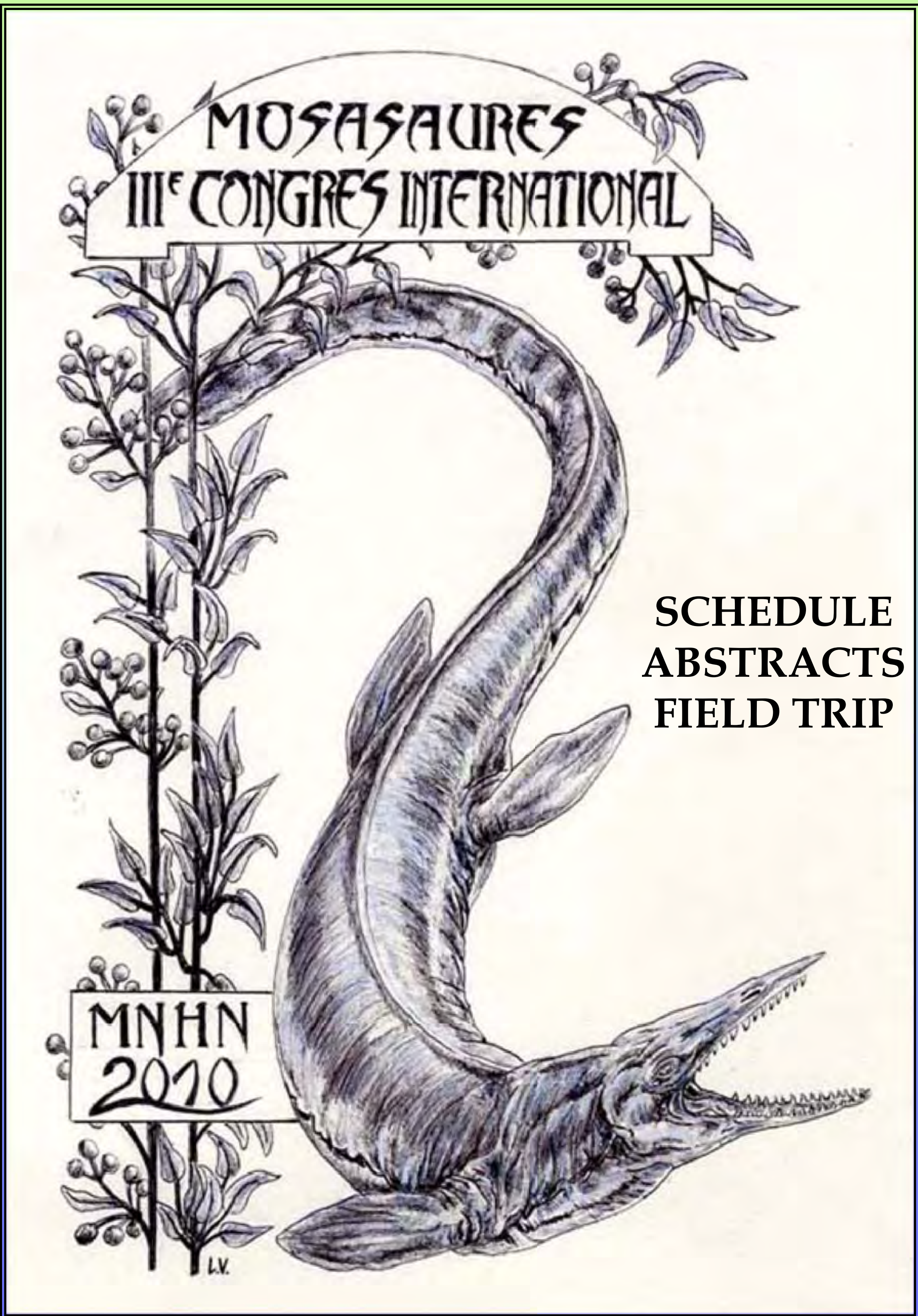
THIRD MOSASAUR MEETING

MNHN, Paris, France, 18-22 May 2010

Organized by Nathalie BARDET



SCHEDULE
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FIELD TRIP

(Frontispiece by Luc VIVES, MNHN, Paris)

UMR 7207 du CNRS - Département Histoire de la Terre
Département des Galeries - Direction des Collections

GENERAL PROGRAM

Tuesday, May 18th	**- 10h-15h: Study of the MNHN mosasaur collections** **- 15-16h: Registration** **- 16h-17h: Visit of the mosasaur exhibition** **- 17h-18h30: Icebreaker party**
Wednesday, May 19th	**- 10h-10h30: Official welcome – Coffee** **- 10h30-12h: Scientific session** - 12h-13h30: Lunch **- 13h30-15h30: Social event: "Public meets Palaeontologists"** - 15h30-16h: Coffee **- 16h30-17h30: Scientific session**
Thursday, May 20th	- 10h-10h30: Coffee **- 10h30-12h: Scientific session** - 12h-14h: Lunch **- 14h-15h30: Scientific session** - 15h30-16h: Coffee **- 16h-17h30: Scientific session**
Friday, May 21st	- 10h-10h30: Coffee **- 10h30-12h: Scientific session** - 12h-14h: Lunch time **- 14h-15h30: Scientific session** - 15h30-16h: Coffee **- 16h-17h: Scientific session** **- 20h-22h: Symposium Dinner on the Bateaux-Mouches**
Saturday, May 22nd	**- 10h-12h: Field trip to the Late Cretaceous chalk quarry of Meudon**

MNHN' SITES HOSTING THE MEETING

1 = Palaeontological Building (Entry for Public, 2 *Place Valhubert*): Registration / Mosasaur exhibition visit / Ice-Breaker Party on May, 18th.

2 = Palaeontological Building (Entry for Researchers, 8 *rue Buffon*): meeting point for those who plan to study the collections on May, 18th.

3 = Auditorium of the *Grande Galerie de l'Evolution* (36, rue Geoffroy-Saint-Hilaire): Scientific Sessions May, 19th to 21st.

MEETING SCHEDULE

WEDNESDAY MAY, 19th 2010

10h-10h30: Official welcome - Coffee – Set up of daily Powerpoint presentations.

First Session – Chairman: Anne SCHULP

10h30-11h - CALDWELL M.W. - What, if anything, is a mosasaur?
11h-11h30 - BARDET N. - The Mosasaurid collections of the Muséum National d'Histoire Naturelle of Paris.
11h30-12h - PIETERS F.F.J.M., ROMPEN P.G.W., JAGT J.W.M. & BARDET N. - A new look at Faujas de St-Fond's fantastic story on the provenance and acquisition of the type specimen of *Mosasaurus hoffmanni*.

12h-13h30: Lunch.

13h30-15h30: SOCIAL EVENT: "Public meets Palaeontologists" around the mosasaurid specimens on exhibition (*Galerie de Paléontologie*).

15h30-16h: Coffee.

Second Session - Chairman: William GALLAGHER

16h-16h30 - CORNELISSEN D., VERDING L., SCHULP A.S. & JAGT J.W.M. - Mosasaurs in the Eben Ezer Tower.
16h30-17h - LEBLANC A., CALDWELL M.W. & LINDGREN J. - Revisiting the cranial anatomy of *Plotosaurus bennisoni* Camp, 1942: insights into the aquatic adaptations of derived mosasaurids.
17h-17h30 - LINDGREN J., CALDWELL M.W., KONISHI T. & CHIAPPE L. - Exceptional soft tissue preservation in a *Platecarpus* specimen from the Niobrara Chalk of Kansas, USA.

THURSDAY MAY, 20th 2010

10h-10h30: Coffee – Set up of daily Powerpoint presentation.

First Session – Chairman: Michael CALDWELL

10h30-11h - HOUSSAYE A. - Vertebral and rib microanatomical characteristics in hydropelvic mosasauroids.
11h-11h30 - REICHLEN A., YOUNG B.A. & COLLINS S. - Vertebral morphometrics and flexibility in varanoid reptiles.

11h30-12h - REICHLEN A., COLLINS S. & YOUNG B.A. - A ventilatory and locomotor mechanics in the water monitor (*Varanus salvator*).

12h-14h: Lunch.

Second Session - Chairman: Johan LINDGREN

14h-14h30 - KONISHI T., BRINKMAN D. & CALDWELL M.W. - New morphological data on *Prognathodon* (Squamata: Mosasauridae) from the Campanian of North America, and its bearing on the systematics of the genus.

