

## Unusual death of a Cretaceous giant

THEAGARTEN LINGHAM-SOLIAR

Information on predatory behavior and fighting in extinct ecological communities is becoming increasingly important (Brett 1990; also see Martill *et al.* 1994 for an interpretation of shake feeding in pliosaurs). Williston (1897) interpreted numerous re-healed broken bones in the fossilized skeletons of mosasaurs as evidence of an aggressive disposition beyond that of normal predatory behavior. The presence of rehealed breaks on massive jawbones of *Mosasaurus hoffmanni* (at over 17 m the largest marine reptile known) and tooth marks attributed to *M. hoffmanni* on the keratinized scute (~2 m in diameter) of a giant turtle, *Allopleuron hoffmanni*, testify to this (Lingham-Soliar 1995). In this note, evidence of a highly specialized killing technique, ramming, may add to our knowledge of the lifestyle of mosasaurs.

Examination of a latex cast of the internal braincase of *Mosasaurus hoffmanni* IRSNB R12 (Institut Royal des Sciences Naturelles de Belgique) showed some unusual damage. The mosasaur cerebellum (see Camp 1942) lying within the braincase, posterior to the cerebral hemispheres, had been severed and displaced laterally by about 1 cm (Fig. 1A–C). Externally, there is no apparent damage to the braincase nor the overlying frontal and parietal bones. Two possibilities are considered regarding the damage, that it was caused in life or that it was post-mortem.

The mosasaur braincase comprises several bones, the paroccipital, exoccipital, basioccipital, opisthotic, basisphenoid and prootic, all ligamentously sutured together (Lingham-Soliar 1995, Fig. 13). This provided a degree of flexibility that is important, since shear and tensile forces were brought to bear on the braincase during the considerable rocking movements involved in feeding. Damage to the braincase of *Mosasaurus hoffmanni* occurred at the anterior part of the vestibular cavity of the prootic.

The interpretation here is that the damage occurred as a result of a powerful concentrated blow to the prootic region of the braincase. The prootic would have sprung inwards, facilitated by ligamentous sutures, broken internally thereby causing the brain to be severed (the jutting fragment can clearly be seen in Fig. 1A, C arrowed), and sprung out again. On the other hand, had the injury been *post mortem*, because of the rapid deterioration of organic ligamentous tissue the prootic would undoubtedly have caved in without springing back.

*Mosasaurus hoffmanni* IRSNB R12 is one of the best preserved mosasaur specimens, and the skull is found *in situ* in the original matrix (Lingham-Soliar 1995, Fig. 3). It shows very little damage, and the bones, including the braincase, are in their natural positions. The

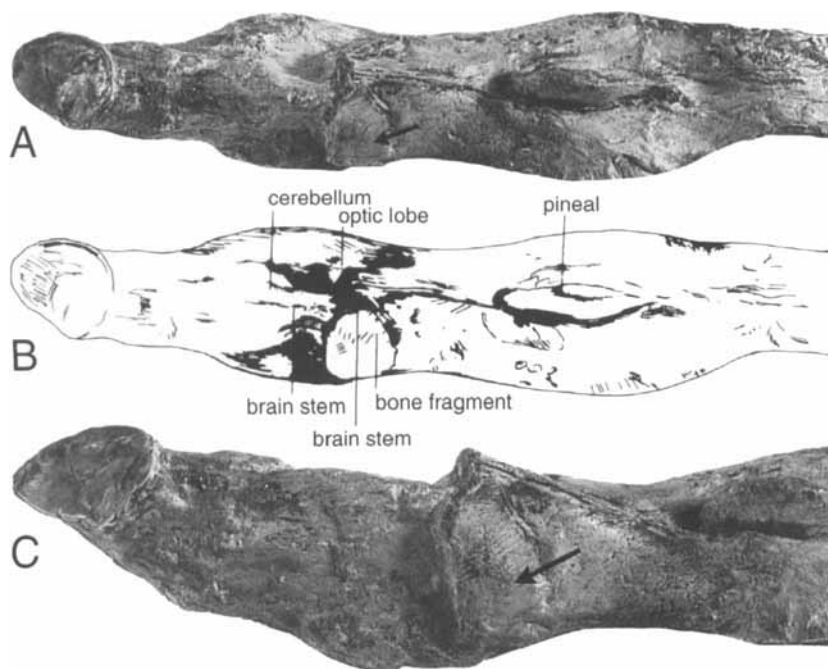


Fig. 1. Brain-cast of *Mosasaurus hoffmanni*. □A. Dorsal view showing severing and displacement of the brain stem by a fragment (arrowed) of the vesicular chamber of the prootic. □B. Drawing of the brain to show the broken brain stem and associated fragment of bone. □C. Dorsolateral enlarged view of brain-cast. Brain cast length 25 cm.

