=left humerus and radius; Cosm 054=1 tooth	Brock	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Cosm 021-Associated material collected while cleaning the block (bone fragments, sauropod teeth and theropod teeth) is with Brock Sisson as of 12 Oct 2016.
AMNH	FARB	33062	Cosm 023, Cosm 032	Allosaurid	Cosm 023=Pes (metatarsal + phalanx), 2 chevron, 2 caudal vertebrae, 2 small vertebrae; Cosm 032=4 articulated vertebrae (at least)	Octavio	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Cosm 023: Blocks A (Chevron), B (Matatarsal), C (Phalanx) and D (Chevron). Cosm 032: Blocks A (2 vertebrae), B (3 neural spines) and C (3 vertebrae). The neural spines of B belong to the vertebrae of C
AMNH	FARB	33063	Cosm 024	Diplodocid	Sacrum (4 vertebrae with 3 neural arches fused)	Emanuel	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33064	Cosm 027	Sauropod	Two caudal vertebrae	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33065	Cosm 028	Sauropod	Two pedal bones	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33066	Cosm 029	Theropod	Small vertebra	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	

AMNH	FARB	33067	Cosm 031	Sauropod	Caudal vertebra neural spine	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33068	Cosm 033	Sauropod	Rib	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33069	Cosm 035	Sauropod	Vertebra neural spine	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33070	Cosm 036	Sauropod	Vertebra	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33071	Cosm 037	Sauropod	Chevron	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33072	Cosm 038	?Ornithopod	Phalanx	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Recovered near "Brock"
AMNH	FARB	33073	Cosm 046	Sauropod	Medial caudal vertebra	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33074	Cosm 049	Sauropod	?Interclavicle	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33075	Cosm 052	?Sauropod	?Scapula	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33076	Part of Cosm 053	Sauropod	Ungual phalanx	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33077	Part of Cosm 053	Theropod	Small phalanx and vertebra	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33078	Cosm 055	? <i>Stokesosaurus clevelandi</i>	tooth	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33079	Cosm 056	Theropod	Phalanx	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found floating near Cosm 009.
AMNH	FARB	33080	Cosm 057	Theropod	Skull bone fragments	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Two fragments found floating near Cosm 026.
AMNH	FARB	33081	Cosm 058	Theropod	tooth	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33082	Cosm 059	Diplodocid	tooth	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found floating near Cosm 032.
AMNH	FARB	33083	Cosm 060	Allosaurid	tooth	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found floating near Cosm 005 and 006.
AMNH	FARB	33084	Dana 001	Stegosaurid	Femur, humerus and rib	Scrappy(?)	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Four blocks (A, B, C and D)
AMNH	FARB	33085	Cosm 050	Sauropod	Two anterior caudal vertebrae	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Articulated
AMNH	FARB	33086	—	?Sauropod	Bone fragments	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic		Morrison	Found as Morrison material that was reworked into overlying Cloverly Fm. and then rolled back down to the Morrison sediments.
AMNH	FARB	33087	—	Sauropod	Twelve gastroliths, one with ?paleozoic fossils	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic		Morrison	According to André Saleiro: The small ones were found at the Cosm Quarry, the large ones were found in sediments from the top of the Morrison Fm. at another locality. Note with the bag of gastroliths said: Gastroliths, top Morrison Fm., [in email from André Saleiro 4 Nov

															2016]1513m [or 1543 or 1593], Road Ten Sleep Hyattville, WY, coll. by OMateus, 12 Sept 2016.
AMNH	FARB	33088	Cosm 013	Sauropod	Phalanx	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	André Saleiro emailed on 4 Nov 2016: Based on the photos you sent, AMNH FARB 33053 might actually be COSM 013.
AMNH	FARB	33089	—	Sauropod	Gastrolith	—	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found near Cosm 023

