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TAPHONOMY OF A NOSE DIVE: BONE AND TOOTH DISPLACEMENT AND MINERAL ACCRETION IN AN ICHTHYOSAUR SKULL.

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ABSTRACT

In July 1998, a partially articulated anterior skeleton of *Opthalmosaurus* was collected from the Redwater Shale Member of the Sundance Formation, Natrona County, WY. The skull was disconnected from the vertebral column at the atlas-axis and rested upside down at a nearly 90° angle to the bedding. The skull and associated vertebrae are partially encased in at least two generations of concretion. Borings on the partially articulated pectoral girdle, ribs and vertebrae suggest that the specimen was exposed on the sea floor. No such evidence, however, was found on the middle and distal portions of the skull, further suggesting that it was partially driven into the sediment by the impact of the carcass.

The bone shows marked plasticity at the middle section of the jaws, suggesting enough inertial damage to cause a ripple effect and a large displacement of distal elements. However, the distal ramus also appears to have been constricted by the sediment enough to hold the teeth better in place at the distal end than at the posterior end of the jaws. Iron-stone and pyrite was noted in the jaws, but not in the foramina or vacuities of the vertebral column. The semi-hollow structure of the jaws may have provided a conduit for mineralization. This skull shows similar damage to that of three other ichthyosaur skulls collected from the Sundance Formation, so analogous conditions of taphonomy may have occurred.

INTRODUCTION

Exploration of the Jurassic Sundance Formation in Wyoming, has resulted in the discovery of several partial skeletons of both juvenile and adult ichthyosaurs (Drake and Wahl, 1994; Massare and Young, 2005; Massare et al., 2006). A survey of the specimens in museums, as well as those recently collected, suggests a fauna from central Wyoming comprised of about 70% ichthyosaurs, all referred to the taxon *Opthalmosaurus natans* (McGowan and Montani, 2003), although most material consists of isolated bones. The discovery of a partially articulated ichthyosaur skeleton with a complete skull preserved in three dimensions was a unique find in the Sundance Formation (Figure 1).

As the largest and probably the most complete ichthyosaur collected from the Sundance Formation, UW 24816 was collected in concreted blocks of the skull and the anterior skeleton, in sections broken at right angles to the long axis that allowed examination of the specimen in cross-sections. This report will describe the taphonomy of this ichthyosaur skull and its subsequent changes during diagenesis. The skull is in a condition with large sections broken a right angles reminiscent of a CT scan series, thus UW 24816 represents an opportunity for high resolution study with the ability to view the interior in cross section.

Geology—The majority of the vertebrate fossils from the Sundance Formation (Bajocian-Oxfordian) have been collected from the Redwater Shale Member, which was the last and most extensive transgressive sequence of the Jurassic in North America (Kvale et al., 2001). The presence of the small cardiocerid ammonite, *Quenstedtoceras colleri,* establishes the lower Redwater Shale as latest Callovian. The Callovian age of the lower Redwater Shale Member is further confirmed by the identification of the coleoid belemnite, *Pachyteuthis densa*, and the pelecypods *Camptenectes bellestrius* and *Ostrea strigilecula* (Kvale et al., 2001).

The upper Redwater Shale Member, however, is Oxfordian in age (Kvale et al., 2001). It represents a shallow, open shelf environment dominated by silty to shaley mudstone, occasional bioturbated shale, and ripple-dominated, glauconitic fine-grained calcareous sandstone (Andersson, 1979; Specht and Brenner, 1979; Kvale et al., 2001). The water depth during the Redwater Shale sequence was estimated to be 40 m (Specht and Brenner, 1979). The presence of glauconitic grains is evidence of a high-energy environment (Specht and Brenner, 1979). The presence of storm damaged bioherms consisting of bits of fragmented *Camptonectes* and *Gryphaea* and winnowed sandstones are further evidence of rough water in the depositional environment of the Redwater Shale (Specht and Brenner, 1979).