14h30-15h - BUFFETAUT E. & BARDET N. - *Prognathodon* from the Maastrichtian of the Cotentin Peninsula (Normandy, Western France).

15h-15h30 - BARDET N., PEREDA SUBERBIOLA X., TORRES J.A. & BOTANTZ B. - New mosasaurid material from the Late Cretaceous of Navarre.

15h30-16h: Coffee.

Third Session - Chairwoman: Florence PIETERS

16h-16h30 - POLCYN M.J., JACOBS L.L., SCHULP A.S., MATEUS O. & LINDGREN J. - An update on the mosasaurs of Angola.

16h30-17h - POLCYN M.J., LINDGREN J., BARDET N., CORNELISSEN D., VERDING L. & SCHULP A.S. - New material of *Halisaurus arambourgi* from the Maastrichtian of Morocco.

17h-17h30 - SCHULP A.S. & BARDET N. - A review of recent discoveries of the durophagous mosasaur *Carinodens*.

FRIDAY MAY, 21st 2010

10h-10h30: Coffee – Set up of daily Powerpoint presentation.

First Session – Chairman: Michael POLCYN

10h30-11h - FERNÁNDEZ M.S. & GASPARINI Z. - Campanian and Maastrichtian mosasaurs from Peninsula Antartica and Patagonia.

11h-11h30 - PÁRAMO-FONSECA M.E. - Mosasauroids from Colombia.

11h30-12h - PALCI A., CALDWELL M.W. & PAPAZZONI C.A. - New mosasaurs from Northern Italy.

12h-14h: Lunch.

Second Session – Chairwoman: Maria PARAMO

14h-14h30 - VERDING L., CORNELISSEN D., MEIJER A.W.F., SCHULP A.S. & JAGT J.W.M. - On tooth replacement in *Mosasaurus*.

14h30-15h - CHINSAMY A., TUNOĞLU C. & THOMAS D. - Dental microstructure and geochemistry of *Mosasaurus hoffmani* (Squamata) from the Late Cretaceous of Turkey.

15h-15h30 - GALLAGHER W.B., MILLER K.G., SHERELL R.M., BROWNING J.V., FIELD M. P., OLSSON R.K., SUGARMAN P.J., TUORTO S. & WAHYUDI H. - Late Maastrichtian mosasaurs and the K/Pg boundary in New Jersey.

15h30-16h: Coffee.

Third Session - Chairwoman: Nathalie BARDET

16h-16h30 - TANIMOTO M. - Mosasaurs and the associated vertebrate faunas of Southwest Japan.

16h30-17h - KONISHI T., TANIMOTO M., CALDWELL M.W. & KANAZAWA Y. - Re-examination of a small mosasaur specimen from the Upper Campanian Izumi Group, Western Japan.

20h-22h: SYMPOSIUM DINNER on the Bateaux-Mouches (Quai de Grenelle)

SATURDAY MAY, 22nd 2010

10h-12h - Field trip to the Late Cretaceous underground chalk quarry of Meudon, led by Mr Alain GALOYER (Meudon).

ABSTRACTS

THE MOSASAURID COLLECTIONS OF THE MUSEUM NATIONAL d’HISTOIRE NATURELLE OF PARIS

BARDET N.

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The collections of the *Muséum National d’Histoire Naturelle* (MNHN) of Paris are not the richest of Europe but they include several important specimens, which are - besides their systematical and phylogenetical importance - interesting on an historical point of view.

At the occasion of the Third Mosasaur Meeting (Paris, 18-22 May 2010), the MNHN mosasaurid collections has been entirely checked. Part of the specimens have been restored (the French species holotypes) and part of them have been the aim of a small exhibition in the *Galerie de Paléontologie* (most of the types and historical specimens).

The MNHN mosasaurid collections include:

- Part of the Faujas de Saint-Fond (1799) collections from the Maastrichtian of Maastricht (some are still lacking), especially the type specimen of *Mosasaurus hoffmanni* Mantell, 1829, the famous “*Grand Animal Fossile des Carrières de Maestricht*” described by Cuvier in 1808, as well as some inedite specimens.
- All holotypes described from France by Gaudry (1892 - *Liodon compressidens* and *Liodon mosasauroides*), Thévenin (1896 - *Mosasaurus gaudryi* and *Platecarpus somenensis*), as well as well as several fragmentary specimens from France described by Gervais, Cuvier, Hébert (for example historical specimens from the Late Campanian Meudon Chalk).
- Types and referred specimens from Morocco, especially *Tethysaurus nopcsai* Bardet et al, 2003 from the Turonian of Goulmima, as well as *Mosasaurus beaugei* Arambourg, 1952, *Platecarpus* (?) *ptychodon* Arambourg, 1952 and *Halisaurus arambourgi* Bardet & Pereda Suberbiola (2005) from the Maastrichtian Phosphates of the Oulad Abdoun Basin.
- Specimens from the United States of America, especially the *Mosasaurus missouriensis* snout considered lost up to recently (Caldwell & Bell, 2005); several specimens from the Kansas Chalk (some from the Sternberg collection), labelled as *Platecarpus coryphaeus* and *P. ictericus*, *Clidastes liodontus* and *C. velox*.
- Unpublished specimens from the Maastrichtian Ciply Phosphatic Chalk.

This work has been possible due to an active collaboration between members of the *Département Histoire de La Terre*, *Département des Galeries* and *Direction des Collections* of the MNHN of Paris to which I am all grateful.

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NEW MOSASAURID MATERIAL FROM THE LATE CRETACEOUS OF NAVARRE

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Mosasaurids from the Late Cretaceous (Campanian-Maastrichtian) of the Basque-Cantabrian Region in the northern Iberian Peninsula have recently been revised by Bardet et al. (1997, 2006). The material, which mainly includes isolated teeth, allow to recognise the following taxa: *Mosasaurus lemonnieri*, *Mosasaurus* sp., *Prognathodon solvayi*, *Prognathodon* sp., *Platecarpus* cf. *ictericus*, and *Tylosaurus* sp.

Here we report on new mosasaurid material from the Late Cretaceous of the Sierra of Urbasa (Navarre). It consists of a fragment of skull with teeth, which was recovered near the town of Olazti in marly deposits with orbitoids and equinoderms from the Puerto de Olazagutia Formation (Maastrichtian; see Amiot, 1982).

The specimen preserves the posterior part of the right maxilla with three dental alveoli and part of the associated prefrontal. Two maxillary teeth are preserved: an erupted, badly preserved one exhibiting part of the ankylosed root and the dentine, and a well preserved replacement tooth with the crown only visible. The replacement crown is long and slender, about twice high than long and wide; the dental ratio (*sensu* Schulp et al. 2008) is 26:15. It is slightly posteriorly recurved and the posterior face seems more or less straight. The basal cross-section is almost rounded. Two well defined carinae antero-posteriorly aligned and without serrations are preserved. The enamel is completely smooth.

The above mentioned dental characters permit to assign the specimen to the mosasaurine *Prognathodon*. The dental ratio of the preserved replacement tooth is comparable to that of the species of *Prognathodon* with "slender dentition", such as *P. sectorius* from the Maastrichtian of North America and Europe, and *P. kianda* from the Maastrichtian of Angola. Due to the fragmentary aspect of the Olazti specimen, it is here provisionally referred to *Prognathodon* sp.

Financial support provided by the Ministerio de Ciencia e Innovación of Spain (project CGL2007-4061/BTE) and the Gobierno Vasco/EJ (research group GIC07/14-361). This work is part of a palaeontological collaboration program between the Centre National de la Recherche Scientifique (CNRS, France), the Muséum National d'Histoire Naturelle (MNHN, Paris), and the Universidad del País Vasco/Euskal Herriko Unibertsitatea (UPV/EHU, Bilbao).

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PROGNATHODON FROM THE MAASTRICHTIAN OF THE COTENTIN PENINSULA (NORMANDY, WESTERN FRANCE)

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Small patches of Late Cretaceous marine sediments have been known since the early 19th century in the central part of the Cotentin peninsula, in the north-western part of Normandy. Microfossils indicate a Maastrichtian age for this "Baculites Limestone", which is no longer easily accessible. During the 19th century, it yielded abundant fossils, including a few mosasaur remains.

