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A NEW SPECIMEN OF THE ELASMOSAURID PLESIOSAUR *ZARAFASAURA OCEANIS* FROM THE UPPER CRETACEOUS (MAASTRICHTIAN) OF MOROCCO

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ABSTRACT

A new specimen of the Moroccan elasmosaurid plesiosaur *Zarafasaura oceanis* from the Maastrichtian (Upper Cretaceous) phosphate deposits of Morocco is described. A partial skeleton with an associated skull is mounted on display at the Wyoming Dinosaur Center, USA. The short preorbital region of the skull and contact of the squamosal with the parietals, jugal and postorbital, allow for identification to the genus. However, large amounts of the skull and mounted skeleton are reconstructed so description is difficult in all but a cursory way. In recent years, the popularity of Moroccan material among collectors and the general public has increased the number of display specimens in museums across the world. As plesiosaurs remain very scarce in these rich marine vertebrate strata, any information expanding our understanding of the osteology of a known species warrants study. The new specimen of *Zarafasaura* provides information on postcranial elements which were previously unknown, along with additional information regarding a fairly complete skull that preserves elements that are missing in the holotype specimen.

INTRODUCTION

Plesiosaurs are an extinct group of predatory marine reptiles which have been discovered from the uppermost Triassic (Rhaetian) to the uppermost Cretaceous (Maastrichtian; see discussion in Smith and Vincent, 2010). Remains of plesiosaurs have been found on all continents, with some key discoveries made in North America, Europe and Australia. They achieved a worldwide distribution during the Jurassic. Specifically, the elasmosaurids flourished during the Maastrichtian (Gasparini et al., 2003). In spite of this, the record of plesiosaurs from Africa is relatively poor, with only five taxa currently recognized, the latest of which being *Zarafasaura oceanis* (Vincent et al., 2011). A phylogenetic analysis of plesiosauroids compiled by Vincent et al. (2011) indicates that *Zarafasaura* shares close affinities with elasmosaurids from the Late Cretaceous of North America and Japan. This newly described elasmosaurid represents the first valid plesiosaur from the latest Cretaceous of Africa (Vincent et al., 2011). The scarcity of plesiosaur remains in Morocco has remained somewhat a mystery. In spite of such a low number of reported plesiosaurian discoveries in Africa, the continent has produced some excellently preserved and scientifically important fossils. Such remains have helped to develop a better and more complete understanding of the paleoenvironments and extinct flora and fauna of the region. Specifically the Cretaceous-Paleogene phosphatic deposits of Morocco are famed for their rich fauna of marine vertebrates, such as crocodyliformes, birds, chelonians and a variety of mosasaurs (Bardet et al., 2010; Vincent et al., 2011).

The previous description of isolated material from this formation assigned it to the "wastebasket" taxon *Plesiosaurus mauritanicus* (Arambourg, 1952). They include the holotype tooth (MNHN PMC 22) and a referred specimen consisting of thirteen articulated posterior cervical to anterior dorsal vertebrae (MNHN PMC 23; Arambourg, 1952). Several isolated teeth and one vertebra (MNHN PMC 24, 25, 26-28) were also referred by Arambourg (1952). However, *P. mauritanicus* was regarded as a *nomen dubium* by Vincent et al. (2011) because: 1) the holotype and paratype specimens are composites, derived from two different individuals from two distinct localities; 2) both the holotype and paratype do not exhibit any autapomorphies; 3) the holotypic tooth is morphologically similar to many other Late Cretaceous elasmosaurids; and 4) the genus *Plesiosaurus* is restricted to the Lias. Based on the geographical location and scarcity of other plesiosaurs, much of the material collected from this region is often attributed to this taxon. As isolated remains, including teeth, are deemed morphologically similar to *P. mauritanicus*, the overview of fragmentary material from this region reduces their usefulness. More recently Vincent et al. (in press) reported several new plesiosaur specimens from the same locations within the Maastrichtian Phosphates of Morocco. This material comprises numerous specimens, including partial skeletons (e.g. OCP-DEK/GE 115), limb elements, and isolated

series of cervical/dorsal vertebrae. All of the described material was determined to belong to Elasmosauridae gen. et sp. indet and could not be referred to *Zarafasaura*, as no cranial elements were found associated. Thus at present, isolated elements cannot be identified taxonomically. But more complete specimens, such as WDC CMC-01, will help solve the issue of identifying fragmentary or isolated material, such as that described by Vincent et al. (in press).

As the majority of plesiosaur remains from Africa are often rather fragmentary or of poorly constrained provenance, the importance of recording more complete or diagnostic material is vital. Vincent et al. (2011) reported on a dorsoventrally crushed skull (holotype), and a partial mandible (the paratype) belonging to a new elasmosaurid, *Zarafasaura oceanis*. No post cranial elements are associated with the type material. Here we describe a new, more complete specimen of *Z. oceanis* from the Upper Cretaceous phosphatic mines of Oued-Zem, Morocco. The specimen includes a nearly complete skull and numerous postcranial elements including limbs, pectoral and pelvic material, and vertebrae. Cranial features of WDC CMC-01 identify this individual as belonging to the taxon. This paper provides a report on this relatively complete individual, although the reconstruction of the material and mount of the specimen makes a thorough description difficult.

Abbreviations Used—FFHM, Fick Fossil Museum, Oakley, Kansas (USA); MNHN Muséum national d'Histoire naturelle, Paris (France); OCP, Office Cherifien des Phosphates Khouribga (Morocco); UCMP, University California Museum of Paleontology, Berkeley (California) USA; WDC, Wyoming Dinosaur Center, Thermopolis (Wyoming) USA.

Materials and Methods—WDC CMC-01 was collected from the type location of OCP-DEK/GE 315, the holotype of *Zarafasaura oceanis*. The location of Sidi Daoui is near the city of Oued Zem, situated within the Khouribga Province of the NE Oulad Abdoun Basin. Here the Maastrichtian phosphatic series is very condensed. The series is considered to be late Maastrichtian in age and comprises from base to top: basal grey phosphatic limestone named 'basal bone-bed'; soft yellow phosphates named 'Couche III inférieure' (Lower CIII level); soft grey phosphates with brown streaks named 'Couche III supérieure' (Upper CIII level); and yellow marls (Vincent et al., 2011). WDC CMC-01 derived from the Upper CIII level, Point A (Figure 1). The specimen was discovered and excavated in April 2004, by collector Mohamed Atid. It was primarily collected in five large plaster jackets, with numerous smaller blocks containing the phosphate matrix and isolated bones. The soft grey phosphatic blocks contained numerous elements, including several articulated sections of the vertebral column, which were largely associated with ribs (Figure 2).

The studied specimen was fully prepared and mounted for display (Figure 3). To ensure no information was lost and the bones and orientation of elements were correct as possible, each fragment of bone was individually marked and numbered before preparation. The majority of the posterior caudal vertebrae are entirely carved, with other parts of the postcranial skeleton reinforced with plaster, and sculpted. Initially the skull was found dorsolaterally flattened (Figure 4), and later taken apart piece-by-piece and constructed in three-dimensions for display and public auction. With the collection and preparation of the studied specimen being rendered for display, it is important to note that the entire reconstruction was based upon specimen UCMP 33912, *Hydrotherosaurus alexandrae* (Welles, 1943), an elasmosaurid from the Maastrichtian of California. The specimen was subsequently acquired by the WDC in 2006.