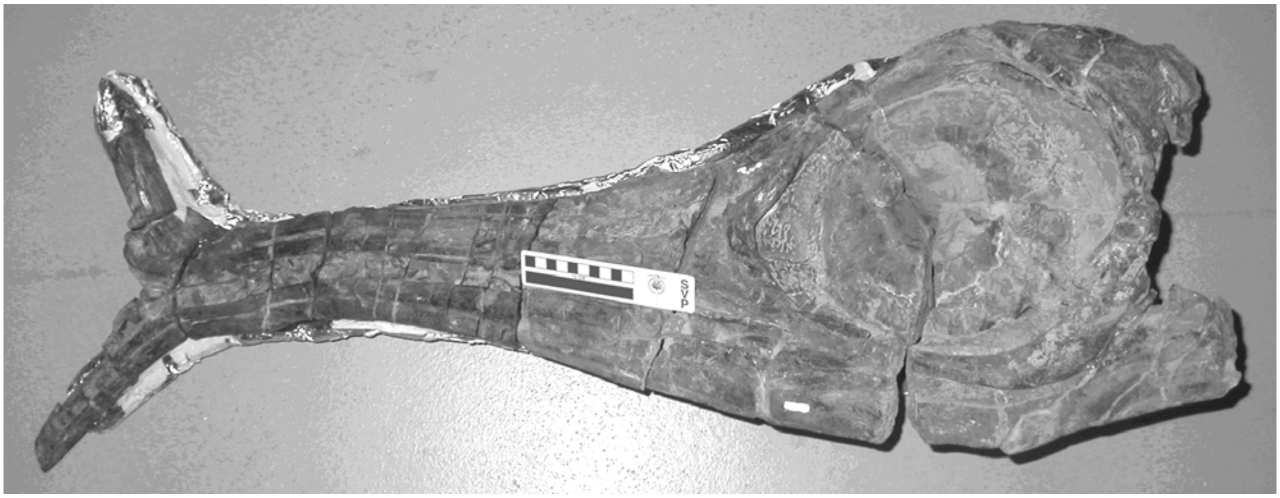

FIGURE 1. Skull of UW 24816. Scale bar= 10cm.

Material—UW 24816 consists of a partially articulated body representing 60% of the skeleton with large portions of the dorsal vertebrae including the neural arches and the associated ribs, as well as possible gastralia, a partially articulated pectoral girdle, and an almost complete skull. Notably missing are all four limbs and the pelvic girdle.

Institutional Abbreviations—UW, University of Wyoming, Laramie, Woming; CM Carnegie Museum, Pittsburg, Pennsylvania.

DESCRIPTION

Disposition—The skull of UW 24816 was found partially buried at an angle of almost 90º to the bedding plane, suggesting that the skull was driven into the sediment and partially buried by the impact of the carcass sinking through the water column. Although the skull lay lower on its left side and was detached and displaced from the vertebral column by approximately 5cm, the occipital area was not noticeably below the level of the postcranial bones (Figure 2). Further deposition of sediment could have settled into the open space bordered by the lower jaws leaving the posterior portion of the skull above the substrate.

The vertebral column extended out from the skull and was lying on a bedding plane. The back of the skull was slightly collapsed and with few bones disarticulated. No evidence was found of differential sediment deposition in the form of sand stringers and disproportionate shell debris or lag facies near the skeleton. This suggests that wave action did not under cut the skull and cause the high angle of repose (Schafer, 1972). Rather, the body appears to have collapsed back onto the sea floor after the head penetrated the sediment. The ventral keel of the articulated pectoral assemblage was found facing upward, suggesting that the carcass landed ventral side up. The skull was upside down and partially laying on the right side, whereas the vertebral column appears to be lying on its left side. This suggests that the body may have twisted slightly at the sediment contact.

There is little evidence of displacement of the specimen, such as crystal growth caused by a diagenetic sediment shift, joint or fault. The skull is fractured into sections from just posterior to the external nares to the distal end of the rostrum. Sections were not displaced from mid-point to the distal end. The pectoral material is comprised of articulated coracoids and scapula and the interclavicles. Pectoral limb bones were not found during collection nor in the concretion during preparation. Limbs may have been scavenged or displaced before final deposition.

Invertebrate borings are visible on the unconcreted pectoral girdle, ribs, and vertebrae. This would suggest that UW 24816 was exposed on the sea floor for some time. No evidence of boring, burrows, or infaunal disturbance could be found, however, on the middle and distal portions of the skull, again suggesting that it had been driven into the sediment possibly below the infaunal interaction level, thus removing it from exposure. There were some trace fossils such as grooves in the bone surface from recent plant growth. These do not appear to be the same shape and do not occur in the same patterns as potential evidence of invertebrate borings.

It has been suggested that vertically oriented skulls were the result of "death throws" on the seafloor or disorientation during death in the water column (Von Huene, 1922). Alternatively, Martill et al, (1993) suggested the gasses generated by bacterial decay within the body may have pushed a pointed skull into the soft sediment. Gas expanding a carcass may displace or resettle a skull into matrix. Martill et al, (1987) also suggested that the sinking of an ichthyosaur carcass head first would be arrested by the projecting pectoral fins, but because no pectoral limbs were found with UW 24816, such a scenario cannot be confirmed.