A poorly preserved mosasaur tooth from the Baculites Limestone at La Bonneville (currently kept at University Claude Bernard - Lyon 1, FSL 532948) was described by Sauvage (1873) as the type specimen of *Mosasaurus platyodon*. Vieillard and Dollfus (1875) mentioned *Mesosaurus Camperi* [sic] from the Baculites Limestone at Sainte-Colombe, but did not specify on what kind of material this record was based. In addition, a yet unpublished well-preserved mosasaur tooth from Fresville is kept at the Natural History Museum (Muséum Emmanuel Liais) in Cherbourg (MEL 2994).

Both are large and robust, only slightly posteromedially recurved, with subequal lingual and labial surfaces, and a compressed oval (FSL 532948) to tear-shaped (MEL 2994) basal cross-section. Both surfaces bear indistinct facets and a thick enamel ornamented with coarse anastomosed ridges giving it a rough silky aspect (more pronounced in MEL 2994). There are two strong carinae, the posterior one being "pinched" in both specimens. In FSL 532948, both are aligned antero-posteriorly, unserrated and abraded towards the tip. In MEL 2994 both bear clear serrations, but the anterior one is laterally located and developed only towards the apex of the crown. These differences between the two teeth are interpreted as linked to different positions on the tooth row (MEL 2994 is a more anterior tooth than FSL 532948) and to different degrees of wear (MEL 2994 is less worn that FSL 532948).

On the basis of the above-mentioned shared characters, both teeth are referred to mosasaurines and more especially to the globidensine genus *Prognathodon*. *Mosasaurus platyodon* Sauvage, 1873 should thus be considered a *nomen dubium*. About ten species of *Prognathodon* are known in the Maastrichtian worldwide (Schulp 2006, Schulp et al. 2008). The teeth from the Cotentin are reminiscent of those of *P. saturator*, *P. giganteus*, and *P. overtoni* but differ from the other species. Pending a global revision of this genus, both teeth are referred to *Prognathodon* sp., even though it is not definitely certain that they belong to the same species.

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WHAT, IF ANYTHING, IS A MOSASAUR?

CALDWELL M.W.

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Since Cuvier (1824), the most common answer to the question, "What, if anything, is a mosasaur?", has been that mosasaurs are derived aquatic varanid lizards. Cope (1869) generated a vitriolic 19th century debate when he rejected Cuvier's answer by hypothesizing a closer relationship between mosasaurs and snakes than between mosasaurs and any other lizard group. 140 years later mosasaurs are popularly defined as derived aquatic "varanoids", a conception of their relationships and ancestry derived from Camp (1923) and little else. As a hypothesis to be tested, the empiricism of such an answer rests in its capacity to predict the morphology of the group in question. Therefore, we should expect for mosasaurs and their kin that they should differ from terrestrial varanid lizards in the morphology of their aquatic adaptations. Observation, at many levels, makes it very clear that this is not the case. For example, the classic varanid-mosasaur homology, the "posteriorly retracted narial opening", is a morphological chimera that describes nothing more than a 'space' between nine different bony elements; Caldwell (1999) defined primary homologies of the snout using the bones as characters, not the 'space' of the narial opening, and found the Mosasauroidea to be basal anguimorphs, not crown varanoids. Rieppel et al. (2007) hypothesized that mosasauroids and dolichosaurs were not basal platynotan taxa, but neither were they crown group varanids; a key character supporting their hypothesis was the 'elongated snout, greater than 45% of skull length', a character reminiscent of the primary homology problems of the retracted naris. Conrad et al. (2008), using the same morphological characters but different taxa, found a tree topology where mosasaurs are basal "platynotans". A recent study of mosasaur ingroup relationships has only rattled the question harder by suggesting that the paddle-like limbs of mosasaurs evolved more than once (Bell and Polcyn, 2005), casting into doubt the concept of mosasaur monophyly. In summary, after more than 200 years of empirical tests, several new "truths" are emerging concerning mosasaurs and their kin: 1) they do not share a most recent common ancestor with *Varanus*; 2) they are not crown Varanidae; 3) they are not confidently placed within a loosely defined Platynota/Varanoidea; 4) their aquatic adaptations may have arisen convergently; 5) the monophyly of the clade is uncertain. To answer the question, "What, if anything, is a mosasaur?", there exists only one solution: provide an answer to a bigger question, "What is a squamate, and when is one of them a mosasaur?". This research program entails a global reanalysis of Squamata if we are to move beyond our current received wisdoms reliance on ad hoc hypotheses (e.g., degenerate characters equal primitive), poorly defined characters and states, and our uncertain knowledge of undefined groups (e.g., "basal squamate lineages" of Evans [2003]). The fossil record must rest at the core of any phylogenetic analysis of squamates and cease to be treated as inconsequential to the problem.

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DENTAL MICROSTRUCTURE AND GEOCHEMISTRY OF *MOSASAURUS HOFFMANI* (SQUAMATA) FROM THE LATE CRETACEOUS OF TURKEY.

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Here we provide an analysis of the microstructure and geochemistry of part of the maxilla and a tooth of *Mosasaurus hoffmani* from the Davutlar Formation of northern Turkey, about 250km from Ankara (Bardet and Tunoğlu, 2002). A fragmented tooth surrounded by matrix was selected for histological, petrographical and chemical analyses. In addition, fragments of the maxilla were sampled for histological analyses. Thin sections of the dental material were prepared according to standard techniques for petrography and histological analyses (Chinsamy-Turan, 2005). Elemental analyses of a *Mosasaurus hoffmani* tooth and associated sediment were performed using energy dispersive spectroscopy (microprobe analysis) and x-ray fluorescence analysis.

Sediment within the pulp cavity of a *Mosasaurus hoffmani* tooth contains calcite, quartz and goethite, and the inner most layers of dentine have been pervaded with goethite and quartz. Despite an association with secondary minerals (and the consequent evidence for diagenetic alteration), dentine maintains a high Ca/P ratio indicative of biogenic apatite (Ca/P = 1.9). As with the mineral chemistry, diagenetic alteration has not substantially altered fine histological detail.

Thin sections of the tooth revealed a distinct enamel layer that overlaid a thick layer of dentine and a central pulp cavity. Histological analysis showed that the enamel layer is about 190 microns thick and that it appeared to be prismatic. However, examination of the "prismatic" structure of the enamel under the Scanning Electron Microscope proved inconclusive, although there appeared to be some regularity of microstructures. In some proximal sections of the tooth, a distinct narrow band of cellular cementum is visible below the dentinal layer, and this is followed by a layer of acellular cementum. Darkly stained calcospherites are distinct in the dentine nearest the pulp cavity. The dentinal layer has an average thickness of 5573.75 microns. Dentinal fibres are well preserved, and distinct incremental Lines of von Ebner are present. Using the average spacing of the daily incremental lines we deduced that the dentine took 511 days to form in the functional tooth (Erickson, 1996). Fortuitously, a replacement tooth was sectioned, which also preserved histological details and therefore permitted deductions of an approximate replacement rate for the mosasaur functional tooth. The maxillary thin sections examined consist of mainly woven fibro-lamellar bone with a large number of blood vessels located within primary osteons.

This study of the histology of the teeth and bone fragments of *M. hoffmani* from Turkey, permitted a detail assessment of the microstructure of these dental tissues, as well as, an indication of the tooth replacement rate of the mosasaur. The results of the chemical analyses provided information pertaining to the taphonomic processes that affected the bones and teeth during fossilisation.

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MOSASAURS IN THE EBEN EZER TOWER

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Robert Garcet (12 April 1912 – 26 December 2001) started his exploitation of flint levels in the type Maastrichtian limestones near Eben Emael, NE Belgium, in the 1930s and continued his activities until a few years prior to his death. From 'his' quarries, an impressive array of vertebrate fossils, including multiple articulated mosasaur specimens, was recovered.

Robert Garcet was a remarkably creative person, with a wide – some would say 'eclectic' – range of interests. During the last decade of his life, the fossils in his collection became part of a *Gesamtkunstwerk*, integrating topics from palaeontology, geology, regional and world history, human origins, mythology and theology, into a seven-story flint tower and an underground maze, representing – amongst other things – his view on the Apocalypse.