DESCRIPTION

The following description of the studied specimen is largely based on the original photos of the articulated skeleton and crushed skull, although some of the descriptions are derived from the tentative reconstruction, and are so stated.

Skull and Mandible—Due to the nature of the original preservation and subsequent reconstruction of the skull, certain cranial features such as sutures and individual bones are difficult to distinguish with certainty. As the skull has been reconstructed in three-dimensions, its original morphology cannot be determined. Additionally, the lack of many distinctive cranial features could also be due to distortion, which may have slightly deformed the general pattern and shape of the skull. Careful preparation of the specimen allowed the skull to be reconstructed with several autapomorphies intact, including the short snout and wide palate. Some carved elements of the skull have slightly changed its original shape, but not dramatically. For this study, the descriptions of the skull are derived from photographs of the unprepared skull, where possible. In describing the morphology of individual bones of the skull, the use of original photographs were vital.

The skull was found partially articulated with both the fused atlas-axis, and at least fourteen partly articulated cervical vertebrae. It was compressed dorsolaterally and slightly crushed, somewhat similar to the holotype specimen that is crushed dorsoventrally (Vincent et al., 2011, fig. 2a-c). After preparation, the skull was rebuilt with each cranial element pieced back together (Figures 5, 6), assuming a typical elasmosaurian shape, ogival in dorsal aspect and slightly rectangular in lateral aspect. As reconstructed, the skull of WDC CMC-01 is the same as the holotype, bearing a shorter

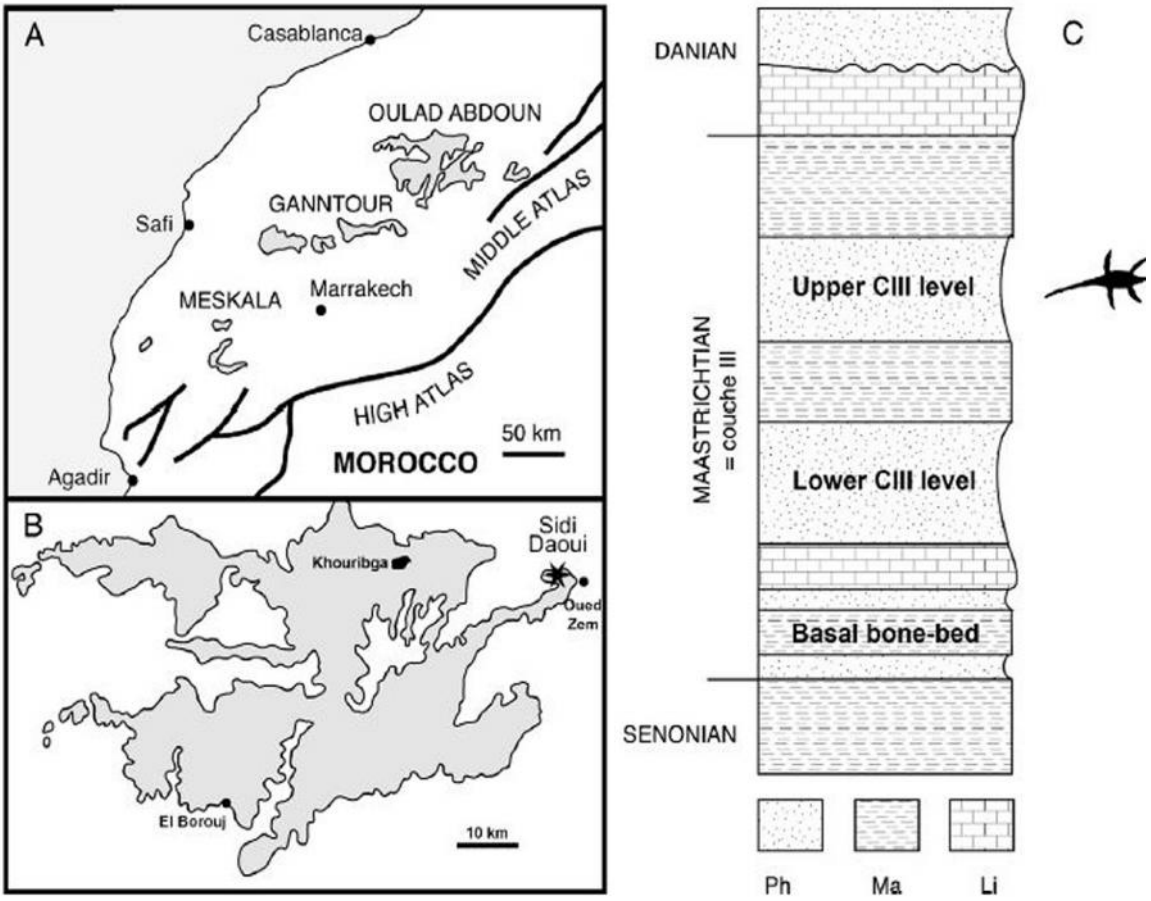

FIGURE 1. Geographical and stratigraphical location of *Zarafasaura oceanis*. A. Main phosphatic basins of Morocco. B. Detail of the Oulad Abdoun Basin, with indication of the Sidi Daoui area where Zarafasaura oceanis has been found. C. Stratigraphical column of the Maastrichtian phosphatic levels in Sidi Daoui area, with indication of the level where the holotype and paratype specimens of *Zarafasaura oceanis* have been found. Abbreviations Ph, phosphates; Ma, marls; Li, limestones. From Vincent et al. (2011), reproduced with permission.

preorbital (about 28% of skull length) and postorbital section, with a long relatively low parietal crest. The front half of the skull is almost entirely original, with very little reconstruction. The premaxillae are both present and give a short snouted appearance to the skull, as suggested for the taxon by Vincent et al. (2011). Like the holotype, the anteriormost portion of the snout is rounded, suggesting an oval cross section at the rostrum. Due to the short snout of the animal, the nares are close to the anterior tip of the skull, as in *Libonectes* (Carpenter, 1999). The premaxillae are complete and fused into a short, stout bone. They form a rounded apex that gives the anteriormost section a 'soft', rugose and triangular appearance, emphasized by the dorsal surface, which has multiple tiny nutritive foramina. The anteriormost portion of the premaxillae is missing in the holotype specimen. Between the premaxillae in WDC CMC-01, a long, original midline suture contact extends up to the level of the external nares, where the premaxillae constitute the anterior and medial margins of the external naris. The facial process is preserved, though it cannot be distinguished in the three-dimensional reconstruction. It can, however, be seen on the original crushed skull where it contacts the parietal posteriorly (Figure 4). Maxillae are almost complete, and both the right and left are original. The maxilla is a long rectangular bone, contacting the premaxillae anteriorly, below the nares. It forms most of the anterolateral margin of the orbit, as in the holotype. A suture line between the maxillae and premaxillae can be seen in both the reconstruction and in the images of the original skull (Figures 4, 5, and 6). The left maxillary segment is near complete but the posterior end is missing and broken, although it has been rebuilt in the reconstruction.