FIGURE 2. UW 24816 *in situ*. Underside of skull is in the front of the image (arrow) with the anterior end pointing vertically into the ground. The vertebral column is in the center of the photo, extending along a bedding plane into the background.

No evidence of scavenging, such as shed shark teeth which are common in Sundance sediments, were around the carcass. It is more likely that the carcass was scavenged in the pelagic environment of the water column after death. Furthermore, no disturbance of bedding, such as flame structures suggesting a delayed push of the skull into the matrix by decay gasses, occurs close to the skull. Also the depth (40m) of water would force some dissolution of the gasses and would probably prevent the explosion of the body (Wetzel and Reisdorf, 2007). Finally, the occipital region of the skull was not displaced below the plane of deposition of the post-cranial skeleton, suggesting that the skull was in full contact with the body.

Concretion Development—Concretions and limey mud lithifications are fairly common in the Redwater Shale Member of the Sundance (Anderson, 1979, Specht and Brenner, 1979). Most of the marine reptile material that has been collected in recent years is from concreted masses (Wahl, 1999; Massare and Young, 2005; Massare et al., 2006). Wetzel and Reisdorf (2007) noted ichthyosaur specimens with partial concretion on the bones and the distortion to the surrounding matrix (sinking) caused by the differential and slow increase in mass of the concretion. It was suggested that the differential and spotty placement of organic matter in biofilms would generate concretions on the exposed bone surface. This observation has implications for the deposition and diagenesis of UW 24816. The articulated post-cranial skeleton was partially concreted with portions of both bone and concretion bearing epibont boring scars (Figure 3). It is suggested here that the portions of exposed bone may have provided less organic material as a resource for concretion material generation. This would provide an excellent situation for preservation as the specimen was deposited in an oxygenated sandy-shale shallow marine environment. Bottom-water oxygenation in combination with a sandy-limey mud sedimentation may have generated spotty or differential biofilm-deposited concretion on the carcass. Most notable are the rib portions with isolated concretions occurring at intervals. It is suggested here that the ribs were partially scavenged before initial burial, leaving sparse flesh or integument to initialize biofilm-generated concretion. Open spaces on the carcass exposed above the sediment would then provide shelter and grazing for patchy sessile epibont islands (Martill,1991,1993, Martill et al.,1994).

At least two generations of calcitic concretion partially encased the posterior portion of the skull atlas, axis and anterior dorsal vertebrae. Two separate layers of shell material consisting of *Camptenectes bellestrius* and *Ostrea strigilecula* hash are mixed into the spaces within the jaws and in between vertebrae respectively, suggesting mixing of the matrix in contact with anterior and posterior skull and post-cranial skeleton, most likely caused by the impact of the anterior skull in initial burial, then the slow accretion of shell hash on the posterior skull. This may further suggest the skull was driven into the shell hash sediment matrix before the articulated body.

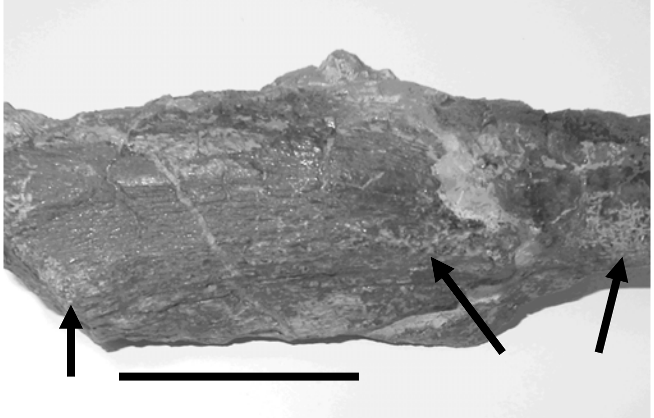

FIGURE 3. The clavicle of UW 24816, exhibiting epibont boring scars (arrows). Scale bar = 6 cm.

The body and head of UW 24816, although equally rigid masses, should be considered as having developed separate concretions. The stiff, articulated mass of the head and body were covered by at least two separate layers of concretion. Distorted matrix suggests these concreted masses of a relatively stiff skull may have caused deformation which is enclosed by compressible sediments (Collinson, 1994). If this occurred, the concretion development may have distorted and deformed the shell hash layer surrounding the skull.

During diagenesis, the difference in sediment and concretion was partially maintained with the additional weight of overlying sediment leading to compaction and displacement of vertebrae more distal to the articulated cervicals series. This differential compaction is noted by minor deformation of the posterior portions of the skull now lying beneath the weight of the mass of the upside-down skull. Articulated neural arches mixed with the corresponding vertebrae, distortion on the rim of the vertebrae, and with breaks occurring at the long axis and the head of the rib, bear further evidence of the differential compaction and concretion development of the skeleton-hosting mass. This suite of occurrences resulted in the lumpy structure of the concretion mass with protrusions of the ribs and rims of exposed vertebrae.