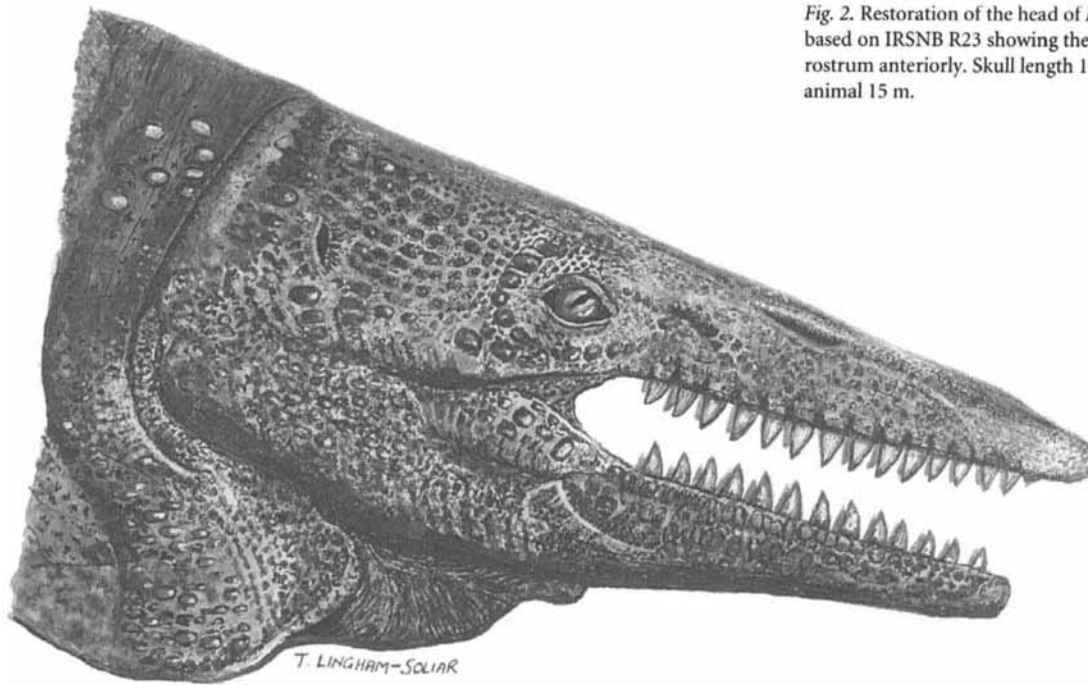


Fig. 2. Restoration of the head of *Hainosaurus bernardi* based on IRSNB R23 showing the large solid bony rostrum anteriorly. Skull length 170 cm; total length of animal 15 m.

remarkable preservation of the teeth, and indeed virtually the entire skull, indicates hardly any rolling or other forms of disturbance following the death of the animal. The prootic region lies well within the intact skull (frontal, parietal, supratemporal arcade). Providing the braincase is *in situ*, i.e. surrounded by the supratemporal arcade and intact frontal and parietal bones, very little damage can occur to it other than by something narrow being driven in. Damage to the braincase usually occurs when it becomes isolated and subsequently rolled. Furthermore, the pterygoid unit (forming the lower part of the posterior skull) and, even more unusually, the palatines and their contact with the pterygoid are rarely preserved intact and *in situ* as they are in *M. hoffmanni* R 12 (Lingham-Soliar 1995), thus providing considerable protection from beneath. Therefore, possible damage to the braincase through rolling or impact is unlikely. Moreover, although this evidence is circumstantial, the small specimen (only two-thirds to half the size of most specimens) of *M. hoffmanni* is probably of a subadult, and its death seems premature.

The only damage to other parts of the skull is minimal and on the right side, coinciding with the brain injury principally around the temporal cavity. In the lower jaws the coronoid and surangular of the upper postmandibular unit also on the right side are dislocated (Lingham-Soliar 1995, Fig. 3) In mosasaurs, the lower jaws are connected to the skull by a shallow articulation (ligamentously) and they are very quickly separated and invariably subject to different histories in the processes of destruction and fossilization. Hence, it would seem to be too much of a coincidence if the damage were not caused by the same blow to the skull.

