SECOND MOSASAUR MEETING

May 2-6, 2007

Abstract Booklet
Michael J. Everhart, (ed.)

Fort Hays State University
Sternberg Museum of Natural History
3000 Sternberg Drive
Hays, Kansas 67601-2006

MEETING SCHEDULE

Thursday, May 3, 2007: Sessions

8:00 AM Registration opens
9:00 AM Welcome by Dr. Jerry Choate, Director, Sternberg Museum of Natural History
Opening remarks and orientation: Mike Everhart

9:30 AM FIRST SESSION - **Moderator: Mike Everhart**
9:30 AM THE MOSASAURS OF GEORGE F. STERNBERG, PALEONTOLOGIST AND FOSSIL PHOTOGRAPHER
Michael J. Everhart
10:00 AM FIRST RECORD OF STOMACH CONTENTS IN *TYLOSAURUS NEPAEOLICUS* AND COMMENTS ON PREDATION AMONG MOSASAURIDAE
Gorden L. Bell, Jr. and Kenneth R. Barnes

10:30 AM BREAK

11:00 AM SECOND SESSION – **Moderator: Anne Schulp**
11:00 AM THE ANATOMY AND SYSTEMATICS OF TYLOSAURINE MOSASAURS
Timon S. Bullard and Michael W. Caldwell

11:30 AM CHRONOSTRATIGRAPHIC DISTRIBUTION OF MOSASAUROIDS FROM THE BIG BEND REGION OF WEST TEXAS

Gorden L. Bell, Jr., Kenneth R. Barnes, and Michael Polcyn.

NOON LUNCH (Provided)

1:00 PM THIRD SESSION – **Moderator: Gorden Bell**
1:00 PM TOOTH ATTACHMENT AND TOOTH REPLACEMENT PATTERNS IN MOSASAURS
Michael W. Caldwell
1:30 PM ONTOGENETIC CHANGES IN THE MARGINAL DENTITION OF *TYLOSAURUS PRORIGER* (SQUAMATA: MOSASAURIDAE): ECOLOGICAL AND EVOLUTIONARY IMPLICATIONS
Takuya Konishi
2:00 PM MORE ON *CARINODENS BELGICUS* FROM THE MAASTRICHTIAN TYPE AREA
John W. M. Jagt, Anne S. Schulp and Eric W. A. Mulder

2:30 PM BREAK

3:00 PM FOURTH SESSION – **Moderator: Johan Lindgren**
3:00 PM PRELIMINARY OBSERVATIONS ON CAMPANIAN MOSASAURS IN ARKANSAS
Kelly J. Irwin

3:30 PM OSTEOLOGY OF THE MIDDLE EAR IN MOSASAURS (SQUAMATA): FROM IMPEDANCE MATCHING TO UNDERWATER HEARING
Michael W. Caldwell, Takuya Konishi, Alexander Dutchak, Gordon L. Bell, Jr., and James Lamb

4:00 PM A CLOSE SHAVE: THE YOUNGEST RECORD TO DATE OF *MOSASAURUS HOFFMANNI* FROM THE MAASTRICHTIAN TYPE AREA
John W. M. Jagt, Anne S. Schulp, Jacques Severijns, Dirk Cornelissen, Louis Verding, and Eric W. A. Mulder

4:30 PM THE FIRST MOSASAUR (REPTILIA: SQUAMATA) FROM THE LLANO ESTACADO OF NORTHWEST TEXAS
Bill D. Mueller, Sankar Chatterjee, William Cornell, David Watkins, and Gretchen L. Gurtler

5:00 PM Social Hour: TBD

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Friday, May 4, 2007: Sessions

8:30 AM Registration opens

9:00 AM FIFTH SESSION - **Moderator: John Jagt**

9:00 AM CALIFORNIA MOSASAURS II: THE MAASTRICHTIAN MORENO FORMATION REVISITED
Johan Lindgren

9:30 AM SOUTHERNMOST OCCURRENCE OF *PLATECARPUS PLANIFRONS* (SQUAMATA: MOSASAURIDAE) FROM THE TOMBIGBEE SAND MEMBER (CA. MIDDLE SANTONIAN) OF ALABAMA, USA
Takuya Konishi

10:00 AM A SEA URCHIN BITTEN BY A MOSASAUR - EVIDENCE OF OPPORTUNISTIC FEEDING?
Christian Neumann and Oliver Hampe

10:30 AM BREAK

11:00 AM SIXTH SESSION – **Moderator: Louis Jacobs**

11:00 AM CONVERGENCE BETWEEN MOSASAURS AND THE HESPERORNITHIFORM BIRDS
Larry D. Martin

11:30 AM MOSASAUROID MATERIAL FROM NORTHERN ITALY: A PRELIMINARY REPORT
Alessandro Palci, Michael W. Caldwell, and Cesare Papazzoni

NOON LUNCH (Provided)

1:00 PM SEVENTH SESSION (POSTERS)

2:30 PM BREAK

3:00 PM EIGHTH SESSION – **Moderator: Mike Caldwell**

3:00 PM THE MOSASAURS OF ANGOLA
Michael Polcyn, Louis L. Jacobs, Anne S. Schulp, and Octávio Mateus

3:30 PM "PACHYOSTOSIS" WITHIN MOSASAUROIDS
Alexandra Houssaye

4:00 PM SKELETOCHRONOLOGY OF THE LIMB ELEMENTS OF MOSASAURS (SQUAMATA; MOSASAURIDAE)
Rodrigo A. Pellegrini

4:30 PM USING ELECTRON MICROSCOPY AND FOCUSED ION BEAM AS A TOOL FOR ANALYSIS OF MOSASAUR BONE
M. Amy Sheldon

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Saturday, May 4, 2007: Sessions

8:30 AM Registration opens

9:00 AM NINTH SESSION - **Moderator: Eric Mulder**

9:00 AM MORPHOLOGY AND SYSTEMATIC POSITION OF *ANGOLASAURUS BOCAGEI* AND THE EVOLUTION OF THE BRAINCASE IN PLIOPLATECARPINE MOSASAURS
Michael Polcyn, Louis L. Jacobs, Anne S. Schulp, and Octávio Mateus

9:30 AM ON DISTRIBUTION, DIVERSITY AND PHYLOGENY OF THE GENUS *PROGNATHODON*
Anne S. Schulp

10:00 AM VERTEBRAL PATHOLOGY IN MOSASAURS
Bruce M. Rothschild

10:30 AM BREAK

11:00 AM TENTH SESSION – **Moderator: Mike Polcyn**

11:00 AM THE TALE OF THE TAIL - TAIL FIN EVOLUTION IN THE MOSASAUROIDEA
Johan Lindgren

11:30 AM MOSASAUR BITE MARKS ON AN AMMONITE. PRESERVATION OF AN ABORTED ATTACK?
William R. Wahl

NOON LUNCH (on your own)

1:00 PM ELEVENTH SESSION – **Moderator: Gorden Bell**

1:00 PM THE DIVERSITY OF AQUATIC LOCOMOTION IN EXTANT VARANOID LIZARDS
Bruce A. Young, M. Boetig, A. Fahey, and A. Lawrence

1:30 PM PRELIMINARY ANALYSIS OF STABLE CARBON ISOTOPES IN MOSASAURS AND OTHER MARINE AMNIOTES
John A. Robbins, Kurt Ferguson, Michael Polcyn, Louis L. Jacobs, and Torben C. Rick

2:00 PM REMAINS OF YOUNG MOSASAURS FROM THE SMOKY HILL CHALK (UPPER CONIACIAN-LOWER CAMPANIAN) OF WESTERN KANSAS
Michael J. Everhart

2:30 PM NEW TOOLS TO UNCOVER TRENDS IN MOSASAUR RICHNESS AND MORPHOLOGY: STRATIGRAPHICALLY CORRELATED ASSEMBLAGES
Marcus R. Ross and David E. Fastovsky

3:00 PM BREAK / END OF SESSIONS

6:00 PM Reception and Banquet- Sternberg Museum of Natural History

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Sunday, May 6, 2007: Field Trip (Meet at Museum by 8:30 AM)

ABSTRACTS

NEW MATERIAL OF *CARINODENS* FROM THE MAASTRICHTIAN PHOSPHATES OF MOROCCO**.**

BARDET, Nathalie, UMR 5143 du CNRS, M.N.H.N., 8 rue Buffon, 75005 Paris, France, PEREDA SUBERBIOLA, Xabier, Depto. Estratigrafía y Paleontología, Fac. Ciencia y Tecnología, Universidad del País Vasco / EHU, 4 8080 Bilbao, SCHULP, Anne S., Natuurhistorisch Museum Maastricht, De Bosquetplein 6-7, NL6211 KJ Maastricht, The Netherlands, and BOUYA, Baâdi, Office Chérifien des Phosphates, Centre Minier de Khouribga, Khouribga, Morocco.

Carinodens has been referred to as a very enigmatic, rare, and certainly the smallest mosasaurid of the latest Cretaceous. It is also one of the oldest figured mosasaur taxa (Faujas de Saint-Fond 1799). It is known from a subcomplete partially toothed dentary and an incomplete dentary fragment from the Maastrichtian of The Netherlands and some thirty-odd isolated teeth from coeval levels worldwide (The Netherlands, Belgium, Bulgaria, Ukraine, Russia, Brazil, Morocco, and possibly Jordan) (Schulp et al. 2006). The Moroccan record is based on a currently lost tooth from the Maastrichtian phosphates described by Arambourg (1952). Here we report on the discovery of five new teeth found in the Upper Maastrichtian strata of the Oulad Abdoun and the Ganntour phosphatic basins of Morocco. The crowns are typically low, swollen, laterally compressed, bicarinate, with a large apical nubbin and are referred to *C. belgicus* (Woodward, 1891). Most *Carinodens* specimens, including the new ones from Morocco, are of late Maastrichtian age. *Carinodens* is mainly known from the northern margin of the Mediterranean Tethys, around palaeolatitudes 40°N. The Brazilian and Moroccan teeth represent the only tropical record and confirm the astonishingly large geographical distribution of this taxon.