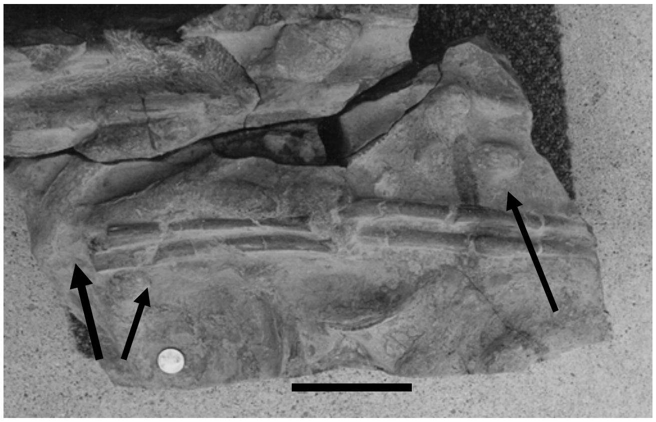

FIGURE 4. Invertebrate burrows in the concretion around UW 24816 (arrows). Scale bar =10 cm.

This scenario would also explain the loss of rib ends and damage to protruding material, which would suggest a weathered appearance to the bone surface though it was found *in situ*. The concreted bone was not weathered and more resistant to further diagenesis. Exposed bone, however, could have been damaged by gypsum, ironstone or pyrite growth. However, although the weight of the skull-hosting concretion increased, the mass did not move relatively downward through the soft matrix. It was partially articulated at the vertebral contact and not separated or displaced from the level of the rest of the linear body shape at the bedding plane.

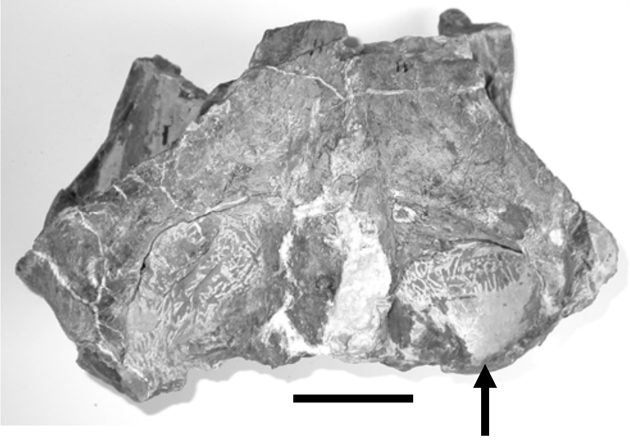

FIGURE 5. The posterior portion of the skull UW 24816 in dorsal view. The right temporal opening is reduced and sub-rounded (arrow) as compared to the left temporal opening. Scale bar=10cm.

The post-cranial bones are partially covered by concretion, with portions of the vertebral column kept together along the bedding plane. The majority of the ribs were disarticulated and moved away from the respective vertebrae. Numerous invertebrate burrows attributed to *Thalassinoides* have been found in the concretion (Figure 4). The burrows were parallel to the skeleton, some even running in and around vertebrae-rib contacts, suggesting that the burrowing may have further moved the bones apart. Decapod material consisting of leg and body cuticle was found within the burrows, suggesting the activity was sustained for sometime on the surface contact with the partially exposed bones (Wahl, 2008). The corresponding burrows do not appear to be compacted and terminus ends are not crushed, suggesting early cementation such that compaction was reduced during burial. These burrows also appear to extend into the surrounding matrix away from the concretion hosting the bones.

Displacement and Distortion—The posterior portion of the skull displays damage to the right temporal opening (made up of the post-frontal, squamosal and parietal bones) this space is reduced and sub-rounded as compared to the left temporal opening (Figure 5). Although this damage could have been caused by impact, open spaces within a skull were probably more susceptible to sediment crushing. Various spaces in the skull were open exposing both thinner and more fragile bones were not similarly crushed. However, the posterior portion of the skull was the only part level with the rest of the body and could have been crushed by accumulating sediment.

The right orbit was equally distorted with the postorbital displaced from the corresponding jugal. This distortion was further displayed by displacement at the jugal/lacrimal maxilla contact (Figure 6).

FIGURE 6. Right orbit of UW 24816 exhibiting distorted post-orbital/ jugal (left arrow) and corresponding displacement at the jugal/lacrimal maxilla contact (right arrow). Scale bar=10cm.