5E. AMNH inventory sheet for the collected fossils of the 2017 expedition

Institution prefix	Collection prefix	Catalog number	Field Number	Taxon Identification	Element(s)	Specimen nickname	Country	State	County	Town or geographic area	Era	Period	Stage	Formation	Remarks
AMNH	FARB	33096	SNDC 1	<i>Ophthalmosaurus natans</i>	Vertebrae, rib fragments, 2 limb bone fragments, phalanx	–	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic		Sundance	Found by Carl Mehling on 3 Sep 2016, but not collected until 2017 (when the state of preservation had degraded).
AMNH	FARB	33097	SNDC 2	<i>Ophthalmosaurus natans</i>	Vertebra	–	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic		Sundance	Found by Alexandra Fernandes 5 Sep 2016.
AMNH	FARB	Not yet assigned	DANA 2	Diplodocidae	Isolated anterior caudal vertebra	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 3	Theropoda ?	3 vertebrae	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 4	Sauropoda	Metatarsal V	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 5	Dinosauria	Neural spine (?), ribs (?), and other unidentified bones	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 6	<i>Apatosaurus</i>	A: proximal end of a femur; B: tibia and fibula(?), part of a femur(?), associated podial material; C: several vertebrae and neural spines (10+), and distal part of a femur	Alex	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 7	Sauropoda	Caudal vertebrae	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	DANA 8	Allosauridae	Anterior caudal vertebra	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33098	–	<i>Ornitholestes</i> (?)	Several bones including claws, vertebrae, teeth, and several associated, unidentified bone fragment	João	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	9 bags containing material as well as material collected associated to the specimen or nearby the collection site, (AMNH FARB 33099 was removed from this lot).
AMNH	FARB	33099	–	<i>Allosaurus</i> (?)	Tooth	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found with <i>Ornitholestes</i> (?).
AMNH	FARB	33109	–	<i>Allosaurus</i> (?)	Tooth	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Found by Octávio Mateus as float a short distance west of AMNH FARB 33098 (too far to be associated). While Carl Mehling was handling it, it broken in half.
AMNH	FARB	33100	–	Theropoda	2 phalanges	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	One complete and half of another.
AMNH	FI	113385	–	Bivalvia	Shell fragments	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	19 distinct valve fragments.
AMNH	FI	113386	–	Gastropoda	Shells	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	7 distinct shells.
AMNH	FP	Not yet assigned	–	Plantae	2 pieces of petrified wood	–	USA	WY	Washakie	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	

AMNH	FARB	Not yet assigned	COSM 16	Sauropoda	Ilium, tibia, and fibula	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Flown hung from helicopter to Dana Quarry by Dennis Charney on September 29th.
AMNH	FARB	Not yet assigned	COSM 24	Diplodocidae	Sacrum (4 vertebrae with 3 neural arches fused)	Emanuel	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	1 main block + 1 block with associated rib. Flown hung from helicopter to Dana Quarry by Dennis Charney on September 29th.
AMNH	FARB	Not yet assigned	COSM 61.17N	Sauropoda	Phalanx, and associated fragment of another phalanx	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 parts. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 62.17S	Sauropoda	Left pedal claw	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"S" in field number denotes that it came from the south end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 63.17N	Sauropoda	Phalanx	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 64.17N	Dinosauria	Small limb bone	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 pieces. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 65.17N	Theropoda	Small tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 66.17N	?	Neural arch (?)/Part of a jaw (?)	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	1 bag (4 small packages and a small bag) and 1 package. "N" in the field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 67.17N	Theropoda	Isolated phalanx	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 pieces. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FI	Not yet assigned	COSM 68.17N	<i>Unio</i> (?)	Shell fragments	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 69.17N	<i>Stokesosaurus</i> (?)	Tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	D-shaped in cross section. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 70.17N	Dinosauria	Radius and ulna	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Divided in 2 blocks. "N" in field number denotes that it came from the north end of the original 2016 quarry.