Faujas de Saint Fond, B. 1799. *Histoire Naturelle de la Montagne de Saint Pierre de Maëstricht*. Paris, 263 pp., 54 pls.
Arambourg, C. 1952. *Notes & Mém. Service géologique Maroc*. 92: 1-372.
Schulp, A. S., A. O. Averianov, A.A. Yarkov, F. A. Trikolide and J. W. M. Jagt. 2006. *Russian J. Herpetology* 13: 175-180.

FIRST RECORD OF STOMACH CONTENTS IN *TYLOSAURUS NEPAEOLICUS* AND COMMENTS ON PREDATION AMONG MOSASAURIDAE

BELL, Gorden L., Jr., Guadalupe Mountains National Park, Salt Flat, Texas, and BARNES, Kenneth R., Mosasaur Ranch Museum, Terlingua, Texas, USA.

An articulated mosasaur specimen identified as *Tylosaurus nepaeolicus* found in the Big Bend Region near Terlingua, TX is from the highest portions of the San Vicente Member of the Boquillas Formation. The specimen was found at a position about 27m (90 ft) below the top of the Boquillas Fm. and probably 55m (180 ft) below the zone of *Inoceramus undulatoplicatus*, based on calculations from local strike and dip. Stratigraphic and biostratigraphic data support an age assignment of Late Coniacian.

The skeleton is intimately associated with approximately 275 disarticulated bones and teeth from other, smaller vertebrate taxa. Several factors support a conclusion that the associated bones and teeth of the other taxa represent the remains of prey items consumed by the tylosaur shortly before its death. The densest concentration of disarticulated remains lies in the posterior visceral region of the articulated tylosaur. Disarticulated bony elements exhibit typical digestive dissolution of cortical bone and exposure of internal spongiosa, the latter being most extensively exposed on protuberant bone structures. Tooth crowns of mosasaurian prey items are also dissolved approximately to the level of skeletal bone surrounding the tooth attachment and open pulp cavities are apparent. Lack of dissolution on the articulated mosasaur skeleton is sufficient evidence to confirm that post-mortem taphonomic processes or diagenesis are not causes of the observed dissolution.

Even though somewhat modified by digestive erosion, the disarticulated bony elements are sufficiently preserved to determine that a minimum of 3 immature individuals of two size classes of *Platecarpus* af. *P. planifrons* are present. Also present are numerous teeth of the shark, *Ptychodus mortoni*, none of which show significant digestive dissolution. No materials of coprolitic texture are present. This evidence suggests that the prey items were ingested shortly before the mosasaur died, possibly within a few days, and that the *Ptychodus* was likely the last item consumed.

A growing body of evidence supports conclusions that mosasaurs actively preyed upon each other, but that congeneric individuals were not among items in the prey selection. Therefore mosasaurs cannot technically be classed as cannibals. Currently there is no evidence that members of the 4 major mosasaur clades dined within their own lineage.

Furthermore, the diversity of prey items found with a majority of tylosaurine remains suggests that they were rather opportunistic in their hunting habits. We also report here, from the same area and stratigraphic interval as the *T. nepaeolicus* specimen, another mosasaur, *Platecarpus* af. *P. planifrons*, that contains several fish vertebrae in relative position consistent with stomach contents. The consistent presence of only fish in the gut contents of two species of *Platecarpus* corresponds well to plioplatecarpine tooth morphology and it is likely that *Platecarpus* specialized in eating only fish.

Table 1 is a synopsis of mosasaurs with associated materials that can arguably be attributed to the remains of stomach contents. Massare (1987) previously listed mosasaurian associations with putative stomach contents. Table 1 incorporates new data but does not include potentially accidental associations or records not attributable to any particular mosasaur clade, as reported in Massare (1987, table 1). Original sources of data are cited from that reference.

Table 1 – Synopsis of Known Mosasaur Specimens with Stomach Contents

Primary Individual & Catalog #	Mosasaurian Prey	Non-mosasaurian Prey	Source
Tylosaurus proriger SDSM&T 10439	*Platecarpus tympaniticus*	*Hesperornis* (bird)shark, fish	Bjork, 1981; Martin and Bjork, 1987
Tylosaurus proriger USNM 8898	None	Polycotylid plesiosaur	Sternberg, 1922
Tylosaurus proriger GSM 1	*Clidastes* sp.	None	This report
Tylosaurus nepaeolicus MRM KB-M-3	*Platecarpus planifrons*	*Ptychodus mortoni*	“ “
Hainosaurus sp. RSM P 2588.1	*Plioplatecarpus* sp. and unidentified mosasaur	None	“ “
Hainosaurus sp. cat. # unspecified	None	Turtle	Dollo, 1887
Platecarpus tympaniticus LACM 128319	none	Fish	Stewart, 1993
Platecarpus planifrons MRM KB-M-19	none	Fish	This report
Platecarpus sp. cat # unspecified	none	fish (to 4 ft length)	Williston, 1899
Mosasaurus sp. TMP 83.126.1	plioplatecarpine	none identified	This report
Plotosaurus tuckeri (=*bennisoni*), # unspecified	none	fish (small)	Camp, 1942

Bjork, P. R. 1981. Food habits of mosasaurs from the Pierre Shale of South Dakota. Abstracts with Programs, Rocky Mountain Section, Geological Society of America, 13(4):191.

Camp, C. L. 1942. California Mosasaurs: University of California Memoirs 13:1-68.

Dollo, L. 1887. Le hainosaure et nouveaux vertebres fossilles de Musee du Bruxelles: Revue des Questiones Scientifiques, series 1, 22: 70-112.

Everhart, M. J. 2004. Plesiosaurs as the food of mosasaurs; new data on the stomach contents of a *Tylosaurus proriger* (Squamata; Mosasauridae) from the Niobrara Formation of western Kansas. The Mosasaur 7: 41-46.

Martin, James E. and Bjork, Phillip R., 1987, Gastric Residues Associated with a Mosasaur from the Late Cretaceous (Campanian) Pierre Shale in South Dakota: Dakoterra 3: 68-72

Massare, J. A., 1987, Tooth morphology and prey preference of Mesozoic marine reptiles: Journal of Vertebrate Paleontology 7(2): 121-137.

Sternberg, C. H. 1922. Explorations of the Permian of Texas and the chalk of Kansas, 1918: Kansas Academy of Science Transactions 30(1): 119-120.

Stewart, J. D. 1993. A skeleton of *Platecarpus* sp. (Lacertilia: Mosasauridae) with stomach contents and extensive integument: Journal of Vertebrate Paleontology 13(Supplement to 3): 58A.

Williston, S. W. 1899. Some additional characters of the mosasaurs. Kansas University Quarterly 8(1):39-41.

CHRONOSTRATIGRAPHIC DISTRIBUTION OF MOSASAUROIDS FROM THE BIG BEND REGION OF WEST TEXAS

BELL, Gorden L. Jr., Guadalupe Mountains National Park, Salt Flat, Texas, BARNES, Kenneth R., Mosasaur Ranch Museum, Terlingua, Texas, and POLCYN, Michael J., Shuler Museum of Paleontology, Southern Methodist University, Dallas, Texas, USA.

Although mostly unpublished, there is a significant succession of mosasauroids from Late Cretaceous marine deposits of the Big Bend region in far southwest Texas. The oldest known specimens occur in lag deposits and calcarenites that are associated with the ammonoids *Prionocyclus hyatti* and *Coilopoceras springeri* in the upper part of the late Middle Turonian *P. hyatti* Zone approximately 36 m above the base of the Ernst Member, Boquillas Formation. All are disarticulated individual elements, some from small plesiopedal forms possibly referable to the basal Russellosaurina clade and some from larger (probably hydropedal) forms definitely referable to Russellosaurina. A fairly well preserved skull and vertebrae of an undescribed tylosaurine is known from a position about 30 meters higher in the Ernst Member also within the *P. hyatti* Zone. Several specimens of *Tylosaurus nepaeolicus* and a specimen of a potentially different Tylosaurus species are known from the upper portions of the San Vicente Member, Boquillas Fm., where it is of Late Coniacian age. Also from this same interval are several specimens of *Platecarpus* af. *P. planifrons*, or a closely related plioplatecarpine with some similarities to *Ectenosaurus*.

A specimen each of *Tylosaurus* sp., *Clidastes liodontus*, *Clidastes* sp., and an undescribed species of *Ectenosaurus* are known from the lower portion of the Pen Fm. in the western part of the Big Bend region. There *Inoceramus undulatoplicatus* is known to occur in the lower Pen Fm., but the stratigraphic positions of these mosasaurs have not been accurately determined relative to the position of that zone. Thus, these mosasaurs may be either latest Coniacian or early Santonian age. Additionally, a single specimen of halisaurine? mosasaur was recovered from a higher but unconstrained level in the Pen Formation. This specimen might range from middle Santonian to early Campanian in age.

BASAL MOSASAUROIDS FROM THE TURONIAN OF VALLECILLO, NUEVO LEÓN, MEXICO

BUCHY, Marie-Céline, Museo del Desierto, Saltillo, Coahuila, Mexico; SMITH, Krister T., Vertebrate Paleontology Lab, University of Texas, Austin, Texas 78758, U.S.A; IFRIM, Christina, and GIERSCH, Samuel, Staatliches Museum für Naturkunde Karlsruhe, Germany.