Prefrontals are both preserved, and they are fairly long and located between the premaxilla and maxilla. The prefrontals form the dorsomedial margin of the orbit. Looking at the original skull, the prefrontal forms a fraction of the external naris, but in the reconstruction it forms a larger amount. The

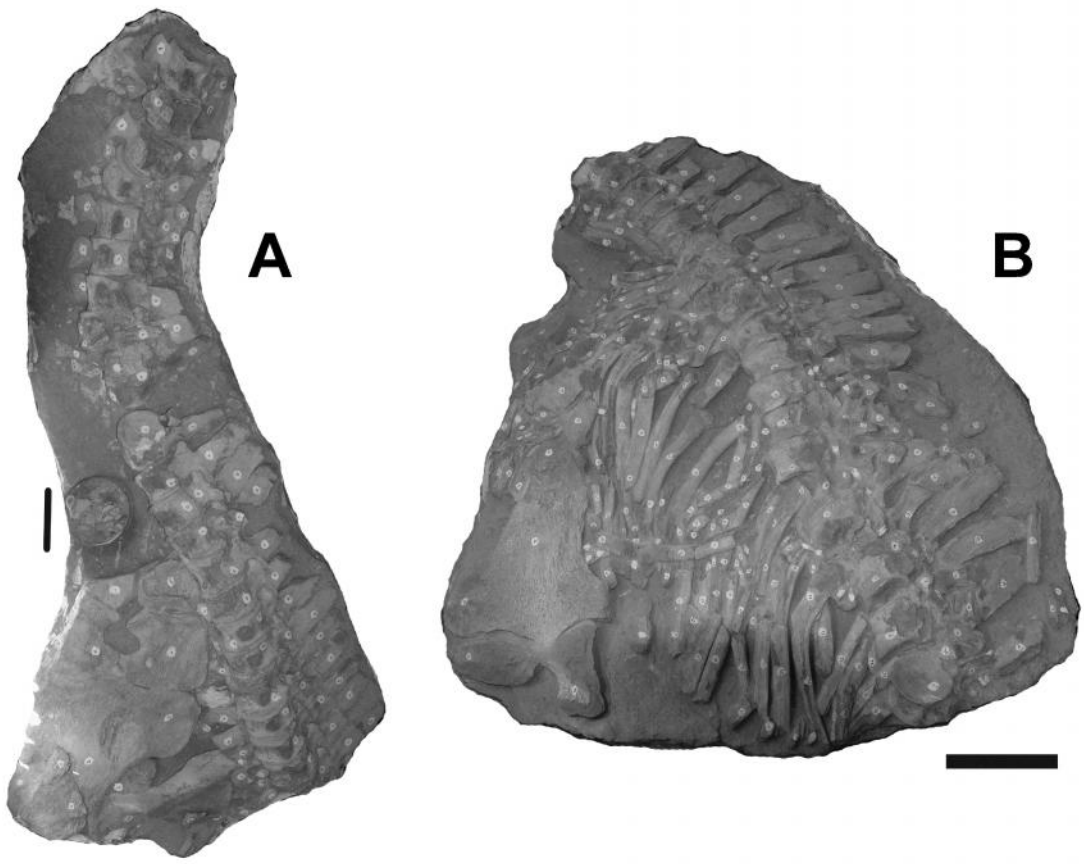

FIGURE 2. Two of the original five large field jackets. A. The large block displays the posterior cervicals, pectorals and dorsal vertebrae; along with the pectoral girdle. B. This large block follows the first, it consists solely of dorsal vertebrae, the left humerus and numerous ribs, note the long and 'squared off' neural spines. Scale bar = 20 cm.

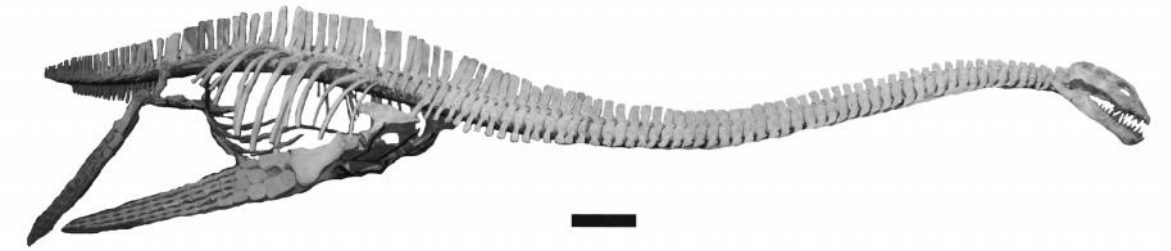

FIGURE 3. Complete mounted skeleton of WDC CMC-01, including reconstructed skull. Scale bar = 20 cm.

right prefrontal is fairly complete and contacts what appears to be the frontal, posteriorly. The left is also preserved, but partly broken and reconstructed. The frontals are difficult to distinguish in the original photo of the skull. In the reconstruction, preserved on the left side of the skull is a triangular-shaped bone, possibly the postfrontal, although it appears to have been placed next to the anterior section of the parietal rather than in its original position. On the inner side of both the prefrontals and contact with the maxilla are an arrangement of relatively large foramina, but it is unclear what they are. It is possible that they could be an artifact of preparation.

The parietal is relatively complete, though partially crushed and distorted. It is a rather narrow bone. The suture line cannot be distinguished with confidence. The anteriormost section of the parietal seems to contact the long facial process of the premaxillae, though this is difficult to determine. The center is genuine, but is damaged by fractures and crushing. It is rebuilt at the contact between the posterior parietal and anterior squamosal. At the

level of half the temporal fenestra length, the squamosal unites with the parietal dorsoposteriorly. In the reconstruction, however, the contact between the anterior squamosal and posterior parietal is almost entirely rebuilt, whereas the original photographs display only matrix and bone fragments.

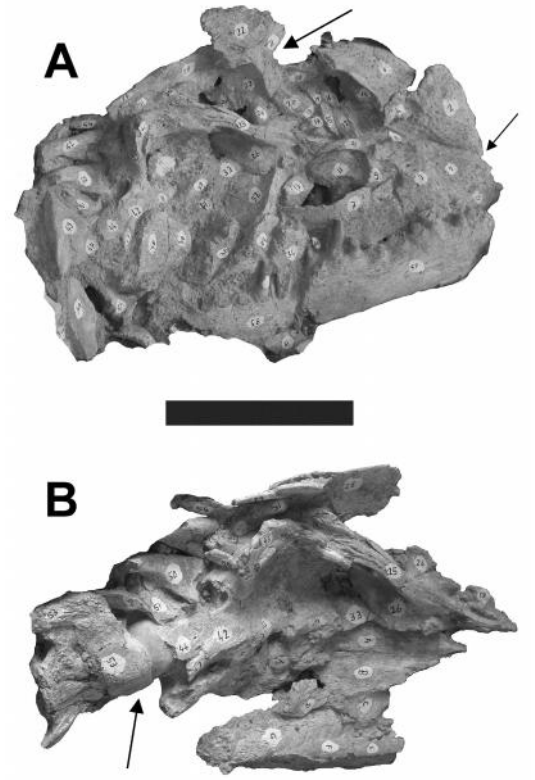

FIGURE 4. Original skull of WDC CMC-01 post preparation and prior to reconstruction. A. Skull in dorsolateral view. Note the sutures between the premaxillae and maxillae (lower arrow) and the bone numbered '21', which may be that protruding into the temporal fenestra (upper arrow). B. Skull in ventral view. Note the atlas-axis and basioccipital (arrow). Scale bar = 10 cm.