Garcet embedded his palaeontological discoveries within his own stratigraphic framework. A reassessment of his stratigraphy and direct comparison with the lithostratigraphic framework currently in use in the region, along with an ongoing inventory of the Garcet Collection, now allows us to refine and expand upon the known ranges of mosasaur species in the Maastrichtian type area. While the majority of quarries in the area expose mostly younger stratigraphic levels, the Garcet quarries provide a well-documented record of the vertebrate fauna from the lower reaches of the type Maastrichtian, i.e. the Lanaye Member (uppermost unit of the Gulpen Formation). The combination of manual exploitation of the quarry and Garcet's keen interest in fossils, resulted in the recovery of multiple important specimens from an otherwise poorly sampled stratigraphic interval.

Of particular note is the fact that *Mosasaurus hoffmanni* is present throughout the last c. 0.7 Ma of the type Maastrichtian, and that this presence can now be confirmed based on multiple articulated cranial remains rather than individual teeth and other isolated fragments. Morphology of the quadrate remains remarkably stable throughout the section.

The current state of preservation of the Garcet Collection poses numerous challenges as far as conservation is concerned. Some of the fossils have been completely embedded in or have been adapted to suit the *Kunstwerk*; artistic requirements in this context did not necessarily follow established current practice in conservation. In collaboration between the Garcet heirs and the Natuurhistorisch Museum Maastricht, the Garcet vertebrate palaeontological collection currently is the subject of a detailed inventory and restoration work, which takes care to consider both artistic and palaeontological heritage in this context.

CAMPANIAN AND MAASTRICHTIAN MOSASAURS FROM PENINSULA ANTARTICA AND PATAGONIA

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Mosasaur records from Patagonia and Antarctic Peninsula are, although scarce, the most abundant and diverse of Western Gondwana. Ameghino (1893) described the first mosasaurs from Patagonia. Based on isolated teeth he erected the new species "*Liodon argentinus*". This material could not be found for revision. Gasparini & Del Valle (1981) reported the first mosasaurs from Antarctica; and in 2008, Fernández et al., described diagnostic material from northern Patagonia. Antartic mosasaurs were found in Vega, Seymour and Ross Islands (northeast of Antarctic Peninsula) and their record comprises from the Late Campanian to the Late Maastrichtian. Campanian record is restricted to tylosaurine remains, among which the most significant specimen is the type of *Taniwhasaurus antarcticus* from the Late Campanian Santa Marta Formation on James Ross Island (Fernández & Martin, 2009). Early Maastrichtian record is represented by a juvenile *T. antarcticus* from the Snow Hill Island Formation on Vega Island, and tylosaurine vertebrae from the basal portion of the López de Bertodano Formation on Seymour Island. The highest diversity has been found in the Late Maastrichtian. Tylosaurines, plioplatecarpines (*Plioplatecarpus* sp*)* and mosasaurines (*Leiodon* sp., *Mosasaurus* sp. cf. *M. lemmonieri*¸ and *Mosasaurus* sp. *aff. M. hoffmanni*) have been recovered from Seymour and Vega islands (Martin, 2006). In the Bajos de Trapalcó, northern Patagonia, Argentina, exposures of the upper part of the Jagüel Formation (Late Maastrichtian) yielded mosasaur remains of three different taxa: *Mosasaurus* sp. *aff. M. hoffmani;* Mosasaurinae indet.; *Plioplatecarpus sp*. An isolated *Prognathodon* tooth has been collected by local people in the same area. Complementing Patagonian record, mosasaurine vertebrae have been found in the Jagüel Fm. (Late Maastrichthian) of Liu Malal, Mendoza, Argentina (Gasparini et al., 2001). Comparison of Patagonian and Antarctic records reveals some differences. Patagonian mosasaur record is restricted to the Late Maastrichtian (no mosasaur remains have been found in Campanian localities where plesiosaurs have been found); and no tylosaurine mosasaurs have been recovered from Patagonia to date.

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LATE MAASTRICHTIAN MOSASAURS AND THE K/PG BOUNDARY IN NEW JERSEY

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Late Maastrichtian mosasaurs are known from at least eight different areas of the world, including the stratotype section at Maastricht in the Netherlands, adjacent Belgium, the Monmouth Group of New Jersey, Missouri, the upper Fox Hills formation of North Dakota, Poland, New Zealand, Seymour Island in Antarctica and possibly California. Recent work on the Uppermost Cretaceous deposits in New Jersey has established that the stratigraphically highest levels of the Cretaceous are Late Maastrichtian in age, and the K/Pg boundary ejecta layer has been located down dip in the subsurface, marked by elevated iridium (Ir) levels, shocked quartz, and microtektites. We report here on a drilling program to establish the K/Pg boundary in shallower up-dip sections correlated with outcrop stratigraphy and paleontology. One site that was drilled produced an Ir excursion (0.5 ppb, elevated 5x over background) from the top of the New Egypt/ Red Bank depositional sequence 0.5 m below the base of the Paleogene Hornerstown Formation. This site is the Meirs Farm locality, historically a source of fossil specimens for O. C. Marsh and others. In 1869, Marsh named *Mosasaurus meirsi* based on a tooth from the marl pits in the K/Pg section here. More recently a string of seven mosasaur anterior caudal vertebrae have been excavated from stream bank outcrops on the farm (MAPS 1233a). These specimens can be placed in stratigraphic context with respect to the K/Pg boundary and the Ir excursion. The vertebrae are assigned to *Mosasaurus* cf. *hoffmanni* . They are associated with a marine invertebrate fauna consisting of the ammonite *Eubaculites carinatus* and the bivalves *Cucullaea vulgaris* and *Pecten venustus*.

The distribution of Late Maastrichtian mosasaurs suggests that mosasaur populations were still widespread late into the last stage of the Mesozoic Era. This argues against the gradualist implication that mosasaurs disappeared as a result of eustatic sea level fall and regression. The stratigraphic position of the mosasaur specimens at Meirs Farm in relationship to the Ir excursion argues for the mass extinction of the Cretaceous fauna represented here at the K/Pg boundary in conjunction with the environmental effects of an asteroid impact, rather than a fauna surviving the K/Pg boundary only to go extinct afterwards. This proposal is based on an Ir excursion at a parting surface at the Tighe Park NJ locality, where Ir level is elevated at a permeability and porosity redox change and probably results from secondary geochemical mobilization of original Ir deposition.

These are the first results from an extensive drill coring program in the Atlantic coastal plain deposits of New Jersey. Data from sections taken at other mosasaur sites in New Jersey await further geochemical and biostratigraphic analysis of K/Pg core samples.

VERTEBRAL AND RIB MICROANATOMICAL CHARACTERISTICS IN HYDROPELVIC MOSASAUROIDS

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Hydropelvic mosasauroids sensu Caldwell and Palci (2007) were the mosasauroids the most highly adapted to an open-sea environment. Contrary to plesiopelvic forms, they are considered to rely on a hydrodynamic, rather than hydrostatic, buoyancy and body trim control strategy. This led previous authors to consider that these taxa would favour bone lightening rather than bone mass increase (cf. Ricqlès & Buffrénil, 2001). Though osteoporosis was indeed described in *Clidastes* and *Tylosaurus*, bone mass increase was reported in *Platecarpus* (Sheldon, 1997). As a matter of fact, the new analysis of vertebral thin sections of various taxa combined with the reanalysis of the rib sections available in Sheldon's PhD Thesis in a microanatomical perspective reveal the absence of both bone mass increase and osteoporosis in these organisms. These taxa in fact display a vertebral microanatomy much peculiar within squamates. It characteristically corresponds to a true network of thin trabeculae whose tightness varies between taxa, probably as a result of both species and individual size, especially the latest. The additional analysis of the pattern of vascularization observed in hydropelvic mosasauroids, which is unique among squamates, might suggest that large size in hydropelvic mosasauroids would mainly rely on protracted rather than faster growth speed.