The lower Turonian lithographic limestones of Vallecillo, quarried for building materials, represent an open marine plattenkalk, deposited at the junction of the Atlantic Ocean and Western Interior Seaway during the Early Turonian. They are known for yielding excellently preserved fish and rare other vertebrate remains. Among the aquatic vertebrates are an aigialosaur-grade mosasauroid, which was presented at this meeting three years since. In late 2006, additional remains were discovered. These include matching fragments containing the thoracic region and forelimbs of “Pablo,” the original aigialosaur specimen, and also “Viktor,” a less well-preserved fragment of a rather larger individual, originally mistaken for a fish. A fragment of a manus as well as “Monika,” a portion of tail, are also known. Additionally, a new and complete skeleton, “Pedro,” represents the smallest individual. Finally, we introduce “Marcelo,” a large and excellently preserved but unfortunately incomplete basal mosasauroid; it preserves the tail, hindlimbs, pelvic girdle and parts of the thoracic region and the skull; soft-tissue is preserved throughout, including gut contents. The taxonomic identity of all the specimens is not yet certain, pending further preparation. Vallecillo, to date, has yielded the remains of six basal mosasauroids and so is the most productive site for these animals in the world. Moreover, ongoing scientific excavations and lasting collaboration with quarrymen will surely yield more specimens from this stratigraphically and paleogeographically propitious site.

THE ANATOMY AND SYSTEMATICS OF TYLOSAURINE MOSASAURS

BULLARD, Timon S.[1], and CALDWELL, Michael W.[1,2], [1]Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada, T6G2E9, [2]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada, T6G2E9.

The type and associated materials of *Hainosaurus pembinensis* (Reptilia: Squamata) from the Middle Campanian Pembina Member of the Pierre Shale, Manitoba, are redescribed. The anatomy of this species is clarified with comparison to *Hainosaurus bernardi* from the Early Maastrichtian of Belgium, and *Hainosaurus pembinensis* is referred to the genus *Tylosaurus*. A new species of tylosaurine mosasaur, from the Late Campanian Bearpaw Formation of Saskatchewan, is recognized. This species represents the youngest occurrence of *Tylosaurus*. The phylogeny of the mosasaur Subfamily Tylosaurinae is the focus of a cladistic analysis of mosasauroids, expanding the work of previous authors to include *Hainosaurus bernardi*, *Taniwhasaurus oweni*, *Tylosaurus pembinensis* and *Tylosaurus* n. sp. The findings are consistent with previous studies, and show that *Hainosaurus bernardi* and *Taniwhasaurus oweni* are the most basal tylosaurines, with the species of *Tylosaurus* forming a monophyletic clade.

TOOTH ATTACHMENT AND TOOTH REPLACEMENT PATTERNS IN MOSASAURS

CALDWELL, Michael W., Department of Earth and Atmospheric Sciences, and Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada, T6G2E9

Recently published data on the tooth attachment histology of the Late Cretaceous marine lizard *Platecarpus* (Mosasauridae) noted the presence of all currently recognized thecodont attachment tissues. In mosasaurs, a woven-fiber bone matrix forms the margins and floor of the tooth alveolus and is identified as alveolar bone based on its histologic and topologic similarities to archosaurian and mammalian alveolar bone. Mosasaurs also appear to possess a cribiform-plate, consistent with histologic evidence indicating the presence of a periodontal ligament. Evidence of the periodontal ligament includes parallel fibers present in multiple, non-resorbed generations of alveolar bone that are similar to mineralized collagen fiber bundles known as Sharpey's fibers. The mosasaur tooth also possesses a dentine root around which is a thin layer of acellular cementum; this tissue is surrounded by a massive amount of cellular cementum which completely fills the alveolar space, increasing in size during tooth replacement. The cementum mass is composed of two histologically distinct tissues: 1) a loosely organized ground matrix; 2) a laminar form surrounding the vascular tissue. Tooth replacement and the ontogeny of these tissues begins with enamel crown development in the dental lamina, posterior and lingual to the tooth position it will later occupy. The crown develops within the lamina in a vertical position and not horizontally as has been recently suggested. Utilizing a mechanism not currently understood, the developing crown and its dental papilla migrate to the posterolingual margin of the tooth position where the lamina and papilla appear to initiate resorption of the cementum mass at the base of the crown. As the resorption pit grows in size, the crown, papilla, and presumably the dental lamina, descend into the pit. Once the resorption pit has achieved a dimension equal to the size of the adult tooth crown, crown growth is truncated, and cementum begins to develop around the non-enameled portion of the tooth. The resorption pit expands to include generalized resorption of the cementum and alveolar bone throughout the alveolus. Growth of cementum tissues appears to be rapid as the mineralized component thickens from the bottom down. The effect is to erupt the tooth vertically in the alveolus; the replaced tooth likely is removed mechanically during feeding as the replacement tooth rises into the alveolus. The mosasaur form of tooth attachment is certainly thecodont and raises intriguing questions about the evolution of pleurodonty and acrodonty within lepidosauromorphs. Likewise, the pattern of tooth replacement in

mosasaurs appears to be unique among squamates specifically, and among thecodont amniotes generally. The conclusion that mosasaurs possess the attachment tissues used to diagnose thecodont ankylosis are explored further here, and examined in the context of a reassessment of the pattern of mosasaur tooth replacement.

IMPEDANCE MATCHING TO UNDERWATER HEARING

CALDWELL, Michael W.[1,2], KONISHI, Takuya[2], DUTCHAK, Alexander[3], BELL, Gordon, Jr.[4], and LAMB, James[5]. [1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada, [2]Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada, [3]Department of Geological Sciences, University of Colorado at Boulder, Boulder, Colorado, USA,[4]Guadalupe Mountains National Park, Salt Flat, Texas, USA, and [5]McWane Center, Birmingham, Alabama, USA.

The anatomical constituents of the mosasaurid middle ear are seldom preserved in their entirety in any one mosasaur specimen as the elements are represented by three skeletal types: 1) ossified endochondral elements; 2) non-ossified/non-calcified cartilaginous elements; 3) calcified cartilage elements. However, by study of many different mosasaur specimens from around the globe, preserved in a variety of sediments and affected by a variety of taphonomic conditions, we have collected sufficient data to reconstruct the middle ear skeleton in its entirety. Beginning externally, we identify a massive, plate-like element filling the expanse of the quadrate conch, as the expanded and fused pars superior, pars inferior and processus posteriorus of the extracolumella. Internally this element presents a short, internally trifurcating process that extends towards the stapedial opening. In this regard, we agree in large part with previous identifications as given by Camp (1942). The fused elements of the extracolumella have continued to be identified, despite Camp (1942), as an ossified tympanum, a myth which has persisted for nearly a century. We differ from Camp (1942) in our identification of the elements internal to the stapedial notch and medial to the quadrate. As the extracolumella passes through the stapedial notch the shaft does not articulate with the processus internus, but rather is fused to it so that the processus internus appears to be a middle ear bifurcation of the extracolumellar shaft. The head of the processus internus inserts into the unique mosasaurid stapedial pit. The length of the fused calcified cartilaginous shaft of the processus internus + extracolumella is extremely long, tapering medially as it approaches the very delicate, ossified, columella. Our new reconstruction of the middle ear anatomy of mosasaurids necessitates two major considerations: 1) re-evaluation of anatomical nomenclature as applied to the processus internus; 2) re-evaluation of the acoustic capacity of mosasaurs as it is not clear if they retained any capacity for impedance-matching hearing in such a massive middle ear skeleton. The phylogenetic implications of this anatomy will be discussed by comparison to more basal mosasauroids, snakes, and other lizards.

REMAINS OF YOUNG MOSASAURS FROM THE SMOKY HILL CHALK (UPPER CONIACIAN-LOWER CAMPANIAN) OF WESTERN KANSAS

EVERHART, Michael J., Sternberg Museum of Natural History, Fort Hays State University, Hays, Kansas, 67601, USA.

The remains of young mosasaurs, especially those that could be considered to be newly born, are poorly represented in the fossil record. This lack of specimens led some earlier workers to suggest that mosasaur babies were born or hatched in other localities such as distant shores, or along the banks of rivers or estuaries. However, no such birthing area or concentration of the remains of young mosasaurs has ever been located. On the other hand, specimens of immature mosasaurs have been found within the Smoky Hill Chalk of western Kansas. The chalk was deposited on the eastern shelf of the Western Interior Sea during late Coniacian through Early Campanian time, hundreds of kilometers from the nearest land. Most of the specimens recovered to date are the isolated premaxillae of small tylosaurines, arguably the most resistant part of the skull of a mosasaur at any age. Most also appear to be the remains of a larger predator's meal because of the digested appearance of the bone and the fact that the teeth have been dissolved into their alveoli. Measurement of the specimens and comparisons to complete skulls of tylosaurines for scaling purposes indicates that the total skull length of these individuals was 18-25 cm. Assuming that the skull to body length proportions (14%) remained approximately equal through life in mosasaurs, the remains represent young tylosaurines that were 1.3 to 1.8 m in length at the time of death. Some specimens (KUVP 5012 and FHSM VP-14845) include additional skull fragments and one specimen (VP-14846 and VP-14847) that includes the partially digested and commingled skull fragments of two small plioplatecarpines. Another tylosaurine specimen (FHSM VP-14848) represents a 2 m long individual that apparently reached the sea bottom relatively intact.

THE MOSASAURS OF GEORGE F. STERNBERG, PALEONTOLOGIST AND FOSSIL PHOTOGRAPHER

EVERHART, Michael J., Sternberg Museum of Natural History, Fort Hays State University, Hays, Kansas 67601, USA.