As the skull was deposited upside down, the space between the jaws formed an empty cone. The sediment could have settled into the open space between the lower jaws, leaving the posterior portion of the lower jaws above the deposited sediment after initial impact of the skull. The semi-concreted, layered sediments within the posterior and middle portion of the skull are bordered by the lower jaws. The long flat bone surface of the pterygoids were not damaged, although the multiple bones that make up the posterior portion of the lower jaws were displaced, with the right side bent slightly inward at an acute angle toward the pteryigoid surface (Figure 7).

The sclerotic rings on either side of the skull were not damaged by the distortion of the bones that make up the orbit. Both rings were sediment filled within the orbit and there was little contact with other bones. The rings are essentially floating within the orbit and the plates did not distort nor displace within the socket, each retaining the angles that interlock together (Figure 8). This suggests that the integument that held the ring in place was strong enough to withstand the impact and collapse of the carcass, and any further displacement of the skull. The open spaces of the skull would suggest a potential weak space to be distorted by compacting sediment. However, neither the orbit nor the open spaces of the posterior skull bordered by the pteryigoids, vomers, jugals, and postorbitals were crushed or substantially distorted. This may suggest a resistant integument contact of bone to bone or resistance to crushing from early infilling of sediment or a rapid infilling of fine-grained sediment to retain the void space within the skull.

The skull of UW 24816 was found resting on its dorsal side at high angle to bedding. Moving anteriorly, following the damage to the mid-portion of the skull, the nasals and premaxilla were damaged and overlap because of the “nose dive” (Figure 9). There was, however, very little damage done to the laterally-oriented nares. Both the interior as well as the exterior, posterior portion of the external nares were not damaged. The facets of the skeletal elements in contact with the nasals are visible and not overlapping below the frontal nasal contact. Remarkably, the funnel shaped channel, presumably used to direct inflow of air in breathing (Andrews, 1910) is not damaged on either side of the skull. These structures are preserved with an odd feathering of the posterior border of the external on the anterior surface of the lacrimal (Figure 10). This odd feathering feature is not present in other observed skulls and is possibly a distorted portion of the external nares caused by the skull moving trough sediment. An alternative suggestion is that the fine grained sediment in close compaction to the skull has preserved an undescribed external feature of the nares.

The slight twisting of the distal skull, as indicated by the distortion, suggests that it may have twisted into the sediment which acerbated the split displacement in the upper jaw at the distal end of the ramus. The skull bones show marked plasticity at specific sections. For example, most of the dorsal rostrum was pushed up, resulting in dorsal sections of the nasals displaced over the anterior portion of the frontal region. Furthermore, portions of the dorsal rostrum seen in cross-section exhibit a rippling of the bone within the open space of the nasal maxilla channel.

There are portions of UW 24816 that are damaged in different ways, suggesting a timeline of distortion. Sediment accumulation was a factor in damage of the posterior portion of the skull, as large open spaces between bones would be distorted by sediment weight. The more distal portions the rostrum appears to have been damaged previous to this by impact in soft sediment. Another possibility was that the back portion of the skull was above the sediment and any integument holding these bones together rotted away faster than the buried anterior portion.

The middle section of the jaws was likewise displaced enough to cause a plastic, ripple effect on the bone surface. The jaws were split open as the distal ramus was subjected to the most dramatic large scale distortion with the upper jaw twisted both dorsally at an angle of less than 45° to the rostrum as well as slightly laterally (Figure 11). The lower jaw was equally distorted ventrally from the line of the jaws at an angle of 35˚. The distal end of the upper jaws is missing and the lower jaws are broken or rotted, as there were bone splinters in the concreted mass at the distal end. Although the distal ramus was displaced, with damage to both the upper and lower jaws, these portions also appear to have been constricted by the sediment enough to hold the teeth in place better at the distal end than at the posterior end of the jaws.

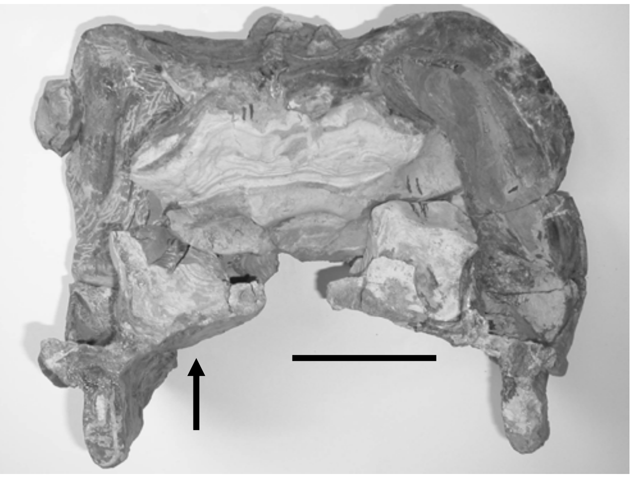

FIGURE 7. Posterior portion of skull of UW 24816 interior aspect view facing forward. The multiple bones that make up the right side were displaced with the lower jaw bent slightly inward toward the pteryigoid surface (arrow). Scale bar=10cm.