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RE-EXAMINATION OF A SMALL MOSASAUR SPECIMEN FROM THE UPPER CAMPANIAN IZUMI GROUP, WESTERN JAPAN

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Previously assigned to *Kourisodon* sp., we here redescribe a small mosasaur specimen (KSNHM-F6-2) from the upper Campanian Izumi Group exposed in Kagawa Prefecture, western Japan. Our re-examination of the specimen demonstrates that it can be diagnosed against any other known mosasaur taxon for the following main suite of characters: round edentulous prow in front of first dentary tooth; low, long premaxillary-maxillary suture posteriorly extending to, or beyond, level of fifth maxillary tooth; marginal tooth crowns long and slender, with high degree of lateral compression; marginal tooth crowns bearing a number of distinct grooves on both medial and lateral sides. The rounded, well-developed predental projection on the dentary, and laterally compressed tooth crowns, together identify this mosasaur as a mosasaurine. However, no known mosasaurine taxa possess such tall, as well as laterally compressed, tooth crowns with distinct vertical grooves as in this specimen, except *Mosasaurus prismaticus*, known from Campanian–Maastrichtian strata in Hokkaido, northern Japan. Only one marginal tooth is known of this taxon however, and the marginal dentition of *M. prismaticus* would likely exhibit heterodonty, if the taxon indeed belongs to the current genus. In contrast, the new specimen from western Japan exhibits very little morphological variation in the first six maxillary teeth; for this reason, we only tentatively assign KSNHM-F6-2 to *M. prismaticus*. Regardless of the taxonomic treatment, it is noteworthy that mosasaurines with not only flattened but also grooved teeth were common to the northwestern part of the Pacific Ocean during the Campanian and Maastrichtian.

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NEW MORPHOLOGICAL DATA ON *PROGNATHODON* (SQUAMATA: MOSASAURIDAE) FROM THE CAMPANIAN OF NORTH AMERICA, AND ITS BEARING ON THE SYSTEMATICS OF THE GENUS

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In 2007, field crews from the Royal Tyrrell Museum of Palaeontology excavated a nearly complete, exquisitely preserved skeleton of *Prognathodon* from the Bearpaw Formation (upper Campanian; ca. 74 Ma) in southern Alberta. The specimen, TMP 2007.34.01, is mostly articulated, and includes the skull and lower jaws, vertebral column, and girdle elements. The massive skull exceeds 0.8 m in length, and constitutes about 13 % of the estimated total body length of approximately 6 m. On the premaxilla, there is a minute predental rostrum, beneath which the first premaxillary tooth projects slightly anteriorly. The premaxillary-maxillary suture is short, terminating posteriorly above the point between the third and fourth maxillary teeth. A pair of median longitudinal ridges extends along the dorsal surface of the dentigerous portion of the premaxilla, and these ridges converge posteriorly to form a median dorsal ridge on the anterior portion of the internarial bar. The maxilla is deep below the premaxillary-maxillary suture. There are 12 teeth on the maxilla, and they are slender anteriorly, become stout and conical in the middle section, then posteriorly the teeth are short and posteriorly curved. The frontal exhibits a median dorsal ridge in the preorbital region, and the bone is finely wrinkled longitudinally in the interorbital area. Posteriorly, the pair of median flanges is short, and the parietal table shallowly invades the frontal anteriorly. The subcircular parietal foramen is small, and occurs in the middle of the parietal table away from the frontal-parietal suture. The prefrontal bears a wing-like supraorbital process, and posteriorly contacts the postorbitofrontal at the lateral edge of the frontal. The latter element is broadly exposed dorsally at the anterolateral corner of the long supratemporal fenestra. The suspensorial ramus and the supratemporal exhibit an extensive overlap. At least six pterygoid teeth are confirmed, the anterior-most four being larger than the last marginal tooth. The suprastapedial process of the quadrate is notched medially, and the cephalic condyle is anteriorly embayed. There are 15 teeth on the dentary, and they follow the same morphological pattern as those on the premaxilla and maxilla. The posterior edge of the high coronoid process merges with the dorsal border of the surangular at a low angle. The surangular is deeply triangular in profile. There are about 40 prepygal vertebrae and 33 pre-terminal caudal vertebrae, more than 10 of which are pygals. The neural and haemal spines of the terminal caudal vertebrae are extended to form a caudal fin. Both the pubic and ischiadic tubercles are strongly developed as in *Mosasaurus*, and phalanges are elongate as in *Clidastes*.

The overall skull morphology of the Alberta specimen closely compares with that of a referred specimen of *Prognathodon overtoni*, SDSM 3393, inclusive of the characters previously unrecognized or misinterpreted in the latter specimen. Despite the relatively early geologic occurrence (i.e., late Campanian) of these *Prognathodon* specimens, they share the following main characters with the generic type, *Prognathodon solvayi*, from the Maastrichtian of Belgium: anterior marginal teeth procumbent; premaxillary-maxillary suture short; frontal broadly triangular; anterior pterygoid teeth large; quadrate with fused supra- and infrastapedial processes; coronoid and surangular deep; and marginal tooth count relatively low. Although the extent of morphological diversity within the genus has been a subject of debate, the antiquity of these characters is well indicated by their presence in these Campanian specimens. Consequently, we caution the recent inclusion of *Liodon* in *Prognathodon* predominantly on the basis of tooth morphology, and propose that many other cranial traits that form the robust skull architecture of *Prognathodon solvayi* should diagnose the genus as well.

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REVISITING THE CRANIAL ANATOMY OF *PLOTOSAURUS BENNISONI* CAMP, 1942: INSIGHTS INTO THE AQUATIC ADAPTATIONS OF DERIVED MOSASAURIDS

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Since the initial description of *Plotosaurus bennisoni*, this peculiar mosasaur has been compared to other groups of secondarily aquatic tetrapods, notably the ichthyosaurs and cetaceans (Camp, 1942; Lindgren et al., 2007). Previous work, however, has mainly focused on the unique morphology and proportions of the postcranium of *Plotosaurus* in reference to the acquisition of an incipient dorsal fin lobe and a stiff, streamlined trunk region (Lindgren et al., 2007; Lindgren et al., 2008). Although there have been extensive revisions to our understanding of the postcranial anatomy of this taxon and its locomotory habits (Lindgren et al., 2007; Lindgren et al., 2008), there have been no reviews of the cranial morphology of *Plotosaurus* since Camp's original description in 1942.

The exquisite preservation of the holotype material of *P. bennisoni* (UCMP 32778) allows us to bring the initial description of the cranial morphology of *Plotosaurus* (Camp, 1942) into the context of the current understandings of mosasaur evolution. Furthermore, the presence of an ossified interorbital septum, a feature hitherto undocumented in extant squamates (Camp, 1942), the unique orientation of the pterygoid dentition and the preservation of an ossified orbitosphenoid provide opportunities to examine finer-scale cranial features, as well as study a mosasaur skull from an undistorted, three-dimensional perspective. Following Camp's (1942) suggestion that a reduction in cranial kinesis is reflective of an aquatic lifestyle, the extensive medial contact of the left and right dentaries, the nearly horizontal inclination of the intramandibular joint and the tight association between the quadrate and suspensorium suggest a significant decrease in intracranial mobility in *Plotosaurus*. Coupled with the unusually large orbit, shortened post-pineal region and peculiar snout bend in UCMP 32778, these cranial features can be compared to the evolution of analogous characteristics seen in the derived ichthyosaurs.

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EXCEPTIONAL SOFT TISSUE PRESERVATION IN A *PLATECARPUS* SPECIMEN FROM THE NIOBRARA CHALK OF KANSAS, USA

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Convergent evolution refers to the independent acquisition of similar traits in unrelated organisms through their evolution in comparable ecosystems. A classic example is the streamlined body shape and crescent-like tail fin of the Mesozoic ichthyosaurs and modern whales. The squamate superfamily Mosasauroidea represents another successful radiation of secondarily aquatic tetrapods at the end of the Cretaceous Period. Apart from rare fossils with calcified cartilage and patches of integument (e.g., Osborn, 1899; Lindgren et al., 2009), morphological knowledge of this group relies chiefly on skeletal evidence alone. Thus, the prevailing view is that mosasaurs, contrary to other pelagic predators, retained long rectilinear bodies and paddle-like tails throughout their existence (e.g., Carroll, 1985; Massare, 1994; Lingham-Soliar & Nolf, 1990; but see also Lindgren et al., 2007). Here we report on an exceptionally complete specimen (arguably the best-preserved mosasaur since the group was first discovered more than 200 years ago) of the russellosaurine *Platecarpus* that preserves an exquisite array of soft tissues and anatomical details, including scales, a partial body outline, putative skin colour markings, a downturned tail, branching bronchial tubes, and probable visceral traces. This unique fossil has been mentioned previously in an abstract (Geist et al., 2002), but is here reported after full preparation. The presence in this specimen of several important hydrodynamic features, such as a fusiform body and deep caudal fluke covered by small, regularly arranged scales, indicate that the ancestral mosasauroids rapidly achieved a level of aquatic adaptation rivalling that of moderately derived ichthyosaurs and cetaceans.