George F. Sternberg is a well known as a field paleontologist who collected fossils primarily from Kansas and also from as far away as Canada and Argentina. His abilities as a photographer are not as well known but were probably developed as teenager while helping his father, Charles H. Sternberg, in the family business. Later, G. F. Sternberg used small versions of his photographs glued to typewritten pages to advertise his fossils for sale to various museums around the country. His well composed and large format black and white photographs represent some of the earliest visual documentation of fossil discoveries and collecting techniques. Although most of G. F. Sternberg's photographic negatives were destroyed in the basement of his home by a flood in 1951, many of his photographs are maintained in the archives of the Forsyth Museum at Fort Hays State University, Hays, Kansas. They include the remains of a *Platecarpus ictericus* collected in 1909, another *Platecarpus* skull collected in 1911, a *Clidastes propython* skull and front paddles (date unknown), a complete *Platecarpus* skeleton sent to Wiman in 1921 along with the type specimen of "*Halisaurus*" *sternbergi*, a complete skull of *Tylosaurus kansasensis* collected in 1924 and sent to Harvard, extensive preparation shots of a nearly complete *Tylosaurus proriger* (VP-3) in 1926, and a 1931 field shot on the dig of a *Tylosaurus*. Sternberg's other photographs document field work and his preparatory techniques as well as his efforts to promote fossils for public school and university collections.

"PACHYOSTOSIS" WITHIN MOSASAUROIDS

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"Pachyostosis" is displayed by vertebrae and sometimes ribs of various varanoid lizards with estimated reduced swimming abilities adapted to shallow marine environments (Ricqlès & Buffrénil 2001). Among mosasauroids, it seems to affect only the plesiopedal form (*sensu* Bell & Polcyn 2005) *Carentonosaurus mineaui* Rage & Néraudeau 2004 and a new plesiopedal taxon (Houssaye, in progress). The histological study of this bone specialization in *Carentonosaurus* reveals that it corresponds in fact to pachyosteosclerosis (Houssaye et al. submitted) caused by the combination of cortical hyperplasy (pachyostosis *s.s.*) and bone compaction due to an inhibition of the chondroclastic and osteoclastic activities (osteosclerosis). "Pachyostosis" had been observed in part of the vertebrae of *Carentonosaurus* because pachyostosis *s.s.* is morphologically observable, but osteosclerosis is not. Other mosasauroids, displaying no external sign of pachyostosis *s.s.*, may therefore present osteosclerosis. Several observations suggest that this may be the case for some "mosasaurs" supposed to have lived in near shore environments (Sheldon, 1997). This specialization, which may be regarded as a neotenic process (Ricqlès & Buffrénil 2001), presents a broad polymorphism in the taxa "affected" (Lee et al., 1999) which suggests important functional implications. Moreover, the fact that it occurs only in Pythonomorpha within squamates raises the question of its possible phylogenetic significance.

PRELIMINARY OBSERVATIONS ON CAMPANIAN MOSASAURS IN ARKANSAS

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Marine vertebrate fossils were first reported from Upper Cretaceous formations of southwestern Arkansas over 150 years ago. However, with the exception of marine turtles, the subsequent literature on Upper Cretaceous marine reptiles from Arkansas is meager. Two mosasaur taxa have previously been reported from the upper Campanian Marlbrook Marl Formation, *Mosasaurus conodon* and *Plioplatecarpus marshi*, based on material from historic collections. Recent fieldwork (2002-2006) in isolated exposures of the upper Marlbrook Marl, in Clark, Hempstead, and Howard counties, has produced material from 32 mosasaurs; allowing for refinement in the determination of taxonomic composition and measures of relative abundance, in this overlooked Gulf Coast mosasaur community. A community comprised of *Mosasaurus conodon*, *Plioplatecarpus primaevus*, and *Prognathodon* sp. is indicated, based on characters of the teeth, vertebrae, humeri, and quadrate morphology. The Marlbrook Marl correlates to the Bluffport Marl Member, Upper Demopolis Chalk in Alabama, constraining this community to the early-middle Mosasaurus Acme Zone (MAZ) (mid-Campanian-Maastrichtian), as defined by C. R. Kiernan in 2002. The MAZ was originally erected as the *Mosasaurus-Plioplatecarpus* Acme Zone by G. L. Bell in 1985, and was modified by K. R. Wright in 1986. Comparison in the relative abundance of genera reveals a significant difference in composition between the Alabama and Arkansas communities. Kiernan's Alabama MAZ (mid-Campanian-Maastrichtian) was based on 30 specimens, with *Mosasaurus* comprising 63.3% of the sample, *Plioplatecarpus* 30% and *Prognathodon* 6.7%. Whereas the upper Campanian Arkansas sample (n=34) is composed of *Plioplatecarpus* 55.9%, *Mosasaurus* 35.3%, and *Prognathodon* 8.8%. This preliminary analysis suggests that a more temporally and stratigraphically restricted "*Plioplatecarpus* Acme Zone" may have existed along the Gulf Coast during the mid- to late Campanian.

MORE ON *CARINODENS BELGICUS* FROM THE MAASTRICHTIAN TYPE AREA

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A single tooth crown (NHMM JJ 13527), assignable to the durophagous mosasaur *Carinodens belgicus*, from the basal 0.1 metre of Meerssen Member (Maastricht Fomation) subunit IVf-6, at the ENCI-HeidelbergCement Group quarry (Maastricht), is the youngest *in situ* find of this species in the type area of the Maastrichtian Stage so far. We have previously considered the extreme rarity of material of this taxon, now known from two lower jaws (one of which is fragmentary) and two dozen or so of isolated tooth crowns, and even done some tests to obtain data on possible prey items (*J. vert. Paleont.* 24: 744-747, 2004; *Neth. J. Geosci.*, 84: 345-357, 2005). Here we plot potential food sources, including hard-shelled prey such as bivalve (predominantly ostreids) and gastropod molluscs, ammonites, nautiloids, belemnitellid coleoids, brachiopods, irregular and regular echinoids as well as crustaceans, in a chart documenting their distribution ranges and acmes. With this in hand it is even more of a mystery why this species is so rare in the area, with such a plethora of food items available. Possibly it lived elsewhere (e.g., either in deeper or shallower waters) and only fed in the area at certain times. Of note also is that, contrary to finds of more or less articulated skeletons of mosasaurines (*Mosasaurus hoffmanni*, *Prognathodon saturator*) and plioplatecarpines (*Plioplatecarpus marshi*) in the area, no postcranial elements of *C. belgicus* are known, or none have been recognised as such to date.

A CLOSE SHAVE: THE YOUNGEST RECORD TO DATE OF *MOSASAURUS HOFFMANNI* FROM THE MAASTRICHTIAN TYPE AREA

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A partial skull (left lower and upper jaws, left splenial, ?coronoid, isolated teeth and tooth crowns), found April 16, 2004 in a severely fractured state and scattered through blasting, was recovered by one of us (JS) from the uppermost Meerssen Member (Maastricht Formation) at the Ankerpoort-Curfs quarry, Geulhem (Valkenburg aan de Geul, Netherlands). Coming from the highest metre of this member (i.e., subunit IVf-6, just below the Berg en Terblijt Horizon = K/Pg boundary), this constitutes the highest *in situ* record of *Mosasaurus hoffmanni* to date. There is general agreement that the Meerssen Member represents deposition in (very) shallow, subtropical waters, with an estimated maximum depth of 2-15 meters. However, compared to other subunits, IVf-6 is marked by increased thickness, possibly related to rapid local subsidence during the latest Maastrichtian. Thus the sea in which this part of the sequence was laid down could still have supported large-bodied mosasaurs such as *M. hoffmanni*. Although no associated skeletal material was discovered at the site, the skull must have belonged to a (semi-)articulated skeleton, rather than a floating carcass. Its importance is twofold; first, it represents an *in situ* record close to the K/Pg boundary (contra Sullivan, 1987, *Contr. Sci. Nat. Hist. Mus. Los Angeles Cty*, 391; and other authors), and second, it enables detailed comparison of skull and dental characters (faceting, enamel structure, etc.) with other material of *M. hoffmanni*, adding to a better understanding of that species. Previous records from this close to the K/Pg boundary comprised isolated tooth crowns only, of a plioplatecarpine and a globidensine, also known, albeit rarely, from basal lag deposits of the overlying Geulhem Member (Houthem Formation) of early Paleocene age.

ONTOGENETIC CHANGES IN THE MARGINAL DENTITION OF *TYLOSAURUS PRORIGER* (SQUAMATA: MOSASAURIDAE): ECOLOGICAL AND EVOLUTIONARY IMPLICATIONS

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Detailed description of juvenile mosasaur (Squamata: Mosasauridae) anatomy has received little attention in the literature. Here I report on the crown morphology of marginal teeth in a well-preserved juvenile specimen pertaining to one of the largest mosasaur species, *Tylosaurus proriger*; the specimen was collected from the lower Mooreville Chalk Formation (Upper Santonian-Lower Campanian) of western Alabama, USA. Compared with the adult dentition, which exhibits closely-spaced, conical, stout tooth crowns having bases that are nearly circular in cross section, the marginal teeth of the juvenile are much more slender and posteromedially recurved, and highly compressed laterally at the bases; there is a proportionally larger gap between the adjacent crowns in the juvenile. The only discernible similarity in the adult and juvenile dental morphology, and thus possibly the only dental character diagnosable of this taxon, is the intercarinal angle, which is about 117^{o} on the labial side.

The evidence suggests that large *T. proriger* individuals sometimes consumed other, smaller mosasaurs such as *Platecarpus*, but the estimated body length of this juvenile specimen at less than four meters is clearly smaller than a fully grown *Platecarpus* specimen. Therefore, the ontogenetic changes in dental morphology reported here in *T. proriger* seem to be correlated with change(s) in diet through its ontogeny, as is also known in the extant, large-bodied monitor lizard, *Varanus niloticus*. The general similarity between the tooth crown morphology of juvenile *T. proriger* and that of adult *Platecarpus* is also discussed from a phylogenetic point of view.