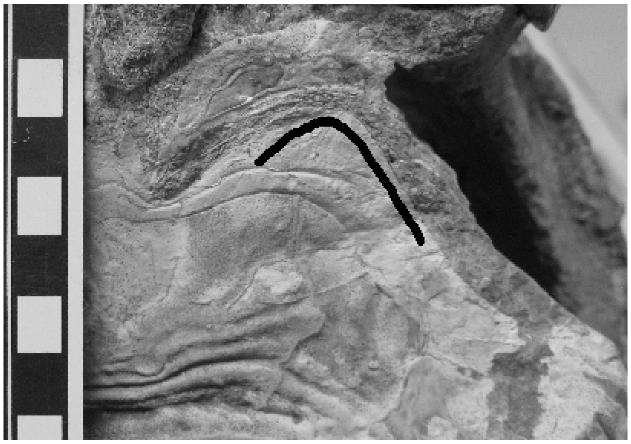

FIGURE 8. Portion of articulated skull of UW 24816 exhibiting undamaged sclerotic ring. The sclerotic plates did not distort nor displace within the socket, retaining the nearly 90° angle in matrix (black line). Scale bar marked in cm.

Iron-stone and pyrite are on the surface of distal portions of the jaws. It is present on the edges of foramina on both lower and upper jaws, with more material occurring at the contact of the upper maxilla and premaxilla (Figure 12). Ironstone and pyrite do not occur in the vacuities of the vertebral column, whereas some calcite crystallization has occurred. It is suggested here that the semi-hollow structure of the jaws may have provided a conduit for mineralization in the fossa and this allowed the accretion of alternating iron-stone cementation around the surface of the distal portions of the bone. In the course of preparation, it appeared that the mineral accretion displaced shell hash material that was packed around the distal portion of the skull, which accumulated when the specimen went through the matrix. The most distal portion of the upper and lower jaw may have rotted away from iron-mineral accretion as evidenced by the splintered bone (Figure 13). There was no iron stone accreted within the spaces between bones or the enervations of the rostrum. This would suggest that the porosity of the skull was open during the impact of the body or at least that the fluid of the deposition matrix contained no iron percolation.

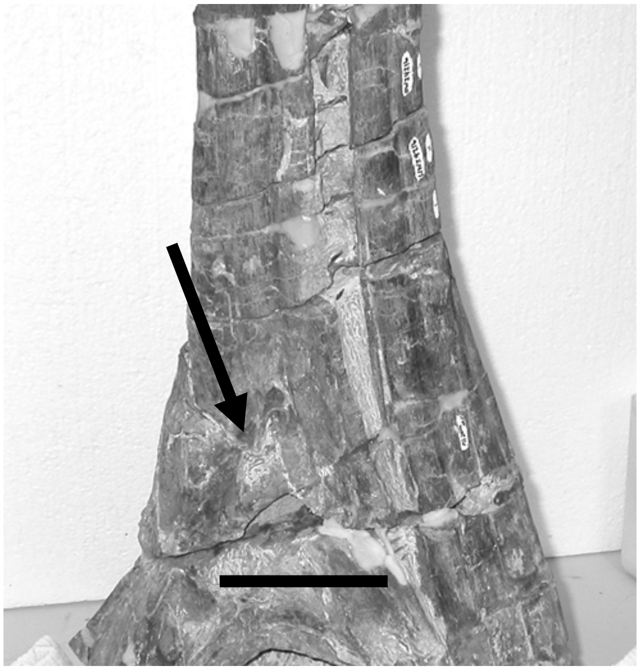

FIGURE 9. UW 24816 nasals overlap the premaxilla (arrow). Scale bar=10cm.

Layered calcite crystals were found on the outside bone surface, below the parietal. This growth occurred with some bone splintering caused by crystal growth below the right parietal. Notably, crystal growth did not occur at the open points in the lower jaws or within the vacuities of the skull proper but occurred below the displaced skull. Settling of the sediment under the skull post-deposition could have opened spaces enabling crystal growth.