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NEW MOSASAURS FROM NORTHERN ITALY

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A series of mosasaur specimens has been discovered in northern Italy thanks to the quarrying operations in the local Upper Cretaceous limestones. These carbonate rocks belong to the Scaglia Rossa Veneta Formation and in particular to a unit informally referred to as the "Lastame". The Lastame is a lithotype loosely dated to the uppermost Turonian-lowermost Santonian (Lozar and Grosso, 1997), however, a recent analysis of the rocky matrix of one of the mosasaurs (MPPS-IGVR 42224) allowed us to date the specimen more precisely to the early Santonian.

So far five mosasaur specimens (NHMV-V7481, MPPS-IGVR 45301, MPPS-IGVR 42224, MPPS-IGVR 45299 and THF-IGVR 64108) have been recovered from quarries located north of Verona: NHMV-V7481 is represented only by isolated skull bones, including the two maxillary bones, the left dentary, the frontal, and the posterior end of the left mandibular ramus; MPPS-IGVR 42224 is a well preserved but fragmentary skull represented by two complete mandibular rami, the left maxilla, the right jugal, the two quadrates, one cervical vertebra, and a series of uncertainly identified bony fragments. The left quadrate of MPPS-IGVR 42224 has been prepared free of the matrix and compares closely with the quadrate of *Russellosaurus coheni* (Polcyn and Bell, 2005); MPPS-IGVR 45301 consists of an incomplete skull and some postcranial material, which unfortunately is poorly preserved. However, on the basis of the similar anatomy of some skull bones and the identical marginal dentition, it is possible to conclude that it very probably belongs to the same species of MPPS-IGVR 42224; MPPS IGVR 45299 is represented only by a poorly preserved series of vertebrae belonging to the dorsal and proximal caudal regions. However, the size and morphology of the preserved elements show a clear resemblance to the vertebrae belonging to MPPS-IGVR 45301. Adding all available data together (morphology, identical locality and horizon) we consider these last three specimens to be congeners, if not conspecific; THF-IGVR 64108 is the most recently found mosasaur of the series, and consists of an almost complete skull (inclusive of jaws, braincase, squamosals, pterygoids, ectopterygoids, and quadrates) and about half of the vertebral column exposed in ventral view.

These mosasaurs have some anatomical characters in common with *Russellosaurus coheni*, but the presence of some distinctive features suggests placement in a new genus and possibly two distinct species. A preliminary phylogenetic analysis of the Mosasauroidea based on a modified version of the data matrix published by Caldwell and Palci (2007) places these new mosasaurs in a clade that is in the sister group to the Plioplatecarpinae and Tylosaurinae.

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MOSASAUROIDS FROM COLOMBIA

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The findings of mosasauroids remains have a recent history in Colombia. They are commonly known by some specimens of the unique genus and species *Yaguarasaurus columbianus* Páramo 1994, found in Upper Turonian rocks of southern Colombia. Over the last years, two new specimens from rocks of different ages and regions have been discovered. Here, I offer an overview of the Colombian mosasauroids and show the principal traits of the new fossils.

The Turonian remains include two skulls and some cranial and vertebrae fragments of *Y. columbianus*. From beds of the same age two vertebrae were collected, one of which belongs to a small mosasauroid and the other probably to a dolichosaurid. *Y. columbianus* shares many cranial characters with *Varanus*, aigialosaurs and some basal mosasaurs, that are not present in other mosasaurs. The proportions of the parietal region and temporal fenestrae, the elongation of the frontal, and the more anterior position of the external nares with well developed septomaxilae are some of them.

The new specimens include a near complete skull and some vertebral fragments found in Lower Coniacian beds of the surroundings of Lebrija, Santander (Northeastern Colombia) and a near complete skeleton found in Campanian beds of the vicinity of Coello, Tolima (Central Colombia). These specimens are presently under study.

Although the anatomical morphology of the Coniacian skull is in general comparable to that of *Y. columbianus*, some differences are noticeable. The new specimen is smaller, possesses an interorbital septum and differs in his quadrate and parietal morphology. The Campanian specimen, currently in preparation, is at present the only one preserving the postcranial skeleton. Some cranial differences with both the Turonian and Coniacian skulls can be seen. It is the smallest in size, its external nares are in a more posterior position; a small rostrum anterior to premaxillary teeth seems to be present. The postcranial skeleton, unprepared yet, seems to show a plesiomorphic condition.

Both the Turonian and Coniacian specimens were found in similar facies of limestones and calcareous black shales containing numerous calcareous concretions. On the contrary, the Campanian specimen was found in noncalcareous clastic black shale. The lithological characteristics of beds holding mosasaurs in Colombia, point out to disoxic conditions at the sea bottom and settling of calcareous detritus during Turonian-Coniacian time. On the other hand, for the Campanian time these characteristics reveal a more clastic shelf.

A NEW LOOK AT FAUJAS DE ST-FOND'S FANTASTIC STORY ON THE PROVENANCE AND ACQUISITION OF THE TYPE SPECIMEN OF *MOSASAURUS HOFFMANNI*

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For over 200 years now, a number of scholars have expressed their doubts over some passages in the chapter 'Tête du Crocodile' of Faujas' *Histoire Naturelle de la Montagne de Saint-Pierre de Maestricht*, published in 1798/99. However, in 1995, one of us, while a student at the University of Maastricht, threw new light on Faujas' fantastic story concerning the famous 'Great fossil animal from the quarries of Maastricht' (Rompen, 1995). In her master's thesis, Rompen proved that a great portion of Faujas' rendition was in fact largely a product of his vivid imagination, with the express aim of concealing the fact that the fossil had been confiscated and transported to Paris as war booty.

The bicentenary of the acquisition of the famous fossil prompted Nathalie Bardet and John Jagt (1996) to thoroughly reconsider the historical facts relating to the way of its removal from the cabinet of the legitimate owner late in 1794 and its final deposit in the collections of the MNHM in Paris in the early spring of the following year. In their historical review, several additional new facts came to light, as well as confirmation of Rompen's research. Bardet & Jagt assumed that Faujas inflated his tale to provide propaganda for the French revolutionary armies.

When the present speaker was invited to read a paper during the international conference on 'Napoleon's legacy' in Amsterdam in 2008, she found some additional evidence for Faujas' dishonesty (Pieters, 2009). In the present talk, we summarise our findings and conclude that it must have been patriotism that induced Faujas to falsify the facts. However, by embellishing the story, he added a substantial supplementary cultural value to the fossil. We shall illustrate this with some examples.

In 2009, the famous type specimen temporarily returned to Maastricht, on loan from the MNHN to the Natuurhistorisch Museum Maastricht, for an exhibition in the scope of the international Darwin Year, entitled: "Darwin, Cuvier et le Grand Animal de Maastricht", where it attracted many visitors. Of course, the *Mosasaurus* owes its great scientific value to Georges Cuvier (1822), who stated that, "La détermination précise du fameux animal de Maestricht, nous paroit surtout aussi remarquable pour la théorie des lois zoologiques, que pour l'histoire du globe".

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AN UPDATE ON THE MOSASAURS OF ANGOLA

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Recent field work of the PaleoAngola project has produced a rich Cretaceous marine vertebrate fauna that includes osteichthyan and chondrichthyan fishes, turtles, plesiosaurs, and mosasaurs. Ongoing preparation and study of the mosasaurs now allow confident taxonomic identification, elucidation of anatomy, and a better understanding of the phylogenetic relationships of heretofore poorly known taxa. Most of the material collected to date comes from two localities, Iembe and Bentiaba.

The Turonian section of Iembe has yielded new material of *Angolasaurus bocagei*, allowing an updated phylogenetic analysis and confirming its taxonomic validity. Phylogenetic analysis supports *Angolasaurus* as the sister taxon to *Selmasaurus*, and along with *Ectenosaurus*, it forms a clade that apparently diverged from the *Platecarpus*/*Plioplatecarpus* lineage in the Turonian. *Tylosaurus iembeensis* remains poorly known and the holotype is lost; however, a single fragmentary new specimen has been recovered. The preserved quadrate has a poorly developed infrastapedial process, similar to that seen in *T. kansasensis.* New additions to the mosasaur fauna from the Iembe area come from younger sediments, possibly Santonian in age based on the associated shark fauna, and include a relatively large indeterminate mosasaurid and a diminutive halisaurine.