The squamosal morphology of *Zarafasaura* is an autapomorphy of the taxon, forming a distinctive contact with the parietals, jugal, and anterior contact with the postorbital. It allows the squamosal to form the whole of the lateral temporal fenestra margin (Vincent et al., 2011), and, as a whole, dominates the posterior of the skull (Figures 5, 6). In the original skull, it is difficult to determine confidently the contact of the squamosal with the jugal and postorbital, although this can be seen in the reconstruction. The dorsal ramus of the squamosal is relatively elongate and thin. In the original skull, the jugals cannot be identified, although there are several large sections of bone which likely belong, in part, to the jugals. For the reconstructed skull, when viewed in left lateral view (Figures 5A, 6A), a large rectangular bone is present. The jugal is rectangular shaped in most plesiosauroids and in the holotype specimen of *Zarafasaura*. We are not confident that this element is the jugal, though its large size and positioning would suggest it as a likely candidate. There appears to be no suture lines present on this bone and it is bounded anteriorly by the postorbital, though the most anterior section is reconstructed. Quadrates are indeterminable in the original skull, but appear to be part of the reconstruction. Although the right is relatively more complete, few details can be derived. Both are surrounded by the reconstructed posterior edge of the squamosal.

The palate is largely rebuilt, though part of the right and left is real with a suture separating the two. There is no suture delineation of the vomer. As the anteriormost section of the palate is missing, it gives a triangular shaped appearance to the palate. The braincase is present but based on the reconstruction is difficult to describe. The basioccipital is original, with a well-rounded occipital condyle. The ventral surface of the brain case is almost entirely reconstructed (Figures 4B, 5D and 6D). The parabasisphenoid, pterygoid and epipterygoid appear to be present, though the pterygoid is rebuilt distally towards the interpterygoid vacuities. The orbits are rounded, well preserved, and easily distinguished. In the original skull, the orbits are seen in dorsal aspect and appear slightly more oval than rounded, as reconstructed. This may be due to flattening of the skull, during diagenesis. Like in the holotype specimen, the orbits are bordered by the prefrontals and frontals medially, the maxillae and ?jugals laterally, and the postorbitals posteriorly (Vincent et al., 2011). The maxilla comprises the majority of the orbital margin. The temporal fenestrae are relatively large and occupy >55% of the reconstructed skull. This figure is much higher than the 45% of the holotype (Vincent et al., 2011). The preservation of the parietal and squamosals in the unprepared skull (Figure 4) indicates oval-shaped temporal fenestrae, shorter than in the reconstructed skull. A dorsally projecting triangular process on the left ?squamosal protrudes into the temporal fenestra and appears to be broken or distorted. It is unclear whether this is original, or an artifact of preparation and/or reconstruction. The unusual triangular process may be that numbered '21' (Figure 4A), but it does not appear to be in its original position, and may be incorrectly placed on the reconstruction.

The mandible of WDC CMC-01 is mostly original. The dentary is a long and straight bone, which is almost complete. The lateral[?] surface bears a longitudinal groove which contains an ornamentation of tiny foramina. The dentary has a diastema between the sixth and seventh pair of teeth. In relation to the length of the skull, the mandibular symphysis is short and is covered with relatively strong, pitted ornamentation. The diamond shape between the two rami of the mandible (Vincent et al., 2011, p. 8) is unclear in WDC CMC-01, as this area is partly rebuilt. As in the holotype, a slightly elevated crest is present where the rami meet the

FIGURE 5. Reconstructed three-dimensional skull of WDC CMC-01 viewed in different aspects. A. Left lateral view. B. Right lateral view. C. Dorsal view. D. Ventral view. Lighter colored areas are reconstructed. Scale bar = 10 cm.

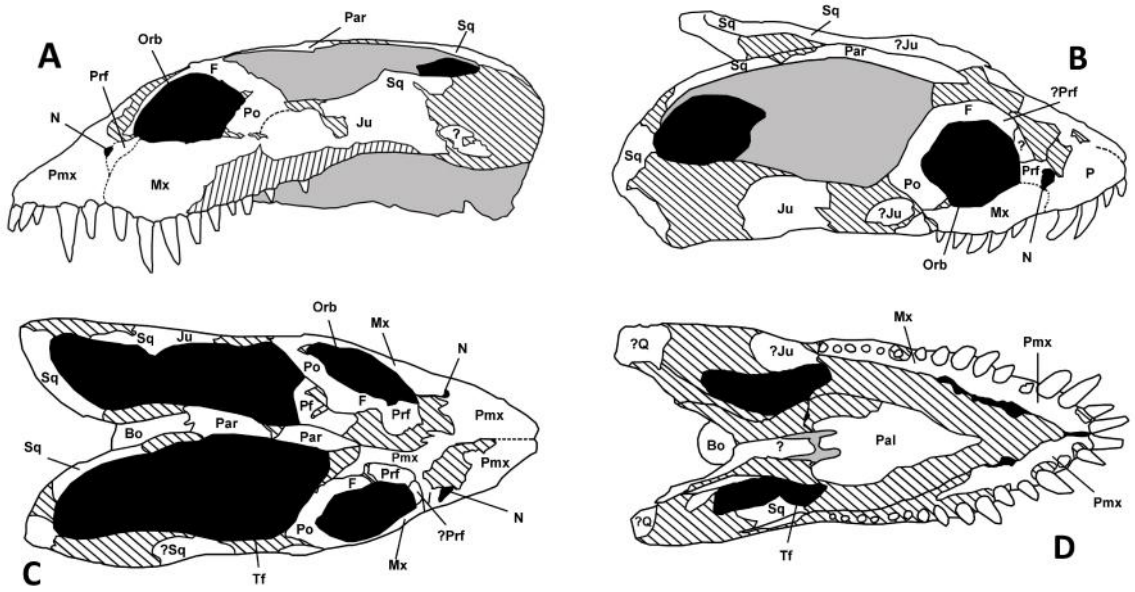

FIGURE 6. Interpretive illustrations of the three-dimensionally reconstructed skull of WDC CMC-01 viewed in different aspects. A. Left lateral view. B. Right lateral view. C. Dorsal view. D. Ventral view. Note that white = original bone; grey = bone from the opposite side of the skull; black = holes and/or foramina; and lines = reconstruction. An isolated question mark indicates that the particular section may or may not be original and cannot be identified. Abbreviations: Bo: Basioccipital; F: Frontal; Ju: Jugal; Mx: Maxilla; N: External naris; Orb: Orbit; Pal: Palatine; Par: Parietal; Pf: Postfrontal; Pmx: Premaxilla; Po: Postorbital; Prf: Prefrontal; Q: Quadrate; Sq: Squamosal; Tf: Temporal fenestra. A question mark with an abbreviation indicates a tentative identification. Illustrations by Reece Davies.

mandibular symphysis. The dentary bears sixteen pairs of teeth. The meckelian canal extends the length of the dentary to the boundary of the angular. On the inner side of the left dentary are an arrangement of nearly vertical marks, perhaps a sign of scavenging or a feature of preservation or preparation (Figure 7). Both the angular and surangular are almost complete. The lateral surface of the surangular is ornamented by strong ridges and is slightly reminiscent of heavy muscle attachment. Both articulars are original, but perhaps slightly deformed. They were reconstructed for display, as the right does not match the left and appears more bulbous in ventral aspect.