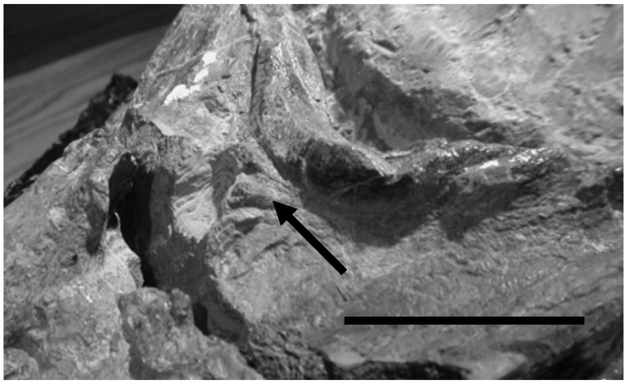

FIGURE 10. Detail view of left side of skull of UW 24816 exhibiting the external nares at anterior edge of lachrymal (arrow). Scale bar=10cm.

FIGURE 11. Split distorted section of the distal ramus of UW 24816. Note intact but displaced teeth. Scale bar=10cm.

COMPARISON TO OTHER *OPTHALMOSAURUS NATANS* SKULLS

The availability of high quality casts has allowed for comparison of UW 24216 with the three known *Opthalmosaurus* skulls preserved in three dimensions at the Carnegie Museum of Natural History. Of the available specimens CM 603, CM 878, and CM 1441, all have damage to the skull with varying degrees of distortion. Although there were no field notes available, some general inferences can be made about the disposition and the similarities in taphonomy to UW 24816.

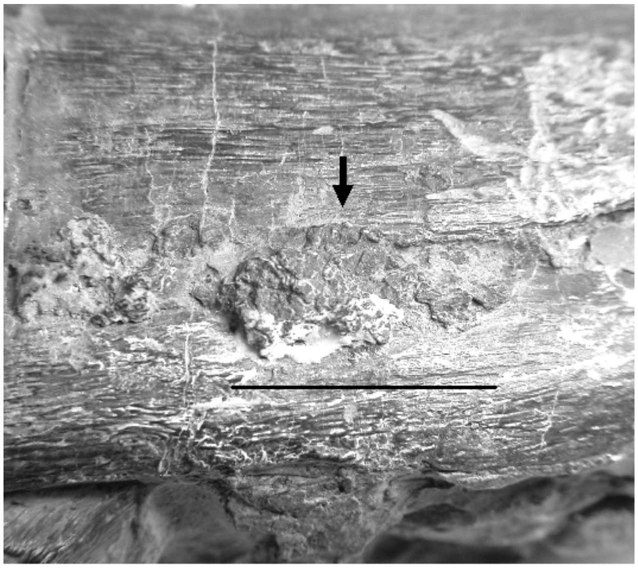

FIGURE 12. Iron-stone and pyrite on the surface of distal portion of the jaw of UW 24816. Note edges of foramina on jaw section (arrow). Scale bar =2cm.

The bones of the orbit and the ramus of the Carnegie specimens were compared to UW 24816. In ichthyosaurs, these are the most noticeable parts of the skull and in all of the available skulls, these portions, where complete, are a consistent indicator of distortion and would indicate damage or deformation because of impact or compaction. Anterior-first impact would not preclude damage in a crushing motion as caused by sediment or tectonic shifts. However, it can be useful to suggest a taphonomic history of the Carnegie skulls CM 603, 878 and 1441, based on the known disposition of UW 24816.

None of the skulls compared to UW 24816 are complete. The most damage on CM 603 is to the back of the skull, with a notable flattening of the braincase and a diagonal distortion to the general box shape of the back of the skull. There is no displacement of the bones of the orbit on the left side, but the right side appears partially distorted. The bones of the fore skull and rostrum are not considerably displaced.

The most complete skull of the three specimens, CM 878, is missing the most distal portion of the ramus and lacks any obvious taphonomic distortion (Gilmore, 1905). However, just as in CM 603, the box shape of the back of the skull of CM 878 is distorted diagonally by 45˚ angled to the left side. Individual bones of the temporal region and orbit of the left side are obscured by portions of the articulated vertebral column. CM 1441 is represented by the majority of the skull but is missing the bones anterior to frontal and nasal contact. This skull is severely distorted with the bones of the orbit on the left side pushed forward over and in front of the frontal, but the right side is intact. Of the 3 skulls, none have noticeable distortion of the rostrum as observed in UW 24816. There is no plasticity of bone or mineral accretion, although the most distal portions of the rostrum in all of the specimens were not available and some material may have been prepared away.