AMNH	FARB	Not yet assigned	COSM 71.17N	<i>Allosaurus</i> (?)	Tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Only the basal half is preserved. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FP	432	COSM 72.17N	Plantae	4 pieces of amber	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"N" in field number denotes that it came from the north end of the original 2016 quarry
AMNH	FARB	33101	COSM 73.17N	<i>Camarasaurus</i>	Tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Complete, but divided in 3 parts. "N" in field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 74.17N	Sauropoda (?)	Rib	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	In the same block as COSM 070 and 075. "N" in the field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 75.17N	Sauropoda	Articulated caudal vertebrae	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	In the same block as COSM 070 and 076. Around 4-5 articulated vertebrae were collected in 2017. One of them was incomplete, since its other half was separated by a fault. More vertebrae may still be in the ground as of 2017. "N" in the field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FARB	Not yet assigned	COSM 76.17N	Theropoda	Vertebra neural spine	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	"N" in the field number denotes that it came from the north end of the original 2016 quarry.
AMNH	FP	Not yet assigned	_	<i>Araucaria</i>	Branch, cones, scales, and other elements	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	1 bag with 14 packages
AMNH	FARB	Not yet assigned	Cosm-II 1	Sauropoda	Metacarpal	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	Cosm-II 2	Sauropoda	Limb bones ends	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	Cosm-II 3	Sauropoda	Caudal vertebra and gastralium	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	1 block, 2 packages.
AMNH	FARB	Not yet assigned	Cosm-II 4	Sauropoda	Associated ulna and gastrolith	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	2 blocks.
AMNH	FARB	Not yet assigned	Cosm-II 5	Sauropoda	Unidentified bone	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	Not yet assigned	Cosm-II 6	Diplodocidae	Small tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	
AMNH	FARB	33102	Cosm-II 7	Theropoda	Very small tooth	_	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Jurassic	Tithonian	Morrison	Near a cervical vertebra.

AMNH	FF	21226	-	Shark	Tooth	-	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Cretaceous	-	Cody Shale (?)	Collected off an anthill north of the road to Cosm Quarry in a black shale layer.
AMNH	FF	21227	-	Ray	Tooth	-	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Cretaceous	-	Cody Shale (?)	Collected off an anthill north of the road to Cosm Quarry in a black shale layer.
AMNH	FARB	33103	-	Crocodylian	Tooth	-	USA	WY	Big Horn	South of Hyattville	Mesozoic	Late Cretaceous	-	Cody Shale (?)	Collected off an anthill north of the road to Cosm Quarry in a black shale layer.
AMNH	FARB	33104	-	Sauropoda (?)	5 gastroliths	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	All gastroliths have fossil (?Ordovician) marine invertebrates (i.e., bryozoans) within.
AMNH	FARB	33105	-	Crocodylian	Tooth	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	Broken in half.
AMNH	FARB	33106	-	Indet.	2 coprolites	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	1 of the 2 coprolites was broken in 5 pieces and left unrepaired because it appears to have inclusions.
AMNH	FARB	Not yet assigned	-	Theropoda	Large tooth in 2 pieces	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	4 gastroliths have fossil (?Ordovician) marine invertebrates (i.e., bryozoans) within and one has a percussion bulb (i.e., it was culturally modified).
AMNH	FARB	33107	-	Sauropoda (?)	5 gastroliths	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	Fossil (?Ordovician) ?bivalve shells exposed on surface.
AMNH	FARB	33108	-	Sauropoda (?)	Gastrolith	-	USA	WY	Big Horn	North of Hyattville	Mesozoic	Early Cretaceous	-	Cloverly (?)	

5F. Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33058

Terms and Conditions of AMNH Specimen Scans

AMNH Loan #: 2016-12-4	Date of Loan: 9/16/2016
Borrower: Octávio Mateus	Due Date / Loan Expiration: 9/16/2017
Specimen #: AMNH FARB 33058	Specimen Taxon: <i>Camarasaurus</i> sp.
Specimen Description: 2 isolated teeth	

As a condition of the loan of the foregoing Specimen by the American Museum of Natural History, 79th Street at Central Park West, New York, NY 10024 to the Borrower above, AMNH and Borrower hereby agree that Borrower may employ only the following technology(ies), specifically detailed below, to create images, scans, photographs, x-rays, rendered data, movies, 3D models, or other representations, electronic or otherwise, of the Specimen (collectively "Scans");

Photogrammetry using Agisoft Photoscan

Use of any additional technology to create Scans of the Specimen or otherwise image, duplicate, replicate, or copy the Specimen shall be allowed only upon written authorization from AMNH.