A NEW SPECIMEN OF *SELMASAURUS* SP., CF. *S. RUSSELLI* (MOSASAURIDAE: PLIOPLATECARPINAE) FROM GREEN COUNTY, WESTERN ALABAMA, USA

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A rare species of plioplatecarpine mosasaur, *Selmasaurus russelli* Wright and Shannon, 1988, has been only known from the holotype. It mainly consists of partial but otherwise superbly preserved cranial materials collected from the Selma Group of western Alabama, USA. Since its erection more than 15 years ago, however, the taxon has never been included in any of the published and unpublished mosasaur phylogenetic analyses, and no additional material has been reported to date. Here I present detailed description of a right quadrate that is assignable to *Selmasaurus* sp., cf. *S. russelli*, collected from the Tombigbee Sand Member (Santonian) of the Eutaw Formation, Green County, western Alabama. Although the quadrate is about 25% taller than that of the holotype, it shares the following characters with the type material: quadrate shaft distinctively bent medially at mid-height; medial surface of suprastapedial process broadly excavated; suprastapedial process not expanded distally; infrastapedial process tall (>40% of quadrate height measured from condylar surface) and pedestal-shaped, with distal end broadly contacting distal portion of suprastapedial process ventrolaterally; stapedial pit broadly keyhole-shaped. While the smaller quadrates of the holotype show no indication of fusion between the supra- and infrastapedial processes, the new specimen preserves a possible cartilaginous remnant filling the small gap between these processes, making them appear to be fused. Although large, identification of the new quadrate as pertaining to *Prognathodon* from North America is rejected based mainly on the proportional narrowness of the element and the non-circular stapedial pit morphology. The element differs from that of *Ectenosaurus* in lacking the distal expansion of the suprastapedial process and the posteriorly overlapping tongue from the infrastapedial process.

SOUTHERNMOST OCCURRENCE OF *PLATECARPUS PLANIFRONS* (SQUAMATA: MOSASAURIDAE) FROM THE TOMBIGBEE SAND MEMBER (CA. MIDDLE SANTONIAN) OF ALABAMA, USA

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Platecarpus is the most commonly found mosasaur taxon in North America, comprising about 60% of mosasaur specimens from the Smoky Hill Chalk Member (Upper Coniacian to Lower Campanian) of west-central Kansas, USA. Specimens of *P. planifrons* (Cope, 1874) occur in the lower part of the member (Upper Coniacian to Lower Santonian), but are known in much fewer numbers compared with the other congener from the member (= *P. ictericus*/*P. tympaniticus*), due partially to the lack of its formal diagnosis until recently. While *P. ictericus*/*P. tympaniticus* is reported from the eastern Gulf region (e.g., Mississippi and Alabama) as well, materials of *P. planifrons* have been known to date only from the aforementioned member in western Kansas.

Here I report on a single frontal element assignable to *Platecarpus planifrons* collected from the Tombigbee Sand Member (ca. Middle Santonian) of Montgomery County, central Alabama, USA. Although missing the anterior extremity of the premaxillary processes, left ala, and a pair of posteromedian flanges, the element is well preserved with no distortion, and shows the following diagnostic characters for the species: preorbital width greater than interorbital width; dorsal surface planar, lacking median dorsal keel; prefrontal and postorbitofrontal not meeting above orbit; lateral border thickened above orbit. This specimen documents the first unambiguous occurrence of this poorly known *Platecarpus* species outside of Kansas, and extends its geographical range as far south as central Alabama. Contemporary occurrence of *P. planifrons* during the Santonian in both western Kansas and Alabama is significant in gaining new insights into vertebrate distribution within the Western Interior Seaway during this interval of Late Cretaceous time.

CALIFORNIA MOSASAURS II: THE MAASTRICHTIAN MORENO FORMATION REVISITED

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Even though the occurrence of mosasaur remains in the Maastrichtian part of the Moreno Formation (Great Valley Group), San Joaquin Valley, central California, has been known since the early twentieth century, surprisingly little has been done to determine the composition of this important assemblage. In the most comprehensive work on California mosasaurs published so far, Camp (1942) erected and described three new and seemingly endemic taxa, "*Kolposaurus*" (*Plotosaurus*) *bennisoni*, "*K.*" (*P.*) *tuckeri* and *Plesiotylosaurus crassidens*, from the Tierra Loma Shale and Garzas Sand member of the formation. More recently, Bell (1997) added yet another mosasaurine to this faunal list when he identified the enigmatic globidensine *Prognathodon rapax* from two partial skeletons collected in the Tumey and Panoche hills, central San Joaquin Valley.

In 2006, a project was initiated with the objective of documenting the diversity and biogeography of the Moreno mosasaur fauna and to date, five genera have been identified from the formation including *Plotosaurus*, *Plesiotylosaurus*, *Prognathodon*, *Mosasaurus*, and *Halisaurus*. Although the material available only permits species determination of *Plotosaurus* and *Plesiotylosaurus*, it is still sufficient enough to conclude that the Moreno assemblage is more similar at the generic level to approximately contemporaneous faunas from the Western Interior, Gulf Coast and Eastern Coastal Plain than previously (Nicholls and Meckert 2002) hypothesized. Moreover, only one species of *Plotosaurus* (*P. bennisoni*), is recognized, as the type materials of *P. bennisoni* and *P.*

tuckeri by all likelihood pertain to a single taxon. A re-examination of the two skeletons purportedly representing *P. rapax* failed to verify the presence of this mosasaur in the Moreno Formation. Instead, one of the specimens is a primitive, yet undetermined species of *Mosasaurus*, whereas the other fossil can be assigned only to *Prognathodon* sp.

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THE TALE OF THE TAIL - TAIL FIN EVOLUTION IN THE MOSASAUROIDEA

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The Mosasauroidea includes distinctive and specialized diapsid reptiles that originated, diversified, and eventually vanished within the last 35 Ma of the Cretaceous. During their comparatively brief geological lifespan mosasauroids were nonetheless very successful, and following their first appearance in the Cenomanian they rapidly became abundant in epicontinental seas worldwide. One of the reasons for this global distribution was the ability of mosasauroids to adapt swiftly to aquatic environments. Early members of the group radically transformed the skull, limbs and axial skeleton to meet the demands of marine life. Moreover, locomotion was transferred from the appendages to the tail, resulting in a very specialized sculling organ.

Despite this remarkable evolutionary transition exceedingly little work has hitherto been done on the different stages of mosasauroid tail fin evolution, and most studies inaccurately assume that they were all anguilliform swimmers powered by isocercal caudal flukes (i.e. single-lobed tail fins supported by a centrally located backbone), unsuitable for rapid, sustained cruising. Nonetheless, recent investigations have demonstrated that at least the derived members of the Mosasauroidea were housed pisciform animals equipped with semilunate tails, making them similar in appearance to moderately derived ichthyosaurs (another group of extinct marine reptiles), sharks and whales.

Here, mosasaur tail fin morphology and evolution are reviewed and reconstructed from key aspects of vertebral osteology, including centrum morphometrics and process orientation. A generalized pattern of regional tail anatomy in derived columns with three discrete structural units (stable proximal tail stock, mid-sectional displacement unit, and distal propulsive surface) is defined and described. Three principal evolutionary trends are recognized that helped transform the pliant tails of the ancestral mosasauroids into stable, hydrodynamically efficient sculling organs – caudal regionalization, reduced inter-vertebral mobility and increased tail depth. The latter was achieved by the formation of a hypocercal tail fluke, i.e. an asymmetrical, two-lobed caudal fin where the axial support is turned downwards.

CONVERGENCE BETWEEN MOSASAURS AND THE HESPERORNITHIFORM BIRDS

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Although convergent morphology is a common occurrence in widely separated phylogenetic lines, examples are less common when the comparison extends to members in different taxonomic classes. However, giant extinct lizards (mosasaurs), share similar jaw morphology with the toothed, marine, ichthyornithiform and hesperornithiform birds. These features include the general shape of the dentary; teeth with expanded bases; a pseudothecodont tooth implantation, and a distinctive intermandibular joint. Superficially the similarity is so strong that it resulted in the misidentification of the jaws of *Ichthyornis* as from a mosasaur and caused workers to question the association of the jaws of *Hesperornis* with its clearly avian skeleton. Finally one researcher actually figured a lower jaw of a small mosasaur as the only jaw certainly pertaining to *Hesperornis.* Because adult mosasaurs are significantly larger than hesperornithiform birds, all of the putative mosasaur jaws were thought to be from juveniles. New fossil bird material shows that the jaws of mosasaurs and birds are dissimilar in detail and no reason exists for further confusion. Mosasaurs have pleurodont teeth with horizontal tooth replacement in an inclined row while bird teeth have vertical tooth replacement with the original implantation in a groove and sockets forming with maturity. Mosasaurs have coronoid bones while ornithurine birds do not. The intermandibular joint is crossed by a projection of the surangular in *Hesperornis* but not in mosasaurs. The dentaries of *Ichthyornis* and *Hesperornis* join a small predentary anteriorly. The extreme similarity between the jaws of the two forms results from similar, but not identical solutions to the problems of being a fish predator in the open ocean.