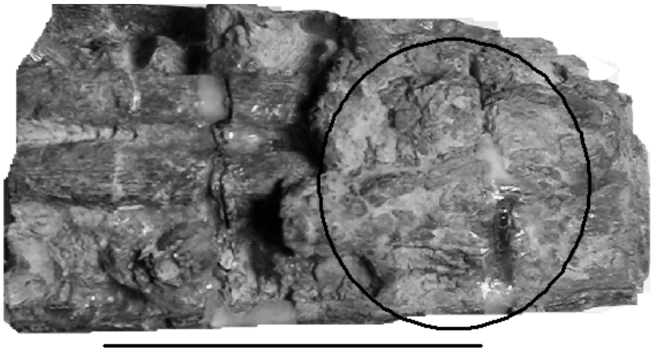

FIGURE 13. Distal portion of the upper jaw of UW 24816. Note mineral accretion and splintered bone (circle). Scale bar =5cm.

The sclerotic ring is intact in each of the Carnegie skulls. The eye region appears to have been able to withstand the pressures of burial enough to retain the round shape. The sclerotic plates form essentially a three dimensional, round basket shape, with each plate slightly overlapping the next. The disarticulated skull, UW 24804, has isolated sclerotic plates that retain a 45° to 90° bend in the mid point of the plate. These bones retain this shape even though the isolated skull bones that make up the orbit are disarticulated and scattered in the excavation.

The difference in other sediments such as that found with the disarticulated skull and body of UW 24804, would suggest a minor change in sediments, soupy shale vs. more shell hash or a shell bed that resulted in body mass disarticulation or body first deposition. It is also possible that the evidence of a resultant "nose dive" of UW 24804 could have been destroyed by rough post-depositional sediment reworking.

So far, based on the consistent taphonomic damage occurring to the back of the three dimensionally preserved skulls, the ichthyosaur specimens collected from the Sundance that retain the semi-complete skull appear to suggest a more common body out-head down configuration. Although field notes describing body position and general taphonomy for the older known skulls (CM 603, CM 878, and CM 1441) is limited or non-existent. Head down or "nose-dive" taphonomy may be relatively normal in soft sediment environments because the opthalmosaur body shape and center of gravity would favor the anterior making contact with the sediment first as the carcass sank to the bottom.

CONCLUSIONS

No *Opthalmosaurus* material from England is known from complete specimens because the material is usually found disarticulated (Andrews, 1910; McGowan and Motani, 2003). This is similar to the Sundance Formation, where most of the opthalmosaur material is also incomplete. However, the exceptionally preserved skulls such as UW 24816 and the Carnegie Museum specimens from the Sundance Formation should be compared with other opthalmosaur material from the Oxford Clay of England or the Neuquen Basin of Argentina. The discovery of a large articulated portion of an ichthyosaur skeleton in shallow marine sediments represents an exceptional case in taphonomy and its exceptional preservation warrants further studies.

UW 24816 suggests a timeline of distortion. Sediment accumulation was a factor in damage of the posterior portion of the skull as large open spaces between bones would be distorted by sediment weight, but the more distal portions the rostrum appears to have been damaged previous to this by impact in soft sediment. The skull of UW 24816, with a few bones disarticulated, was found partially buried at a steep angle to the bedding plane. The body drove the skull into the soft sediment, then collapsed over to lay on its dorsal side. The skull was displaced from the vertebral column, leaving the posterior portion of the jaw exposed.

The skull suffered from impact distortion but also diagenetic damage as the anterior skull is fractured into sections. Further mineral accretion through the open spaces of the skull caused some post-impact bone splintering. UW 24816 was exposed on the sea floor for some time, with evidence of borings, burrows and infaunal disturbance. The burrows were parallel to the skeleton. Decapod material suggest sustained activity was found within the burrows

The skull displays damage to the right temporal opening with the post-orbital, a jugal displaced posteriorly and laterally, displacement at the jugal/lacrimal maxilla distorting the right orbit. The resistant plates of the sclerotic rings were not damaged by the distortion of the orbit. The nasals and premaxilla were damaged and overlap because of the "nose dive" though very little damage was done to the laterally-oriented nares, preserving the anterior surface of the lacrimal. The ramus exhibits intact teeth but large scale distortion with both jaws twisted at extreme angles with distal portions broken or rotted.

Concretion development may have caused a slow increase in mass and distorted the surrounding matrix caused by the differential increase in weight. It may be suggested that the spotty placement of organic matter in biofilms generated spotty concretions on the exposed bone surface of the body mass. The spotty sediment accumulation, plus the additional weight of the biologically generated concretion and overlying sediment lead to compaction and displacement of some bones. This series of taphonomic events resulted in the lumpy structure of the concretion mass with protrusions of weathered bones.

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