In addition, AMNH and Borrower hereby agree as follows:

1. Molds/Casts: Borrower will not create physical molds or casts of the Specimen without separate written agreement from AMNH.
2. Other Party Scans: Borrower will not allow any other entity to create Scans of the Specimen unless otherwise authorized in writing by AMNH.
3. Assignment of Scan Rights to AMNH: Borrower hereby assigns to AMNH all rights, including copyrights, in and to any Scans and associated raw and pre-processed data (i.e., image files such as .tif, .jpg, .DICOM, and other imaging files) of the Specimen created by Borrower. In addition, Borrower will provide AMNH with free electronic copies of any Scans of the Specimen and underlying Scan data prepared by Borrower as soon as practicable following creation of such Scans, and in no event later than one (1) year following the creation of such Scans.
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- b. Borrower cannot and shall not deposit the Scans in any electronic or other repository that requires the depositor to grant rights to the Scans that are more expansive than the rights granted to Borrower herein, including repositories that require Scans to be provided under a Creative Commons or similar license, without the express written permission of AMNH in each instance.
- c. Borrower's use of the Scans shall include the following attribution to AMNH in each instance:
- i. "[Title Specimen/Scan], [AMNH Specimen Catalog Number], © American Museum of Natural History"
5. **Embargo:** Unless otherwise agreed by the parties in writing, AMNH will not itself reproduce, make derivative works of, distribute, and/or display the Scans (except as required for AMNH's own internal record-keeping and archival purposes) or allow third parties to do so until the earlier of: (i) Borrower's publication of the Specimen Scans in any form pursuant to the foregoing license, or (ii) three years from the date of this Agreement. Notwithstanding the foregoing, Borrower acknowledges and agrees that this in no way limits or restricts AMNH or other AMNH-approved entities from creating their own Scans of the Specimen, which shall not be subject to the above with respect to Borrower.
6. **Scans from AMNH Facilities:** Notwithstanding the foregoing, any Scans created using AMNH's own facilities and/or equipment, including Scans created in AMNH's Microscopy and Imaging Facility (MIF), shall not be subject to the restrictions set forth above in paragraph 5, and Borrower acknowledges and agrees that AMNH may retain copies of all Scans and associated data created using AMNH's facilities and/or equipment immediately upon creation.
7. By signing below, Borrower acknowledges that it has read and agrees with the additional terms for AMNH specimen loans provided [here](http://www.amnh.org/our-research/paleontology/loans) (<http://www.amnh.org/our-research/paleontology/loans>).

Accepted and agreed:

American Museum of Natural History

Name: _____

Title: _____

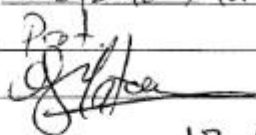
Sign: _____

Date: _____

Borrower

Name: Ochsuid Matias

Title: Prof.

Sign: 

Date: 17.6.2017

5G. Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33061

Terms and Conditions of AMNH Specimen Scans

AMNH Loan #: 2016-12-4	Date of Loan: 9/16/2016
Borrower: Octávio Mateus	Due Date / Loan Expiration: 9/16/2017
Specimen #: AMNH FARB 33061	Specimen Taxon: Allosauridae indet.
Specimen Description: Left metatarsals I, I, III, and IV, phalanges I-1, III-1, III-2, and III-3, 3 ungual phalanges, and left maxillary tooth	

As a condition of the loan of the foregoing Specimen by the American Museum of Natural History, 79th Street at Central Park West, New York, NY 10024 to the Borrower above, AMNH and Borrower hereby agree that Borrower may employ only the following technology(ies), specifically detailed below, to create images, scans, photographs, x-rays, rendered data, movies, 3D models, or other representations, electronic or otherwise, of the Specimen (collectively "Scans"):

Photogrammetry using Agisoft Photoscan

Use of any additional technology to create Scans of the Specimen or otherwise image, duplicate, replicate, or copy the Specimen shall be allowed only upon written authorization from AMNH.