The Maastrichtian locality of Bentiaba is extremely rich in vertebrate fossils, most restricted to a single horizon, and is apparently the densest concentration of marine reptile fossils currently known. *Prognathodon kianda* is the most abundant taxon at the locality and previous reports of *Liodon* from Bentiaba are referred to that taxon. New specimens of *Globidens phosphaticus* confirm the taxonomic validity of that species and also support a sister-taxon relationship with the late Campanian North American *G. schurmanni*. The enigmatic halisaurine *Phosphorosaurus*, based on an isolated frontal, is also present at Bentiaba as well as a new species of *Halisaurus*, represented by two partial skeletons. *Mosasaurus*, *Plioplatecarpus*, and "*Platecarpus*" *ptychodon* are currently known only from teeth and isolated appendicular elements. The Bentiaba fauna also contains juvenile and sub-adult material including immature mosasaurine mosasaurs.

NEW MATERIAL OF *HALISAURUS ARAMBOURGI* FROM THE MAASTRICHTIAN OF MOROCCO

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Halisaurine mosasaurs are poorly known, represented by a small number of specimens from the Santonian-Maastrichtian (~86 Ma - ~66Ma), but enjoyed broad geographic distribution during that time. They are important for understanding mosasaur evolution as certain aspects of their morphology retains the plesiomorphic or minimally modified squamate condition; however, existing material is limited and details of certain anatomy are lacking. We report here two new specimens of *Halisaurus arambourgi* including a well-preserved, nearly complete skull and skeleton, and a partial skull of another specimen that preserves details of the braincase and quadrate.

In addition to reported synapomorphies uniting *H. arambourgi* and *H. platyspondylus*, are the anteriorly broad frontal bearing a dorsal median ridge, a thin ridge surrounding the pineal foramen, and the pineal foramen does not invade the forontoparietal suture; together corroborating a close relationship of those two taxa to the exclusion of *Phosphorosaurus*. Additionally, the distal terminus of the parietal ramus thickens ventrally in both taxa, forming a novel process that articulates with the parocciptial process below, and likely provided enhanced strength in the dorsoventral axis. As in *Eonator sternbergi*, *Phosphorosaurus ortliebi* and a new form from Angola, the supratemporal articulates in a vertical plane with the lateral terminus of the parietal rami. A vertical orientation is also present in *H. platyspondylus* and a prior report of an oblique articulation was a misinterpretation of crushing present in that specimen. The relationship of the supratemporal and supraoccipital with the parietal and braincase suggests suppression of the metakinetic axis. The squamosal provides the primary support for the quadrate. The quadrates have a broad, sutural contact with the pterygoid rami and the anterior pterygoid forms an oblique articulation with the palatine. Taken together, the nature of the frontoparietal suture and the relationship of those elements with the postorbitofrontal, and the nature of the articulations of the quadrate, pterygoid and palatine, indicate that both *H. arambourgi* and *H. platyspondylus* had largely eliminated the mesokinetic axis and limited rostrocaudal streptostyly.

Judging from the proportions of the epipodials and the vertebral centrum morphometrics of the tail segment of the vertebral column, *H. arambourgi* is more derived than the Santonian to early Campanian *Eonator sternbergi* but less derived than the mid-Maastrichtian *Halisaurus* sp. from the Moreno Formation of California, USA. This suggests that the evolution of the Halisaurinae towards an obligate marine existence was complex and probably included independent evolution of several lineages of halisaurines. Moreover, vertebral morphometics reveals that *H. arambourgi* possessed a downturned tail that likely supported a crescent-like fluke.

VERTEBRAL MORPHOMETRICS AND FLEXIBILITY IN VARANOID REPTILES

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The degree of intervertebral mobility among mosasaurs remains poorly understood. Some workers have argued for dorsal vertebrae flexible enough to assist in propulsive undulation, while others have argued for a relatively rigid dorsal series. We explored this issue by performing 3-D scans on the dorsal vertebrae of extant aquatic and terrestrial varanids. Scanned images were then used for morphometric analyses. Histological sections were made through the intervertebral joints to identify anatomical limits to intervertebral mobility. Kinematic analysis was performed on walking and swimming varanids in an effort to document "typical" ranges of vertebral mobility. Lightly anesthetized specimens were manually positioned in poses representing differing degrees of body flexion; radiographs taken at each pose enabled a quantification of vertebral mobility at each pose. Lastly, specimens were fixed in linear and flexed poses, and the vertebrae imaged using high-resolution micro CT. The resulting data set of vertebral morphometrics and kinematics is intended as a platform with which we can model the different vertebral, and overall body, types described from the mosasaurid radiation.

VENTILATORY AND LOCOMOTOR MECHANICS IN THE WATER MONITOR (*VARANUS SALVATOR*)

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Previous studies of the "Carrier Constraint" have shown that in many lizards, the muscles responsible for vertebral flexion also function in ventilation; making it difficult and/or impossible for the animal to locomote aerobically. At the same time, the relative contribution of lateral vertebral flexion to locomotion is unclear, as is the functional basis of this vertebral mobility. The extent to which this functional complex differs when lizards locomote through water, as opposed to over land, has received little attention. We explored this functional complex using sub-adult water monitors (*Varanus salvator*) trained to locomote both on a treadmill and in an aquatic flow tank. During locomotor trials the animals wore a respiratory mask which enabled quantification of both ventilatory airflow and respiratory gas exchange. Prior to the locomotor trials, dorsal markers were positioned along the vertebral column, bipolar emg leads were implanted into the axial musculature at regular intervals along the trunk and tail base, and strain gauges were attached to the dorsolateral scalation. Once recovered from the anesthesia the animal was placed in the locomotor apparatus and its kinematics recorded using a high-speed digital video camera. Quantification of the body markers from the kinematic record, when coupled with the strain gauge and emg data sets, enables a determination of the propagation of the lateral vertebral flexion, the relative contribution of active and passive movements, and regional variation in the flexion propagation. Direct comparison of the aquatic and terrestrial data sets can document the relative variation and dual modalities present in this functional complex. Integration of the ventilatory and pulmonary data sets with the mechanics of vertebral flexion will document how locomotion and ventilation is coupled in this species. Understanding of these functional complexes can provide insight into the ecological and biogeographic radiation of mosasaurs.

A REVIEW OF RECENT DISCOVERIES OF THE DUROPHAGOUS MOSASAUR *CARINODENS*

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In recent years, multiple new discoveries of the durophagous mosasaur *Carinodens* have seen the light of day, greatly extending its known geographical range. Here we present a review of the material available so far, including two new species described early this year (Schulp et al., 2010; Kaddumi, 2010).

The first description of *Carinodens* dates back to 1913 (Dollo, 1913), although an individual tooth was mentioned (then identified as crocodilian) well over a century earlier (Faujas de Saint Fond, 1799). Most of the reports until 2010 dealt with occurrences of isolated teeth, and one single dentary fragment with three teeth preserved (Schulp et al., 2004).

New material from the Maastrichtian phosphates of Morocco includes three new dentaries, assigned in Schulp et al., 2010 to *Carinodens belgicus*, and the newly described, much more slender species *C. minalmamar*, preserved as two – again isolated – dentaries.

New material recognized in a rock saw operation in Jordan yielded the first *Carinodens* remains beyond teeth and dentaries: Kaddumi (2010) describes a relatively complete cranium, cervical and dorsal vertebrae and two partial flippers from a single individual from the Muwaqqar Chalk of Harrana (Jordan).

Of note is that *Carinodens* has more teeth than initially assumed by Dollo (1913): 17-18 rather than 13; a previous reconstruction now requires revision, and so does the assumed tendency of a continuous reduction of tooth number within globidensine mosasaurs from *Prognathodon* -> *Globidens* -> *Carinodens* as suggested in Schulp et al., 2004.