THE FIRST MOSASAUR (REPTILIA: SQUAMATA) FROM THE LLANO ESTACADO OF NORTHWEST TEXAS

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The Mosasauridae is believed to have originated in the Cenomanian with *Haaisiasaurus*, from Israel being the oldest well-documented taxon. Here we report on two isolated mosasaur vertebrae found on a cotton farm in the Llano Estacado of northwest Texas. The youngest Cretaceous strata on the Llano Estacado and adjoining Gypsum Plains are middle Late Albian, but there are no Cretaceous exposures associated with the vertebrae. A fragment of an ammonite, *Mortoniceras* (Late Albian), was collected near one of the vertebra's original location. The nearest Late Cretaceous exposures are over 300 km away; however, an analysis of limestone matrix from the neural canal produced calcareous nannofossils. These nannofossils indicate that the probable age of the vertebrae to be Early Campanian.

A SEA URCHIN BITTEN BY A MOSASAUR - EVIDENCE OF OPPORTUNISTIC FEEDING?

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Although mainly coastal, Early Maastrichtian mosasaurs occasionally roamed the open ocean of the northwest European chalk sea as evidenced by scarce findings of teeth or skeletons (Stolley, 1892; Gripp, 1964). The chalk sea, however, was a nutrient deficient environment, with low abundances of suitable prey items for large predators. At the sea floor inoceramids and large deposit feeding echinoids of the genus *Echinocorys* dominated the macrobenthos community. Here, we present a large *Echinocorys ovata* (Leske) from the Lower Maastrichtian of Hemmoor (NW Germany) with tooth marks produced by a large animal. The tooth incisions are well preserved and were regenerated by the sea urchin, meaning that the attack was unsuccessful and not lethal. Analyses of the biting trace using methods of forensic odontology as well as experiments with jaw models and clay dummies suggest that the sea urchin was bitten by an animal with large pointed teeth arranged in a prognath position. By exclusion of other probable suspects (i.e., sharks, large teleosts, plesiosaurs, crocodiles) we strongly suggest that the bite was produced by a mosasaur of the genus *Prognathodon*, most probably *P. solvayi* (Dollo) which has been recorded from the Early Maastrichtian chalk (Dortangs et al., 2002).

The bitten echinoid provides clues for the functioning of the Maastrichtian chalk sea paleo-food web. As the saying goes, "beggars cannot be choosers": in modern nutrient deficient environments, opportunistic feeding is the prevalent feeding strategy of large predators. Our examples show that *Prognathodon* was a feeding opportunist rather than a specialist, being capable of taking advantage of even hard-shelled benthic organisms when other prey was not available. Additionally, our observation shows that not only mosasaurs like *Carinodens* and *Globidens* (which possessed a crushing dentition) were able to feed on armoured prey. Moreover, conical tooth morphologies not necessarily reflect dietary specialization – as has recently been documented also from plesiosaurs which possessed pointed conical teeth and were also capable to feed on benthic hard-shelled invertebrates (McHenry et al., 2005).

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NEW MOSASAUROID MATERIAL FROM NORTHERN ITALY: A PRELIMINARY REPORT

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New and up to now undescribed mosasauroid material is reported from the Turonian-Coniacian of Northern Italy (Lessini Mountains). The mosasaurs were collected from units of the Scaglia Rossa Veneta Formation, and more precisely within the lithozone informally known as the "Lastame", an assemblage of well-bedded, reddish, often nodular marly limestones. The material is curated in two different collections: The Natural History Museum in Verona and the Paleontological Museum in Sant'Anna di Alfaedo. The specimen in Verona (MCSNV V7481) includes the right and left maxillae, the right dentary, the frontal, and the posterior end of the lower jaw (surangular + articular complex), while the specimens in Sant'Anna di Alfaedo are represented by a very well preserved but fragmentary skull (IGVR 4224), and by an almost complete but very badly preserved skull and postcranial skeleton (IGVR 4301). On the basis of the unique combination of anatomical characters (e.g. tooth morphology and number, shape of the frontal, quadrate, maxillary and dentary) the preserved material cannot be directly referred to any known mosasaur species and may represent two different species and a new genus. Based on currently available anatomical details (additional preparation is planned), these Turonian-Coniacian mosasaurs show marked similarities to the recently described *Russellosaurus coheni* Polcyn and Bell, 2005. In order to address the taxonomic position of this Italian material a thorough comparison with all basal mosasauroids is deemed necessary, especially with the known taxa currently assigned to the subfamilies Halisaurinae, Plioplatecarpinae, and Tylosaurinae, and to the genus *Russellosaurus*.

SKELETOCHRONOLOGY OF THE LIMB ELEMENTS OF MOSASAURS (SQUAMATA; MOSASAURIDAE)

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Skeletochronology is a method used to determine the age of an individual from bone histology. The method is based on growth lines found in cortical bone, an area until now seldom examined in mosasaurs. For the first time, diaphysial thin sections of *Tylosaurus*, *Platecarpus* and *Clidastes* limb bones are studied using skeletochronological techniques. Results indicate that sexual maturity in mosasaurs was reached between ages five and seven, and that the mosasaurs studied exhibit a typical sauropsid growth pattern, although their growth rates are interpreted as faster than those of extant taxa because of fully aquatic adaptations.

A NEW SPECIES OF *ECTENOSAURUS* FROM TEXAS AND KANSAS

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The mosasaur specimen KUVP 1024 was found by Charles Sternberg in the 1890s and has had a checkered taxonomic history. It was originally named *Clidastes stenops* by Williston (1902) based on Copes description of *Edentosaurus stenop*s (1872), referred to *Mosasaurus ivoensis* by Russell (1967) based on the description of a tooth from Sweden by Persson (1963) and identified as possibly a new species of *Ectenosaurus* by Bell (1993). Bell's identification was questioned by Lindgren and Everhart (2000) on the basis of the tooth count in the maxilla and other apparent differences. The recent discovery of a nearly complete skull and partial postcranial skeleton in southwest Texas appear

to represent the same taxon as KUVP 1024 and confirms Bell's (1993) identification of the Kansas specimen as *Ectenosaurus*. Further, the Texas specimen supports Bell's (1993) suggestion that KUVP 1024 may be a new species.

A PHYLOGENETIC ANALYSIS OF FHSM VP-13910; AN UPDATE ON THE MOSASAUR FORMERLY AND INFORMALLY IDENTIFIED AS *PLATECARPUS PLANIFRONS*

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Mosasaur remains discovered in 1997 and currently in the collections of the Sternberg Museum has been informally referred to as *Platecarpus planifrons* since 1998. The well-preserved specimen included a complete but disarticulated skull, vertebrae and ribs, and was collected from the Smoky Hill Chalk (lower Santonian) of Gove County, Kansas. Closer examination of the specimen and comparison with the type material of *P planifrons* and other plioplatecarpine mosasaurs, however, does not support the earlier identification. The specimen was recently included in a phylogenetic analysis of plioplatecarpine mosasaurs. The results of this analysis suggests that FHSM VP-13910 is the sister taxon to a clade comprised of (*Angolasaurus* (*Platecarpus* + *Plioplatecarpus*)) and *Ectenosaurus* is the sister taxon of that clade. FHSM VP-13910 presents a unique mosaic of derived and plesiomorphic characters. In addition, the specimen also displays a number of autapomorphies defying referral to any known genus of mosasaur, and thus represents a new taxon within Plioplatecarpinae.

MORPHOLOGY AND SYSTEMATIC POSITION OF *ANGOLASAURUS BOCAGEI* AND THE EVOLUTION OF THE BRAINCASE IN PLIOPLATECARPINE MOSASAURS

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Recent field work in Angola has led to the discovery of new specimens of the Turonian mosasaur *Angolasaurus bocagei* providing new details of the anatomy of this taxon and allowing reassessment of its phylogenetic position. One of the new specimens was encased in a well-cemented sandstone and preserved in a fashion similar to the type specimen, but is significantly less crushed than the type. A second unprepared specimen includes an articulated skull and partial postcrania in a poorly-cemented sandstone matrix, and promises to be the best representative of this taxon known to date. The type specimen and one of the new specimens were CT scanned to study previously unavailable details of the internal surfaces and the skull and braincase. Additionally a series of braincase CT scans of Turonian through Campanian plioplatecarpine mosasaurs was performed for comparison and assessment of characters such as basalar artery path. Phylogenetic analysis supports a sister-taxon relationship to the clade *Platecarpus* + *Plioplatecarpus* but indicates that the ascription of *Angolasaurus bocagei* to the genus *Platecarpus* is unjustified.

THE MOSASAURS OF ANGOLA

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Although occurrences of marine reptiles have been previously reported from Angola, with the exception of two Turonian taxa, these reports were based largely on isolated teeth. Fieldwork in 2005 and 2006 yielded well-preserved remains of marine reptiles including plesiosaurs, turtles, and mosasaurs. The mosasaurs discussed here were recovered from two field areas: Turonian sediments at Iembe along the north coast and Maastrichtian sediments at Bentiaba on the south coast. The Turonian section near Iembe produced at least two new specimens of *Angolasaurus bocagei* and one fragmentary specimen of *Tylosaurus iembeensis*. One of the *Angolasaurus* specimens is represented by a well preserved, complete and articulated skull and partial postcrania, including portions of the forelimbs and pectoral girdle. The preservation of material from the Bentiaba locality is remarkable due to the grain support of the entombing sandstone, which preserves fine anatomical details with little apparent crushing, and in the number of articulated, semi-articulated, and associated skeletons. Identifications from the field and preliminary preparation show the Bentiaba mosasaur fauna is represented by at least five genera including *Mosasaurus, Prognathodon, Globidens, Plioplatecarpus* and *Halisaurus*. Collectively, these new specimens greatly expand our knowledge of the anatomy and systematics of Angolan mosasaurs.