In addition, AMNH and Borrower hereby agree as follows:

1. **Molds/Casts:** Borrower will not create physical molds or casts of the Specimen without separate written agreement from AMNH.
2. **Other Party Scans:** Borrower will not allow any other entity to create Scans of the Specimen unless otherwise authorized in writing by AMNH.
3. **Assignment of Scan Rights to AMNH:** Borrower hereby assigns to AMNH all rights, including copyrights, in and to any Scans and associated raw and pre-processed data (i.e., image files such as .tif, .jpg, .DICOM, and other imaging files) of the Specimen created by Borrower. In addition, Borrower will provide AMNH with free electronic copies of any Scans of the Specimen and underlying Scan data prepared by Borrower as soon as practicable following creation of such Scans, and in no event later than one (1) year following the creation of such Scans.
4. **Grant of License to Borrower:** AMNH hereby grants to Borrower a non-exclusive, non-transferable, worldwide license to reproduce, make derivative works of, distribute, and display the Scans solely for the following non-commercial uses: (i) publication by Borrower in peer-reviewed academic journals; and (ii) Borrower's own classroom use. This grant is subject to the following:
 - a. Borrower shall have no rights to sublicense the foregoing rights in and to the Scans for any purpose except as necessary for publication in peer-reviewed academic journals without the express written permission of AMNH;

- b. Borrower cannot and shall not deposit the Scans in any electronic or other repository that requires the depositor to grant rights to the Scans that are more expansive than the rights granted to Borrower herein, including repositories that require Scans to be provided under a Creative Commons or similar license, without the express written permission of AMNH in each instance.
 - c. Borrower's use of the Scans shall include the following attribution to AMNH in each instance:
 - i. "[Title Specimen/Scan], [AMNH Specimen Catalog Number], © American Museum of Natural History"
5. **Embargo:** Unless otherwise agreed by the parties in writing, AMNH will not itself reproduce, make derivative works of, distribute, and/or display the Scans (except as required for AMNH's own internal record-keeping and archival purposes) or allow third parties to do so until the earlier of: (i) Borrower's publication of the Specimen Scans in any form pursuant to the foregoing license, or (ii) three years from the date of this Agreement. Notwithstanding the foregoing, Borrower acknowledges and agrees that this in no way limits or restricts AMNH or other AMNH-approved entities from creating their own Scans of the Specimen, which shall not be subject to the above with respect to Borrower.
6. **Scans from AMNH Facilities:** Notwithstanding the foregoing, any Scans created using AMNH's own facilities and/or equipment, including Scans created in AMNH's Microscopy and Imaging Facility (MIF), shall not be subject to the restrictions set forth above in paragraph 5, and Borrower acknowledges and agrees that AMNH may retain copies of all Scans and associated data created using AMNH's facilities and/or equipment immediately upon creation.
7. By signing below, Borrower acknowledges that it has read and agrees with the additional terms for AMNH specimen loans provided [here](http://www.amnh.org/our-research/paleontology/loans) (<http://www.amnh.org/our-research/paleontology/loans>).

Accepted and agreed:

American Museum of Natural History

Borrower

Name: _____

Name: Octavio Mateo

Title: _____

Title: Prof.

Sign: _____

Sign: 

Date: _____

Date: 17.6.2017

5H. Paleo 3-D scanning (non CT) Agreement for AMNH FARB 33062

Terms and Conditions of AMNH Specimen Scans

AMNH Loan #: 2016-12-4	Date of Loan: 9/16/2016
Borrower: Octávio Mateus	Due Date / Loan Expiration: 9/16/2017
Specimen #: AMNH FARB 33062	Specimen Taxon: Allosauridae indet.
Specimen Description: Left metatarsal IV and phalanx IV-4	

As a condition of the loan of the foregoing Specimen by the American Museum of Natural History, 79th Street at Central Park West, New York, NY 10024 to the Borrower above, AMNH and Borrower hereby agree that Borrower may employ only the following technology(ies), specifically detailed below, to create images, scans, photographs, x-rays, rendered data, movies, 3D models, or other representations, electronic or otherwise, of the Specimen (collectively "Scans"):

Photogrammetry using Agisoft Photoscan

Use of any additional technology to create Scans of the Specimen or otherwise image, duplicate, replicate, or copy the Specimen shall be allowed only upon written authorization from AMNH.