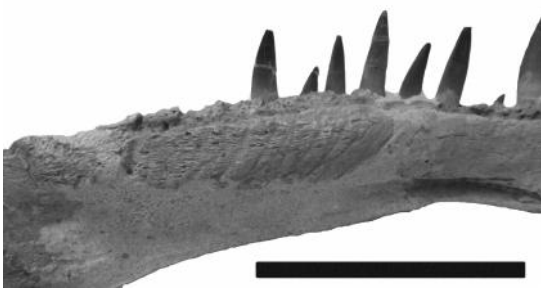

FIGURE 7. Vertical, serration-like marks preserved on the inner side of the left dentary. Lighter colored area is reconstructed. Scale bar = 10cm.

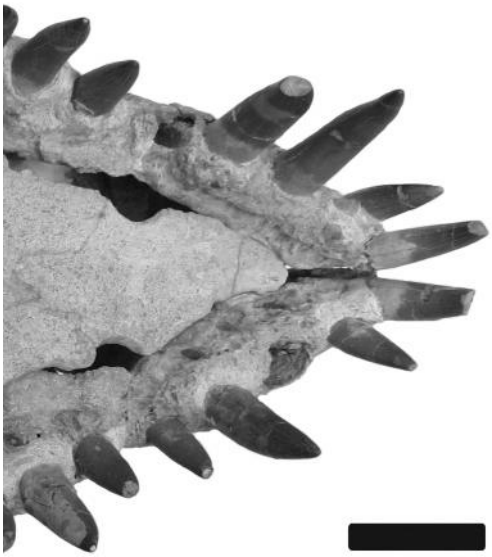

FIGURE 8. The odd, strong rugosity that surrounds the base of the posterior premaxillary teeth and is preserved atop the meckelian crest. Scale bar = 4cm.

As many as 12 partial teeth were discovered *in situ* in their original position in the jaw (Figure 5). Very few were preserved with a complete apex; the majority were broken or eroded. From information supplied from the preparator, every tooth, except for a few tips that are slightly protruding from the mandible, were replaced with other isolated teeth from the same formation. The same tooth type, which was described for *Plesiosaurus mauritanicus*, are found in all the phosphatic Maastrichtian levels of Morocco (Vincent et al., 2011). Of the original teeth, the crown is rather slender and linguolabially compressed and recurved, forming a thin cone-shaped morphology with a pointed apex. Fine longitudinal enamel ridges are present on both the lingual and labial surfaces, and they run the length of the tooth. This general tooth morphology is typical for plesiosauroids (Vincent et al., 2011) and considered a piercing tooth form by Massare (1987). There are a total of 6 premaxillary teeth and 10 maxillary teeth. The largest teeth of WDC CMC-01, as in the holotype, occur around the premaxilla-maxilla suture as the sockets are larger at this point than elsewhere. In this area, an unusual rugosity surrounds the tooth alveoli and the base of the tooth itself (Figure 8). This can also be seen in the anterior of the dentary surrounding the teeth above the meckelian canal.

Axial Skeleton—The vertebral column was preserved in five large sections (Figure 9). For the mount of WDC CMC-01, numerous copies of vertebrae were created, based upon *Hydrotherosaurus*, in order to complete the vertebral column. The most prominent reconstructed sections of the vertebral column were the cervicals and caudals. Including the casts, there are a total of 121 vertebrae (counting the atlas and axis as two) associated with WDC CMC-01: 56 cervicals (35 original); 4 pectorals (all original); 26 dorsals (all original); 3 sacrals (all original) and 30 caudals (7 original).

Atlas-Axis and Cervical Vertebrae: The first block, which contained the skull, included the fused atlas-axis complex, which is rather elongated and partially reconstructed in the center (Figure 4B). The atlas-axis was preserved on the same block as at least fourteen cervical vertebrae. An additional cast vertebra was inserted after the atlas-axis. We feel that this is incorrect and do not include the inserted cervical in the following description (or cervical count, above). The cervical centra are fairly circular, slightly wider than they are tall, and display a prominent rim. The first cervical (not the cast) is partially reconstructed. Cervicals 1, 2 and 3 are moderately smaller than the rest. Both c6 and c7 are partly reconstructed, especially c7, as the majority of the vertebra was poorly preserved and broken on one side. Cervicals 8, 9, 10, 11 and 12 are well preserved. Cervical 13 is also largely rebuilt and was badly broken when collected. Cervical 14 consists of the neural spine and a very poorly preserved centrum. After c14 is the insertion of 20 cast vertebrae into the cervical series. There is a distinctive difference between the last original anterior cervical and the next original posterior cervical, thus suggesting that vertebrae are missing. The preparator opted to include an additional series of vertebrae at this point. The next original vertebra (c35) is relatively robust and preserves the majority of the centrum and a near complete neural spine, which is also far more robust than those of the previous cervicals. The next fourteen vertebrae are similarly preserved to that of c35, most missing sections of the cervical ribs, which have been reconstructed. Cervicals 51, 52 and 53 are relatively complete, though like the previous are missing fragments of the ribs. The only feature that can be noted is that the ribs are very rugose on both sides, which is probably not diagnostic. All cervical ribs are fused to the centra, suggesting an adult age for WDC CMC-01.