It is interesting to consider the predator that could have delivered such a well pin-pointed and lethal blow to a large animal such as *Mosasaurus hoffmanni*. Fishes, primarily swordfish, and marine crocodiles are unlikely, since to my knowledge they have not been found in the Maastrichtian localities in which *Mosasaurus hoffmanni* is known. Ichthyosaurs were already extinct by the Maastrichtian. Pliosaurus are infrequent but, in addition, are broad-snouted, and a blow to the braincase of *Mosasaurus hoffmanni* would have caused widespread damage to virtually the whole posterior part of the skull. However, it is among the last group considered, the mosasaurs themselves, that the most likely attacker, *Hainosaurus bernardi*, is found. *H. bernardi* was a gigantic 15 m long tylo-

saurine mosasaur (Lingham-Soliar 1992) and known from Maastrichtian localities close to those of *M. hoffmanni*. Significantly, they possessed a large solid bony rostrum at the tip of their snout that was evidently used in the ramming of prey (Lingham-Soliar 1992) either to kill or to stun. Tylosaurines were ideally designed to deliver a powerful blow with the rostrum by rapid acceleration from a virtually stationary position. The attack, probably from an ambush (Massare 1987), was enhanced by a long powerful tail adapted for burst speeds, as in crocodiles. These mosasaurs are also known to have had enormous diets. The gastric contents of a single specimen in the South Dakota School of Mines consisted of the small mosasaur *Clidastes*, the marine fish *Bananogmius*, a shark and the diving bird *Hesperornis* (Martin & Bjork 1987).

The solid bony rostrum of tylosaurines is unique among marine vertebrates, and hence it is hard to find close analogues among living forms for the kind of behavior described above. However, bottle-nosed dolphins (*Tursiops truncatus*) use their beaks in defence to kill or see-off lemon sharks (*Triakis semifasciata*) (Watson 1988), and crocodiles show some form of ramming behavior in male-male fights (Lingham-Soliar 1995). With our knowledge of mosasaurs it seems reasonable to associate the large rostrum in tylosaurine mosasaurs with the kind of offensive behavior described above.

*Acknowledgements.* – I thank P. Bultynck and D. Nolf for access to material and facilities at the IRSNB and two anonymous referees for useful comments.

## References

- Brett, C.E. 1990: Predation. In Briggs, D.E.G & Crowther P.R. (eds.): *Palaeobiology – A Synthesis*, 368–372. Blackwell, Oxford.
- Camp, C.L. 1942: California mosasaurs. *Memoirs of the University of California* 13, 1–68.
- Lingham-Soliar, T. 1992: The tylosaurine mosasaurs (Mosasauridae, Reptilia) from the Upper Cretaceous of Europe and Africa. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 62, 171–194.

- Lingham-Soliar, T. 1995: Anatomy and functional morphology of the largest marine reptile known, *Mosasaurus hoffmanni* (Mosasauridae, Reptilia) from the Upper Cretaceous, Upper Maastrichtian of the Netherlands. *Philosophical Transactions of the Royal Society, London B* 347, 155–180.
- Martill, D.M., Taylor, M.A. & Duff, K.L. 1994: The trophic structure of the biota of the Peterborough Member, Oxford Clay Formation (Jurassic), UK. *Journal of the Geological Society, London* 151, 173–194.
- Massare, J.A. 1987: Tooth morphology and prey preference of Mesozoic marine reptiles. *Journal of Vertebrate Paleontology* 7:2, 121–137.
- Martin, J.E. & Bjork, P.R. 1987: Gastric residues associated with the mosasaur *Tylosaurus* from the Late Cretaceous (Campanian) Pierre Shale, South Dakota. *Dakoterra* 3, 68–70.
- Watson, L. 1988: *Whales of the World*. 302 pp. Hutchinson, London.
- Williston, S.W. 1897: Range and distribution of the mosasaurs. *Kansas University, Quarto* 6, 177–189.
- Theagarten Lingham-Soliar* [lenin33@paleo.ru], *Paleontological Institute, Russian Academy of Sciences, ul. Profsoyuznaya 123, Moscow, 117647 Russia; 14th June, 1997; revised 12th November, 1998.*