In addition, AMNH and Borrower hereby agree as follows:

1. Molds/Casts: Borrower will not create physical molds or casts of the Specimen without separate written agreement from AMNH.
2. Other Party Scans: Borrower will not allow any other entity to create Scans of the Specimen unless otherwise authorized in writing by AMNH.
3. Assignment of Scan Rights to AMNH: Borrower hereby assigns to AMNH all rights, including copyrights, in and to any Scans and associated raw and pre-processed data (i.e., image files such as .tif, .jpg, .DICOM, and other imaging files) of the Specimen created by Borrower. In addition, Borrower will provide AMNH with free electronic copies of any Scans of the Specimen and underlying Scan data prepared by Borrower as soon as practicable following creation of such Scans, and in no event later than one (1) year following the creation of such Scans.
4. Grant of License to Borrower: AMNH hereby grants to Borrower a non-exclusive, non-transferable, worldwide license to reproduce, make derivative works of, distribute, and display the Scans solely for the following non-commercial uses: (i) publication by Borrower in peer-reviewed academic journals; and (ii) Borrower's own classroom use. This grant is subject to the following:
 - a. Borrower shall have no rights to sublicense the foregoing rights in and to the Scans for any purpose except as necessary for publication in peer-reviewed academic journals without the express written permission of AMNH;

- b. Borrower cannot and shall not deposit the Scans in any electronic or other repository that requires the depositor to grant rights to the Scans that are more expansive than the rights granted to Borrower herein, including repositories that require Scans to be provided under a Creative Commons or similar license, without the express written permission of AMNH in each instance.
- c. Borrower's use of the Scans shall include the following attribution to AMNH in each instance:
 - i. "[Title Specimen/Scan], [AMNH Specimen Catalog Number], © American Museum of Natural History"
- 5. **Embargo:** Unless otherwise agreed by the parties in writing, AMNH will not itself reproduce, make derivative works of, distribute, and/or display the Scans (except as required for AMNH's own internal record-keeping and archival purposes) or allow third parties to do so until the earlier of:
 - (i) Borrower's publication of the Specimen Scans in any form pursuant to the foregoing license, or
 - (ii) three years from the date of this Agreement. Notwithstanding the foregoing, Borrower acknowledges and agrees that this in no way limits or restricts AMNH or other AMNH-approved entities from creating their own Scans of the Specimen, which shall not be subject to the above with respect to Borrower.
- 6. **Scans from AMNH Facilities:** Notwithstanding the foregoing, any Scans created using AMNH's own facilities and/or equipment, including Scans created in AMNH's Microscopy and Imaging Facility (MIF), shall not be subject to the restrictions set forth above in paragraph 5, and Borrower acknowledges and agrees that AMNH may retain copies of all Scans and associated data created using AMNH's facilities and/or equipment immediately upon creation.
- 7. By signing below, Borrower acknowledges that it has read and agrees with the additional terms for AMNH specimen loans provided [here](http://www.amnh.org/our-research/paleontology/loans) (<http://www.amnh.org/our-research/paleontology/loans>).

Accepted and agreed:

American Museum of Natural History

Borrower

Name: _____

Name: Octavio Mateo

Title: _____

Title: Prof.

Sign: _____

Sign: 

Date: _____

Date: 17.6.2017

5I. Links to 3D models and model quality data provided by Marco Marzola

N°		ID	Max quality (million faces)	Error (µm)	PDF	OBJ	PLY
- Material for André Saleiro's Master's thesys (COSM Quarry - Wyoming 2016)							
	<i>Camarasaurus</i> sp.						
1	AMNH FARB 33058	Tooth 1	4,9	12	link	link	link
2	AMNH FARB 33058	Tooth 2	4,4	11	link	link	link
	Allosauridae indet.						
3	AMNH FARB 33061	Metatarsals I	5,5	10	link	link	link
4	AMNH FARB 33061	Metatarsals V	4,4	10	link	link	link
5	AMNH FARB 33061	Metatarsals II-IV	17,1	12	link	link	link
6	AMNH FARB 33061	Phalanx I 1	4,2	19	link	link	link
7	AMNH FARB 33061	Phalanx III 1	9,2	16	link	link	link
8	AMNH FARB 33061	Phalanx III 2	7,1	21	link	link	link
9	AMNH FARB 33061	Phalanx III 3	6	12	link	link	link
12	AMNH FARB 33061	Ungual I 2	3,3	7	link	link	link
11	AMNH FARB 33061	Ungual III 4	3,5	19	link	link	link
10	AMNH FARB 33061	Ungual IV 5	3,4	13	link	link	link
13	AMNH FARB 33061	Tooth	5	7	link	link	link
	Allosauridae indet.						
14	AMNH FARB 33062	Metatarsal IV	14,4	15	link	link	link