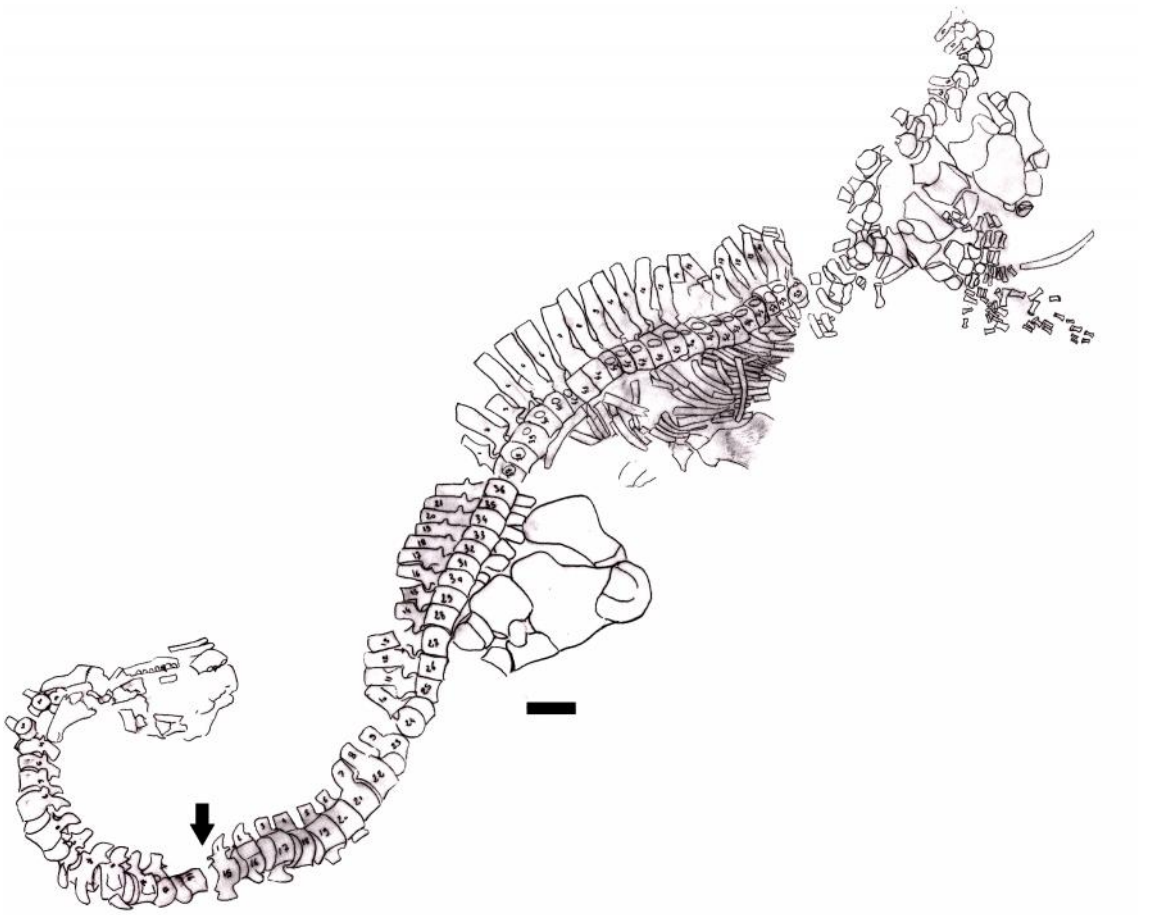

FIGURE 9. Original in situ sketch of entire specimen as discovered, with individual blocks placed together. The arrow indicates missing cervical vertebrae. Numbers do not include the casts of cervical and caudal vertebrae. Scale bar = 10 cm.

From the atlas-axis to the insertion of the casted cervicals (at cervical 16), the neural spines have the same height from the post-zygapophysis to the top of the neural arch. The neural spines are inclined caudally at an angle of 45° from the horizontal, much the same as *Libonectes* (Buchy, 2005). Several neural arches from the posterior cervicals (post c35) retain a bulbous edge at the top of the spinous process. This bulbous edge was not reconstructed in the corresponding vertebrae casts or on reconstructed neural arches post c35. This bulbous feature appears natural and may have been a bone lesion associated with tendon attachment. Also post c35, the neural arches are "squared off" at the tip. This feature is consistent to the caudals, regardless of whether it is real bone or a cast.

Pectoral Vertebrae: In the total series (including atlas-axis) vertebra 58 is the first pectoral vertebrae, the following three appear to be pectorals also. The majority of the pectorals have some restoration. However, the neural spines are relatively well preserved and display a long rectangular shape, the base of which is quite wide and gradually narrows, becoming thinner towards the spinous process. Pectoral ribs are only partly preserved and are not fused with the transverse process. The proximal portion of the shaft of the pectoral ribs exhibits a caudally directed crest, which is positioned well before the taper to the lateral shaft.

Dorsal Vertebrae: Vertebra 62 of the series is likely the first dorsal, although the reconstruction makes this determination difficult. The dorsal centra are oval to fairly circular in shape. The difference in shape from one dorsal to the next could be due to slight flattening from taphonomic processes (Figure 2). Ten of the dorsals are identified by their transverse processes and the separation of ribs. These are mounted at the position above the pelvic girdle, where the column corresponds with the ribs. The dorsal vertebrae are relatively well preserved, far more robust than the cervicals, and more complete. The cross-sectional shape of the centra is unclear due to some of the reconstruction. As there are some breaks across the vertebrae, there is more reconstruction of the neural arches and zygapophyses of the dorsals and sacrals than on the pectorals. The

dorsal vertebrae are reconstructed with the fan-shaped neural arches, as in the cast cervicals c16 to c34/35.

Sacral Vertebrae: Vertebra 88 is likely the first sacral vertebra. The following two vertebrae are almost certainly sacrals. The sacral vertebrae have a large, kidney-shaped rib facet, partially reconstructed on the center of the lateral face of the centrum. The dorsal and sacral centra appear to be sub-cylindrical and slightly higher than they are long. Notably, both the dorsal and sacral vertebrae were found articulated. The neural spines, like their predecessors, are partially rebuilt although quadrangular shaped at the edge. Some of them are associated with ribs.

Caudal Vertebrae: Almost every posterior caudal vertebra is a cast, except for 6-7 partial. The caudals consist solely of isolated centra with no processes preserved. All of the chevrons are reconstructed.

Ribs and Gastralia: Elements of the gastral basket are reconstructed as the typical spindle shape with a shallow longitudinal groove on the ventral surface where the gastralia fit together. Preserved ribs are relatively small fragments with the odd medium-sized to large chunk, but most are missing and replaced by the casts. The ribs that are preserved are quite robust and convex anteriorly, as noted in *Libonectes* (Buchy, 2005).

Pectoral Girdle—The pectoral girdle of WDC CMC-01 is relatively complete with only a few parts reconstructed (Figure 10). The entire girdle is 70 cm long, 54cm wide at the lateral margin of the glenoid, and 68 cm wide across the posterior cornuae. The posterior edge of the right coracoid is largely rebuilt, but this section is almost fully preserved in the left coracoid, which displays a fan-shaped curvature to the posterior part. The coracoid measures 56 cm long by 33 cm wide. The most striking feature of the coracoid is the unusually deep mesial notch or intercoracoid vacuity. The notch is relatively long (13cm) and narrow (4.5cm), and protrudes anterolaterally about half way through the coracoid (Figure 10). This area is missing in the right coracoid and has been rebuilt to match the left. The glenoids are relatively long, and robust, the center of