THE POSSIBLE OCCURRENCE OF *ANGOLASAURUS* IN THE TURONIAN OF NORTH AND SOUTH AMERICA

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A partial skull of a mosasaur was collected from the Eagle Ford Formation near Waco Texas in about 1918 and briefly mentioned by Adkins (1924, 1928). The specimen found its way to Sweden through a donation and was housed in the collections of Lund University until relocated by one of us (GB) and recently prepared for study. The specimen includes the posterior portion of the skull, preserved to approximately the anterior terminus of the frontals, the atlas, axis and a portion of the first hypapohysis-bearing cervical vertebra. It is remarkable in both its Turonian age and the preservation of the osseous portion of the hyoid apparatus. The dimensions of the frontal and parietal, the path of the frontoparietal suture, the position of the pineal foreman in the center of the triangular parietal table, and an enlarged posteroventral process of the parietal meeting the supraoccipital allow tentative referral of the specimen to the genus *Angolasaurus*. A second specimen consisting of a partial premaxilla and jaw fragments containing teeth from the *Prionocyclus hyatti* zone of the Eagle Ford Formation south of Dallas, Texas is also likely referable to *Angolasaurus*. Further, two teeth reported from the Sergipe Basin in Brazil are virtually indistinguishable from those in the type specimen of *Angolasaurus*. Thus *Angolasaurus* appears to be the only Turonian mosasaur genus represented on both sides of the Atlantic Ocean. Preservation of the hyoid allows comparison with other squamates and is consistent with the morphology found in varanoid lizards and markedly different from that of snakes and thus has bearing on the broader relationships of mosasaurs.

PRELIMINARY ANALYSIS OF STABLE CARBON ISOTOPES IN MOSASAURS AND OTHER MARINE AMNIOTES

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Little detail is known about the trophic webs of the complicated marine communities of which mosasaurs were a part. Analyses of stable carbon isotopes have proven useful in dietary studies of terrestrial organisms and in archaeology. An initial study by Biasatti (2004; Palaeogeography, Palaeoclimatology, Palaeoecology, 206: 203-216) on marine turtles indicates major shift in $\delta^{13}C$ values between consumer and food species. Similar offsets are seen in red abalone (*Haliotis rufescens*) and marine iguanas (*Amblyrhynchus cristatus*) and their foods. We report here initial carbon isotope data for the carbonate component of tooth enamel from mosasaurs and some modern marine amniotes to develop baseline hypotheses for the interpretation of trophic levels in Cretaceous seas. Preliminary values suggest a 15‰ shift in the carbon isotopic value from macroalgae (~-15‰) to the carbonate component of tooth enamel in marine iguanas (-0.55‰), a value comparable to those of the carbonate component of humeri in green turtles (*Chelonia mydas*), which feed on marine angiosperms. Using the same isotopic difference (“δ = 15‰), one value from a *Coniasaurus* sp. tooth (-2‰) suggests that this species subsisted primarily on bony fish, shrimp, and crab.

NEW TOOLS TO UNCOVER TRENDS IN MOSASAUR RICHNESS AND MORPHOLOGY: STRATIGRAPHICALLY CORRELATED ASSEMBLAGES

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Existing high-resolution marine biostratigraphic systems (e.g., ammonites, belemnites, calcareous nannofossils) offer tremendous precision in dating vertebrate fossils. However, due to the comparative rarity of vertebrate remains in any particular microfossil or invertebrate biozone, and the potential for non-recovery of an index taxon due to various environmental, ecological, or human factors, individual biozones are ineffective sampling windows. As a result, most analyses of marine vertebrate diversity consist either of local/regional studies with high temporal resolution (e.g., Sheldon, 1996; Mulder *et al*., 1998) or studies on far broader scales with concomitantly lower temporal resolution (e.g., Russell, 1993; Hirayama, 1997; Kriwet and Benton, 2004).

Stratigraphically correlated assemblages (SCAs) are informal sub-stage level subdivisions, based primarily on grouped ammonite and calcareous nannofossil biozones, sequence stratigraphy, and, where possible, radioisotope-derived dates. The fifteen late Cretaceous SCAs are designed to provide a framework for correlations among marine shelf and epicontinental sea deposits, particularly in North America but broadly enough defined to be useful globally. Though not uniform in duration (SCAs range from 1.2-3.0 myr using timescale of Gradstein *et al*., 2004), SCAs offer a convenient method for compiling and organizing marine vertebrate fossils from far-ranging localities with high levels of biostratigraphic resolution.

Following a brief description of the SCAs, we provide examples of their use. Utilizing an online global database of catalogued mosasaur specimens (MOSABASE), we employ SCAs as sampling bins to track changes in biogeography, diversity, extinction, and intra-clade morphological trends throughout the entirety of their distribution during the late Cretaceous. The results of this study include recognition of an initial and statistically significant expansion of mosasaurs during the Coniacian and Santonian, followed by stable generic richness levels until their mass extinction at the K-Pg boundary. Surprisingly, despite stable generic richness levels during the Campanian and

Maastrichtian, mosasaur morphological diversification, as measured by novel tooth forms, expands as new forms proliferate at the expense of less-derived members.

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VERTEBRAL PATHOLOGY IN MOSASAURS

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Three forms of pathology are routinely noted in the vertebrae of mosasaurs: shark bites, avascular necrosis and fusion, in addition to isolated reports of ‘tumors.’

Grooves on vertebrae evidence shark bites, while associated new bone formation allows recognition of predation. The former is common; the latter, relatively rare but provides insights to behavior of both the mosasaur and its attacker.

Recognition of diving disease in mosasaurs was based upon identification of a specific associated pathology, avascular necrosis. The devitalized bone typically becomes necrotic (and lucent to x-rays), secondary to loss of vascular supply. The resultant loss of mechanical integrity makes the surface susceptible to compression stresses across the shoulder and hip joint, respectively. The resultant damaged bone can no longer resist the normal stresses across the joint and partly collapses, producing a visible subsidence zone. Avascular necrosis was invariably present in *Platecarpus, Tylosaurus, Mosasaurus, Plioplatecarpus, Prognathodon, Hainosaurus* and an Antarctic mosasaur, and invariably absent from *Clidastes, Ectenosaurus, Globidens, Halisaurus* and *Kolposaurus*.

Fused mosasaur vertebrae are attributable to reactive bone from trauma and infection (e.g., related to trauma of shark bites) and perhaps to splinting or a disease documented in contemporary varanids. It would appear that fusion through vertebral centra occurs whenever motion is lost at that segment. However, there is another form of fusion through the outer layers of what is presumed to have been an intervertebral disk, as has been documented in contemporary *Varanus*.

Isolated suggestion of tumors is a more complex subject. Moodie’s suggestion of osteoma must be rejected on the basis of apparent lesion size and location. The only other recognized ‘tumor’ has been called an osteoma, but its size complicates histologic examination to assure it is not simply a hamartoma, as human skull so-called osteoma have been now reclassified.

ON DISTRIBUTION, DIVERSITY AND PHYLOGENY OF THE GENUS *PROGNATHODON*

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Globidensine mosasaurs constituted a highly successful, morphologically diverse group which, during the latest Cretaceous, was widely distributed geographically and had diversified into a considerable array of ecological niches. During this time, the globidensine genus *Prognathodon* achieved worldwide distribution, with the late Maastrichtian *Prognathodon saturator* being one of the larger, most massively built representatives. The holotype of this species, discovered in 1998 at the ENCI-Heidelberg Cement Group quarry (Maastricht), is compared with material from New Zealand, Israel, Belgium and the USA. Cladistic analysis places *P. saturator* with the Maastrichtian *P. waiparaensis* and *P. solvayi*; contrary to previous interpretations, the Campanian *P. currii* is considered more closely related to the globidensine mosasaur *Globidens*. The North American species *Prognathodon stadtmani* does not belong to the genus, rather representing a more basal form, more closely related to *Mosasaurus*. Two new partial mosasaur skulls from the Upper Cretaceous of Angola are briefly discussed, and tentatively assigned to the genus *Prognathodon*, pending excavation of the remainder of the skeleton.

MORPHOLOGY AND FUNCTION OF TAILBENDS IN MOSASAURS

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The existence of a downward bend in mosasaur tails is not yet firmly established, in particular for derived members of the group. Mosasaur skeletal mounts and reconstructions often overlook the tail bend, but as early as 1899 H. F. Osborn confirmed ventral tail flexure in an articulated specimen of *Tylosaurus* and concluded that the tail possessed a swimming organ. In the early 20th century, J. C. Merriam and C. J. Wiman further discussed tail flexure in specimens of *Halisaurus*, *Clidastes*, and *Platecarpus*, and compared mosasaur tails to those of ichthyosaurs and metriorhynchid crocodylians. Our studies confirm the presence of downward tail bends in the early mosasaurs *Clidastes*, *Platecarpus*, and *Tylosaurus. A*rticulated caudal series of each of these genera reveal slightly wedge-shaped vertebral centra, with dorsal and ventral lengths differing between 0.5 and 1.5 mm. Although this variation is not visibly apparent, it accounts for a cumulative tail flexure of ~30 degrees. Throughout the tail curve, equal spacing of neural spines is maintained by a successive anterior to posterior inclination. The most pronounced anterior inclination of neural spines coincides with the most pronounced downward flexure of the tail, a feature paralleled in early ichthyosaurs and marine crocodiles. The down-turned segment of mosasaur tails are dorso-ventrally expanded and stiffened 'paddles', a feature reflected by elongate neural spines and haemal arches, and loss of transverse processes coupled with lateral compression of caudal centra.

Unlike the tails of derived ichthyosaurs and marine crocodilians, groups that possess a fish-like dorsal caudal fin, mosasaur tails are not sharply bent and bear no abrupt change in morphology. The hypocercal tails of mosasaurs bear a gentle sinuous curve throughout their length, with a slight upward flexure anterior to a more significant downward flexure. This shape, likely lacking a pronounced dorsal caudal fin, would produce downward thrust to compensate for positive buoyancy. Mosasaurs retain elongate neural and haemal spines in the area of the downward bend, heightened in the manner of primitive ichthyosaurs, which coupled with elongate body plans indicates a similar from of eel-like swimming in early members of both groups. Future work on mosasaur skeletons with preserved integument should focus on evidence of the tails outline.