The models provided are:

- PLYs, based on the best quality possible obtained, for 3D printing;
 - OBJs, based on 5M-face models (except when the best quality obtained model is lower than 5M faces), for elaboration and measurements on PC (i.e. Mesh Lab);
 - PDFs, based on 1M-face models, good for depository and easy access to anyone.
- All the PLYs and OBJs are scaled, PDFs cannot be scaled.

5J. Theropod teeth measurements, following the anatomical, and morphometric terminology and measurement variables of Hendrickx et al., 2015

Teeth Measurements	AMNH FARB 33061	AMNH FARB 33077	AMNH FARB 33078	AMNH FARB 33081	AMNH FARB 33083
<u>Crown</u>					
AL (mm)	46.5	18 ^(p)	5	13 ^(p)	22 ^(p)
CH (mm)	43	15 ^(p)	6.5 ^(p)	11 ^(p)	18 ^(p)
CBL (mm)	22	5.5 ^(p)	~4.5	9	13.5 ^(p)
CBW (mm)	10	5 ^(p)	~4.1	4	6
CBR	~0.45	1.1	~0.91	~0.44	~0.44
MCL (mm)	18	6	4	6.5	12
MCW (mm)	9	3	3	3	4.5
MCR	0.5	0.5	0.75	~0.46	0.375
<u>Denticles</u>					
DSL (mm)	43	10.5 ^(p)	6	9 ^(p)	13 ^(p)
DDH (mm)	0.75	~0.25	?	~0.25	~0.30
DDL (mm)	~0.37	~0.25	~0.25	0.25	0.25
DDW (mm)	1	~0.50	~0.50	~0.50	~0.50
DA	13 (/5mm)	18 (/5mm)	?	?	?
DC	14 (/5mm)	13 ^(p) (/5mm)	6 (/2mm)	15 ^(p) (/5mm)	19 (/5mm)
DB	23 (/5mm)	?	8 (/2mm)	20 ^(p) (/5mm)	10 ^(p) (/5mm)
MSL (mm)	40	18 ^(p)	4	?	8 ^(p)
MDE (mm)	6.5	?	1	?	10
MDH (mm)	0.50	~0.25	?	?	~0.10
MDL (mm)	~0.40	0.25	0.25	?	0.25
MDW (mm)	0.50	~0.37	~0.25	?	~0.50
MA	13 (/5mm)	17 (/5mm)	?	?	?
MC	17 ^(p) (/5mm)	7 ^(p) (/5mm)	6 (/2mm)	?	14 ^(p) (/5mm)
MB	0	?	0	0	0

Abbreviations: ^(p), partially preserved; ?, missing data; **AL**, apical length; **CH**, crown height; **CBL**, crown base length; **CBW**, crown base width; **CBR**, crown base ratio; **MCL**, mid-crown length; **MCW**, mid-crown width; **MCR**, mid-crown ratio; **DSL**, distal serrated carina length; **DDH**, distal denticle height; **DDL**, distal denticle length; **DDW**, distal denticle width; **DA**, distoapical denticle density; **DB**, distobasal denticle density; **DC**, distocentral denticle density; **MSL**, mesial serrated carina length; **MDE**, mesial denticle extension; **MDH**, mesial denticle height; **MDL**, mesial denticle length; **MDW**, mesial denticle width; **MA**, mesoapical denticle density; **MB**, mesobasal denticle density; **MC**, mesocentral denticle density.