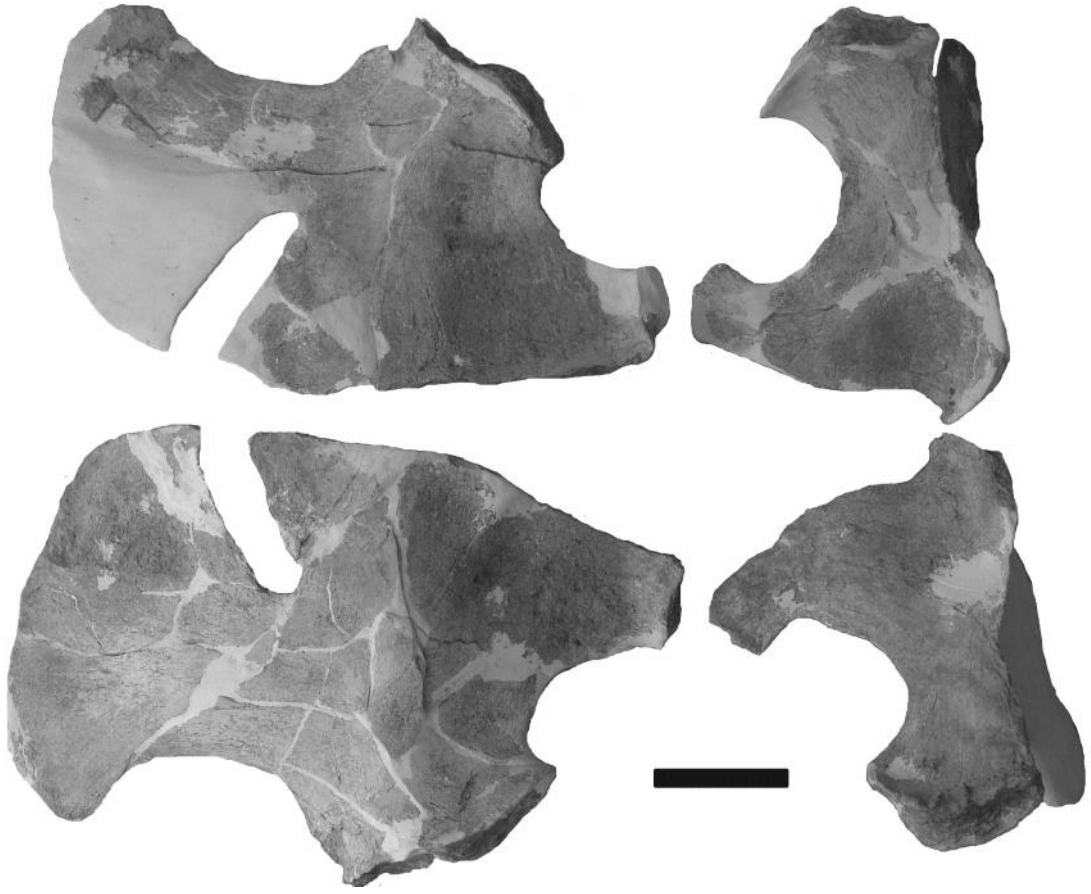

FIGURE 10. Complete pectoral girdle of WDC CMC-01 in ventral view. Note the unusual narrow notch of the coracoid (left set of bones). As the photos were taken prior to the mount of the specimen (and we could not access them) the positioning of the scapulae and orientation could not be changed. Light colored regions are reconstructed. Scale bar = 10 cm.

FIGURE 11. Right humerus of WDC CMC-01. A. Dorsal view. B. Ventral view, note the interesting depression situated towards the base of the shaft. Compare the size of the radius facet to the ulna facet. Scale bar = 10 cm.

which has a fairly strong ornamentation within the cavity. Only a small section of the glenoids are rebuilt. The pectoral bar of the coracoid forms a triangular-shaped anterior process, although part of the right pectoral bar is reconstructed. Both scapulae are preserved. The left scapula was articulated with the coracoid when found. The right scapula measures 33 cm long by 26 cm wide; the left measures 32 cm long by 27 cm wide, but they are both partly reconstructed. The clavicles and interclavicles appear to be missing but the facets are present on the respective scapulae. The facets are prominent in length, extending 13 cm from the partial midline symphysis to the furthest anterior edge of the scapulae, and the depth of the facet ranges from 5 cm to a maximum of 7.5 cm. The scapulae are not mounted with the left and right in articulation with each other, and so the "keel" and the corresponding angle of the elements could not be determined. The pectoral fenestra, as formed by the posterior edge of the scapulae and the anterior edge of the coracoids, are oval in medial-lateral view.

Forefins—Both forefins are partially preserved. The humerus of the right forefin measures 38 cm long by 28 cm wide, and is nearly complete, with restoration of the head only (Figure 11). The radius is complete but only a fragment of the ulna is preserved. The radiale is near complete and the intermedium may partly be preserved. The rest of the right forefin has been cast. As for the left forefin, the humerus measures 38.5 cm long by 31 cm wide and is complete, but only anterior fragments of both the radius and ulna are preserved. The rest has been cast. The propodials are very robust and short, and display a very low length to width ratio, with a thick shaft and an oval cross-section at the center of the shaft. The heads of both humeri appear to have been flattened taphonomically though the reconstruction does not allow the extent to be noted. The proximal shafts are thick with several prominent muscle attachments. On the ventral side (in the center dorsal surface) of the right humerus is a large sub-circular depression measuring 10 cm by 7 cm. This depression appears to penetrate several layers of bone with a portion of the intact bone having been pushed inward (Figure 11). This may be evidence of predation, but no corresponding mark on the dorsal side is present. Alternatively this may suggest a form of differential distortion, though other large flat bones are not damaged in the same way.

The distal ends of both humeri are very wide. Both facets are preserved and the radius facet is almost double the length of the ulna facet (17 cm and 9.5 cm, respectively), as seen in other elasmosaurids such as *Elasmosaurus platyurus* and *Styxosaurus snowi* (Welles, 1943). Compared to the ulna, the facet for the radius is relatively shallow, though the ulna facet bears a 'hook' at the posterior trailing edge. The leading edge of the humerus and corresponding radius, radiale and metacarpal appear to comprise a thin edge, as seen in *Styxosaurus* (Welles and Bump, 1949). This could be a factor of the proportional growth of the limb to the body, as noted in the subadult elasmosaurid FFHM 1974-823 (Everhart, 2006).

Pelvic Girdle—WDC CMC-01 has an almost complete pelvic girdle, with some sections partially restored (Figure 12). The pelvic girdle is roughly 1/5 smaller than the pectoral girdle. The right side of the pelvis is more complete than the left. The pubis is a large flat quadrangular shaped bone. Both pubes are partially reconstructed. The left pubis is largely reconstructed at the distal end. The right pubis is 26cm long and about 33 cm wide, with the maximum width at the anterior of 56 cm and the minimum width at the posterior of 23cm. The midline symphysis at the contact of the pubis is 14 cm long and at the contact of the ischia the posterior symphysis is 10cm long. However, as the pelvis was mounted flat, these contacts may have produced a "keel". Both ischia are relatively complete. The ischium is a rather flat bone, which is widely expanded at the distal end, although the proximal end is robust. The right ischium is estimated at 24 cm long and 23 cm wide. Together the pubes and the anterior process of the ischia form a sub-circular pelvic fenestra. The pelvic fenestrae are partially bordered by the pelvic bar of the ischia and otherwise by the pubis and ischia respectively. The fenestrae are 9.5 cm by 10 cm and the pelvic bar extends anteriorly, separating the fenestra by 7cm from the medial extension of the ischial "neck". However, the furthest anterior edges of the pelvic bar are reconstructed. The ilia are long and thin bones that are both estimated at 17 cm in length, at the boundary of the ilial blade (where it contacts the rebuilt sacral ribs) they expand from 4 cm to 6.5 cm in width. Likewise both ilia are partly restored. The acetabulum facet is compact and oval in lateral view, 5 cm high by 12 cm long.