USING ELECTRON MICROSCOPY AND FOCUSED ION BEAM AS A TOOL FOR ANALYSIS OF MOSASAUR BONE

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Traditionally it has been accepted that elements in biological tissue have been replaced over time by elements from the surrounding sediments. Using standard light microscopy investigators have shown that soft tissue as well as the expected calcified tissue is preserved. Further work has shown that bones are either not changed or just premineralized, leaving microstructure in place. As a result, research into fossil bone histology is a growing area of inquiry. Incorporating histological study into the investigation, present new opportunities for gaining data to understand better the ontogeny, ecology and evolution of vertebrates.

I have restricted the fossil material in this study to ribs and vertebrae. Ribs are not shown to have important morphological data relating to systematics or evolution therefore their destruction does not impede the research of others. Vertebrae were collected as isolated specimens on outcrops but are identifiable to genus and growth stage.

Histology has given new insight to changes in growth and bone architecture for vertebrates especially those that secondarily moved to marine environment, Vascular tissue and analysis of chemical composition are processes that reveal valid data. Preserved structures are visible using SEM (Scanning Electron Microscopy). Focused Ion Beam (FIB) processes allow the removal of minute wafers of material to be further analyzed using TEM (Transmitting Electron Microscopy).

KOURISODON SP. FROM THE UPPER CAMPANIAN OF JAPAN

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The small mosasaurine mosasaur *Kourisodon* characterized by having laterally compressed teeth was first described by Nicholls and Meckert (2002) from the upper Santonian Nanaimo Group of the Vancouver Island, Canada. They also cited the report of a similar type of teeth from the Maastrichtian Izumi Group of southwest Japan by Tanimoto et al. (1998).

Tanimoto and Kanazawa (2001) published an abstract on the partial skull and mandible of a small mosasaur specimen (Kanazawa specimen) from the upper Campanian Izumi Group. At that time, however, the paper by Nicholls and Meckert (2002) was not published yet, and Kanazawa specimen only remained as Mosasauridae gen. et sp. indet. After the paper by Nicholls and Meckert (2002) was published, Kanazawa specimen was readily identifiable as *Kourisodon* because it had the unique, laterally compressed tooth morphology (Tanimoto et al, 2004).

Thereafter, through the progress of cleaning of this fossil, it became clearer that the shape of the edentulous prow of the left dentary is also similar to that of *Kourisodon puntledgensis* from Canada, more so than Tanimoto et al (2004) had initially considered. Although the teeth of Kanazawa specimen are laterally compressed to the same degree as the specimen from Canada, the prismatic ornamentation appears to be more clearly defined in Kanazawa specimen than in the other. Nevertheless, the final recognition of such a feature will be pending the direct comparison of both specimens. The left maxilla of Kanazawa specimen has distinctly slenderer teeth than those of the dentary: such a tendency is observed in *Kourisodon puntledgensis* and the similarly small mosasaurine *Clidastes propython* to a lesser extant. Consequently, the Japanese specimen is tentatively treated as *Kourisodon* sp., albeit probably not pertaining to the generic type from Canada.

From the Izumi Group sediments, many fragmentary mosasaur remains have been discovered in the last decade. As most of them are anatomically small in size, they may well represent *Kourisodon* or related forms.

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MOSASAUR BITE MARKS ON AN AMMONITE. PRESERVATION OF AN ABORTED ATTACK?

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Preserved bites are a rare demonstration of predator and prey and give a useful view of paleoenvironments. Non-invasive tests were utilized in an investigation of bites in a specimen of *Placenticeras meeki* at the Wyoming Dinosaur Center, Thermopolis, Wyoming. (WDC-Bps-002). This investigation led to a reevaluatition of the limpet home marks vs. mosasaur predation bite hypothesis.

The specimen was collected by Canada Fossils (Government of Alberta, Disposition no. 2-707) from the Bearpaw Shale in Alberta, Canada, and it consists of a complete specimen (49cm by 37cm) with what appears to be a single bite mark (14cm by 6cm) across both flanks (FIG.1, FIG.2). It was suggested that the specimen might be a composite specimen, mixing a phragmocome of one and a body chamber of another, or a near-complete specimen with a body chamber with a wedge of another containing a “bitten portion”. However, a CAT scan indicated a consistent thickness of shell, suggesting both portions are from an original intact but fractured specimen.

This specimen is unique in that it preserves a single bite mark with an opposing tooth mark pattern (i.e. on either flank of the ammonite) (G.E.G. Westermann, 2007, personal communication). In most specimens with multiple bite marks, the pattern is not obvious making it hard to visualize whether or not the tooth marks actually match in pattern (Tsujita and Westermann, 2001).

It appears that the specimen has the entire body chamber preserved which is also unusual. Most bitten specimens exhibit more damage often missing a portion of the body chamber (Tsujita and Westermann, 2001). Even though the “bite marks” are within the phragmocone, the CAT scans and 3D surface scans suggested that the phragmocone contact at the body chamber was sediment filled but not collapsed.

The hypothesis that the holes are limpet home marks was reevaluated as mosasaur bite marks on shells and mentioned in other studies (Kauffman and Kesling, 1960.Tsujita and Westermann, 2001; Kauffman, 2004). The option of thin-sectioning WDCB-Bps-002 to establish this hypothesis was not available. However, the bite marks are aligned through the shell flanks and pierce into the septa. CAT scans of this ammonite lined up on these punctures provided non-invasive views within the septa section revealing an inverted “v” opening unlike those that would be produced by the limpet hypothesis (Tsujita and Westermann, 2001)(FIG.3).

Equally interesting about this specimen is that the bites are aligned but offset on both flanks. The 3D scanned images of the aligned bites on WDCB-Bps-02 were superimposed together. Measurements taken from this image suggested the alignment was offset by 12 degrees (FIG.4). A robot set of jaws modeled after a mosasaur was used in a previous study to determine the effect of bites on cephalopod shells (Kase et al, 1996). As the jaw structure of the robots was dimensionally linear the effect was uniform punctures across the shell. However it has been suggested that such may have neglected the offset flexing of the midline dentary hinge (Kauffman and Kesling, 1960; Tsujita and Westermann, 2001).

It is interesting to note that the phragmocone contained the only punctures. The flat planispiral section of the shell of WDCB-Bps-02 is full of complex structural septa that react differently to the teeth of a mosasaur than that of the open unsupported body chamber (Tsujita and Westermann, 2001). The spacing of holes was preserved by the complex large spaces in between septa (Westermann, 1996). Not only would complex septa provide more elasticity to the shell wall (thus inhibiting shattering), but they would support the shell wall more evenly. Also, the spaces within the body chamber are analogous to those at the anterior end of the belemnite shells in the Jurassic Sundance Formation (Wahl, 1998). These open belemnite phragmocones are crimped and smashed by a center point of force; which is what would be expected from a tooth. The *Placenticeras meeki* phragmocone might instead hold the tooth shape without much crushing as in the open spaces of a body chamber.

The surface puncture exhibits an extra tooth mark that may have been a pathology or artifact of an initial or secondary bite (FIG.5). Mosasaur tooth series occasionally display new teeth growing vertically beside the old teeth (Rieppel and Kearney, 2005). The extra hole may correspond to a large "newer" tooth that is preserved out of alignment. However, it may also represent where only one tooth mark was made in an initial or "mouthing" bite. The odd puncture hole was beyond the extent of the mantle and based on healed bite marks in other species thus would not likely have been repaired (Bond and Saunders, 1989). The extra puncture could not have been present before the main bite marks, as any hole in the phragmocone would have led to the phragmocone flooding and ammonite death (Gordon Bell, 2007 personal communication). Interpretation of the bite suggests it would have gone through parts of the ammonite that would have been exposed outside the body chamber. However, it has been suggested that ammonites could withdraw the majority of the body into this chamber (Kauffman, 2004).

Finally, why bite the shell if not to feed? The bite may have occurred as an attack on a gas-filled floating shell of a dying or dead ammonite; or the ammonite could have been one of dozens of ammonites bitten in a frenzy and just sank while others were eaten. Likewise it is not beyond expectation that a mosasaur would have been attracted by fish to rotting ammonite carcass. Of course, if the shell records only one "bite event," then it might mean that the attack was aborted for some reason and the ammonite died, sank and was buried without being consumed.

Specimens with corresponding bites on both sides are rare. Single bites occurring relative to the ammonite phragmocone/body chamber contact are rarer still. Interpretation of predator prey relationships will benefit from additional finds.

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THE DIVERSITY OF AQUATIC LOCOMOTION IN EXTANT VARANOID LIZARDS

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It is generally recognized that there is a close phylogenetic relationship between the aigialosaurs, mosasaurs and the extant varanoid lizards. The aigialosaurs, as traditionally recognized, would appear to represent a functional intermediate in being aquatic forms with limbs similar to those of terrestrial varanoids. As a first step toward exploring the potential locomotor dynamics of these groups; we examined the kinematics and mechanics of aquatic locomotion in terrestrial and semi-aquatic monitors (*Varanus*). A large swimming tank was constructed and the kinematics of aquatic locomotion recorded using standard and high-speed digital video. Electromyographic recordings of axial, tail, and limb muscles during unrestrained swimming helped identify several discrete modes of aquatic locomotion. Among the monitors examined there is a sharp difference in both swimming mode and performance between the terrestrial and semi-aquatic species. Of particular significance is the diversity of functional roles played by the hindlimbs during swimming.