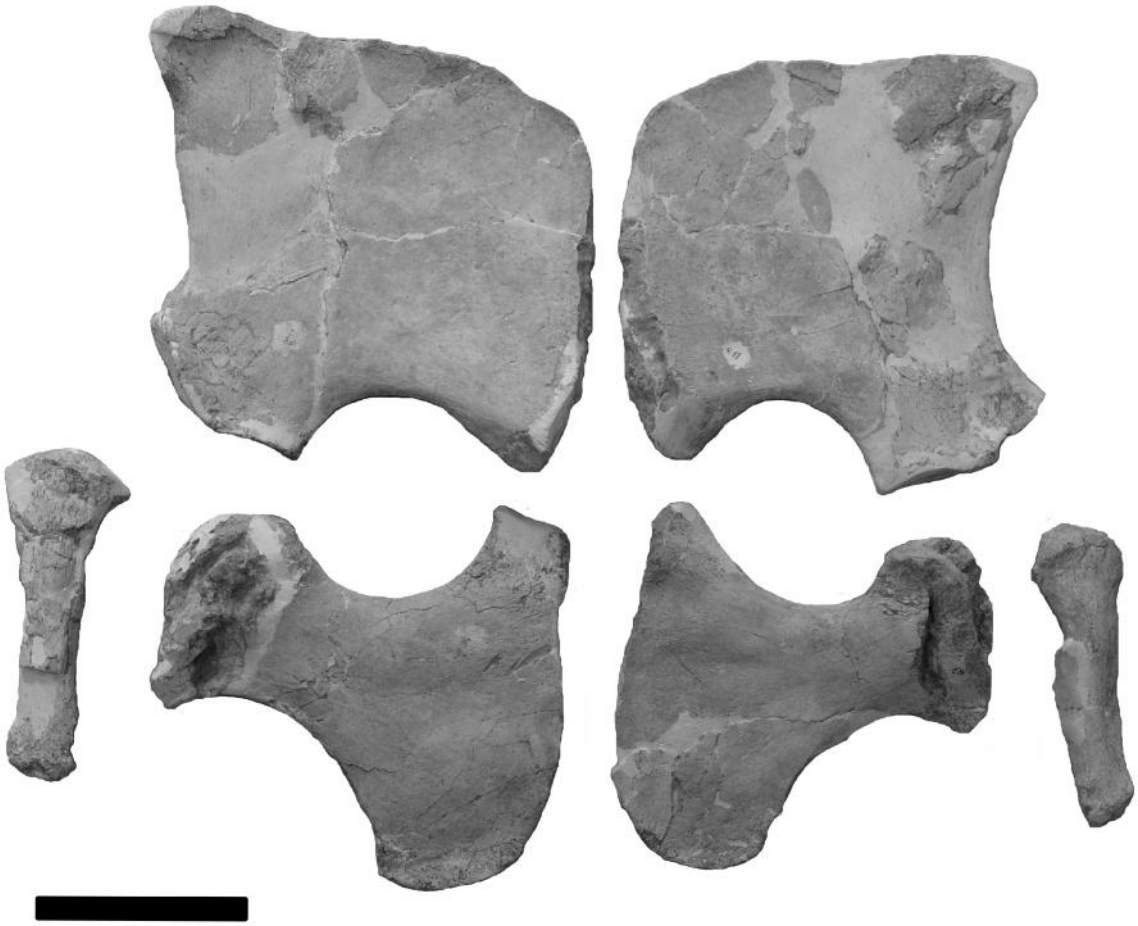

FIGURE 12. Complete pelvic girdle of WDC CMC-01 preserved in dorsal aspect. The photographs were taken prior to the mount of the specimen (and we could not access them), thus they are loosely arranged in rough relative position. Light colored regions are reconstructed. Scale bar = 10 cm.

Hindfins—Both hindfins are partially complete. The right femur measures 29 cm long by 18.5 cm wide and is nearly complete, with restoration of the distal portion of the shaft. The right femur appears bulbous and more pronounced than the left, and may reflect a pathologic condition. The tibia and fibula are both preserved and partially reconstructed, as are the three mesopodials and some of the metapodials. A total of 25 phalanges appear to be original, with digit IV being the most complete.

The left femur measures 29 cm long by 19 cm at its widest point, and is complete with a minimum of restoration. The left tibia, fibula, mesopodials and metapodials are well preserved, with little restoration. As for the digits, each has some complete and restored phalanges. Digit III is the most complete with at least 8 original phalanges. A total of 33 phalanges are complete to partially restored (Figure 13). A phalangeal formula for either hindfin cannot be determined as the hindfins were largely disarticulated and partly scattered when found.

The femora are smaller than the humeri, with a much more rounded and thinner shaft, the head of which is robust and elongate. The shaft quickly expands into a fan-shaped posterior giving a relatively wide distal end. Both facets of the tibia and fibula are only slightly sub-equal in length. The intermedium is relatively hexagonal in shape and the fibulare more robust then the tibiale.

CONCLUSION

The description of the skull of *Zarafasaura* (Vincent et al., 2011), in which the taxon was established, has enabled this description of WDC CMC-01. Vincent et al. (2011) described the discovery of *Zarafasaura* as key to understanding the expansion of Late Cretaceous plesiosaur paleobiodiversity. As part of the general review of

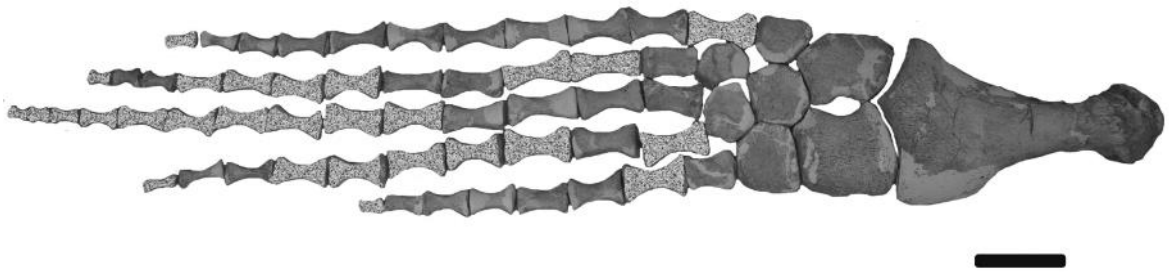

FIGURE 13. Left hindfin of WDC CMC-01 in dorsal view. Note the relatively complete anterior elements including the femur. Light colored regions of elements have been reconstructed. Stippled elements have been entirely reconstructed. Scale bar = 10 cm

marine reptiles from the Late Cretaceous Phosphate beds of Jordan, Bardet and Pereda-Suberbiola (2002) described isolated teeth and limb bones of elasmosaurid plesiosaurs, but could not confidently assign them to a taxon. In addition, as mentioned previously, isolated material found in the vicinity of the phosphate beds of Morocco were previously considered to belong to *Plesiosaurus mauritanicus*, although this taxon is now regarded as a *nomen dubium* by Vincent et al. (2011). For this, WDC CMC-01 may allow for a review and identification of some of the isolated plesiosaur elements that have been collected in the area, potentially recognizing their taxonomic and scientific value (e.g. the material described by Vincent et al., in press). Thus there lies the prospect of identifying specific elements, previously considered to be *P. mauritanicus* or Plesiosauria indet., as *Zarafasaura oceanis*, helping to develop a better understanding of the morphology of the taxon.

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