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MOSASAURS AND THE ASSOCIATED VERTEBRATE FAUNAS OF SOUTHWEST JAPAN

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Here, I introduce the associated vertebrate faunas with mosasaurs from the Izumi Group of southwest Japan (Tanimoto, 2005). Altough shark teeth are abundant in the Izumi Group, the current contribution focuses on non-chondrichthyan vertebrate taxa.

1) Shikoku Island (the upper Campanian): From the Hiketa Formation, many chelonian fossils have been found, and most of them pertain to gigantic *Mesodermochelys*. An isolate humerus or femur belongs to a small plesiosaur. The Hiketa Formation has also yielded an osteichthyan *Enchodus petrosus*. A small mosasaurine from the formation was previously referred to *Kourisodon* sp. (e.g., Tanimoto, 2008), while this generic assignment is currently under review (Konishi et al., this volume).

2) Awaji Island (the upper Campanian-the lower Maastrichtian): From the Seidan Formation (the upper Campanian), an incomplete mosasaur vertebra was found. An azhdarchid pterosaur cervical vertebra was also found here. Several trionychid fossils are present in this formation as well. The Kita-ama Formation (the lower Maastrichtian) has yielded some incomplete mosasaur specimens. Other vertebrate fossils are abundant, including the only dinosaur material known from the Izumi Group (a lambeosaurine hadrosaur). This formation is also rich in *Mesodermochelys* fossils, although the specimens are smaller in comparison with those from the Hiketa Formation. To be noted is a nearly complete skeleton of *Gillicus*, a big osteichthyan. Shimonada Formation of the same island is the early Maastrichtian in age, and the formation has yielded plesiosaur and mosasaur remains. Some specimens of *Enchodus gladiolus* were also reported from this formation.

3) Honshu Island (the Maastrichtian): The Mutsuo Formation has yielded two types of mosasaurine fossils (Tanimoto et al., 1994, Tanimoto et al., 1998), which constitute an incomplete skeleton of *Mosasaurus* sp. and *Kourisodon*-like teeth. In the formation, no other reptilian fossils are yet known except for an incomplete turtle material.

From the present survey, the worldwide tendency of high abundance of mosasaur fossils in Maastrichtian strata is also confirmed in southwest Japan.

ON TOOTH REPLACEMENT IN *MOSASAURUS*

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The discovery of new dentary and maxillary material of *Mosasaurus hoffmanni* Mantell, 1829 from the type Maastrichtian (SE Netherlands, NE Belgium) has permitted a detailed macroscopical review of tooth growth and replacement patterns in this large-sized Cretaceous marine squamate. Although the first account of tooth development and replacement in mosasaurs was published in the late eighteenth century (Camper, 1786), most studies on *M. hoffmanni* that have appeared since were based on small samples, in part due to the –by necessity– destructive nature of such analysis.

One may expect natural selection to favour as short as possible a time span between the shedding of the 'old' tooth and the moment the replacement tooth becomes functional and firmly placed in position. This is certainly the case in *M. hoffmanni*, and in this contribution, thanks to a number of newly collected, fairly disarticulated and damaged specimens, we have been able to document tooth development in this taxon in great detail.

We recognise that the tooth replacement process involves *two* zones of resorption and redeposition of bone material. The first zone, positioned caudolingually in the tooth socket, provides space for the initial development and growth of the crown of the replacement tooth from the apex down; the second zone (within the pulp cavity) ultimately provides a separation point between the tooth crown and the remainder of the tooth which is to become resorbed. This second zone develops in order to separate the tooth crown *sensu stricto* from the lower dentine cone. Of note is the fact that the basal aspect of the majority of shed teeth is smooth or nearly so, indicating that the teeth are only released once the major portion of bone and dentine has been resorbed in this zone, rather than just breaking off. The pulp cavity of shed teeth is almost completely filled with dentine during the separation process. The exposed alveolus appears to have become covered with a centripetal outgrowth of the dental collar. The apex of the replacement tooth penetrates into the pulp cavity, and moves from a caudolingual position to emerge at a more central position, to perforate from there the collar, which is resorbed during this phase. Once the tooth is in place, the tooth sockle becomes partially fused to the mandibular bone.

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FIELD TRIP GUIDE

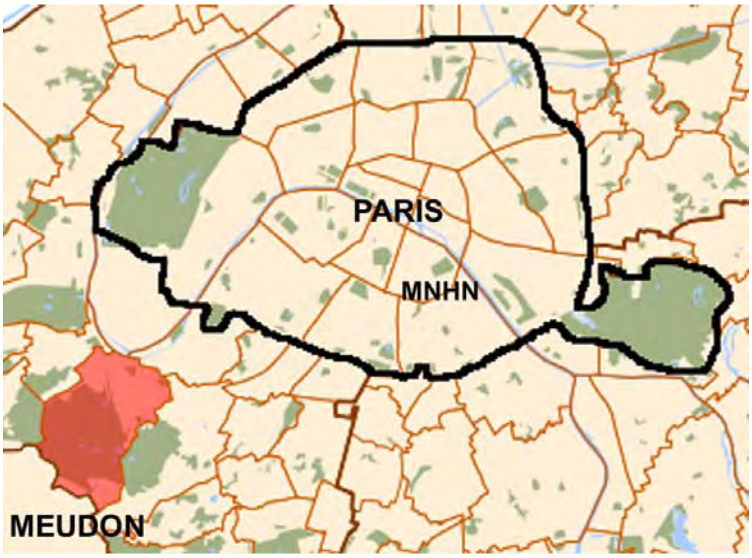
THE VERTEBRATE-BEARING MEUDON CHALK (CAMPANIAN) AND MEUDON CONGLOMERATE (SPARNACIAN) AT MEUDON (YVELINES)

Visit of the underground quarries at 15, route des Gardes, Meudon, led by Mr Alain GALOYER (Meudon).

Introduction

The city of Meudon is well known among French palaeontologists since the 19th century for two vertebrate-bearing geological formations, the **Campanian Meudon Chalk** and the **Sparnacian Meudon Conglomerate**. The field trip will provide an opportunity to examine both formations in underground quarries which normally are not accessible to the public.

Meudon is located SW in the suburbs of Paris. It extends NS from the level of the Seine River (0 m altitude) to a large forest named *Bois de Meudon* (173 m altitude), forming in the landscape a natural hill looking North. This topographical characteristic is due to the WE oriented Meudon Anticline and allows to cross all the geological strata forming the Paris Basin, from the Chalk at the level of the Seine River to quaternary alluvions at the top of the hill, passing by several sand, clay, gypsum and limestone levels. All these geological resources are exploited in the area for a very long time.



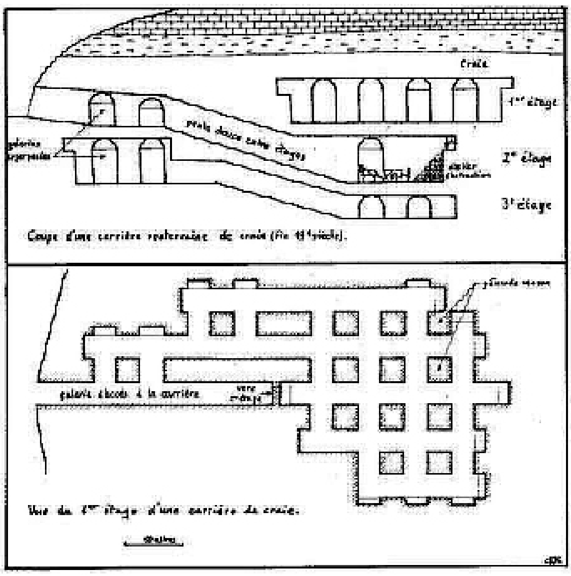
The Exploitation of the Meudon Chalk

At Meudon and neighbouring cities like Issy-les-Moulineaux, Bougival, Port-Marly, and Louveciennes (better known by paints of Impressionnists like Sisley and Monet), the Late Cretaceous Chalk was quarried in an extensive network of underground galleries. The excursion will visit some of the galleries, which still display evidence of the techniques used for quarrying the chalk and of the everyday life of the quarrymen (graffiti, chapels, etc...).

The Meudon Chalk is exploited since at least the 18th century in Meudon area for the production of the famous *Blanc de Meudon* (Meudon White, Paris White or Spain White), a substance that was obtained by mixing crushed chalk with water.

At this time, the chalk exploitations were open-air but they rapidly became underground, due to the scarcity of available extraction surface on the hill slope.

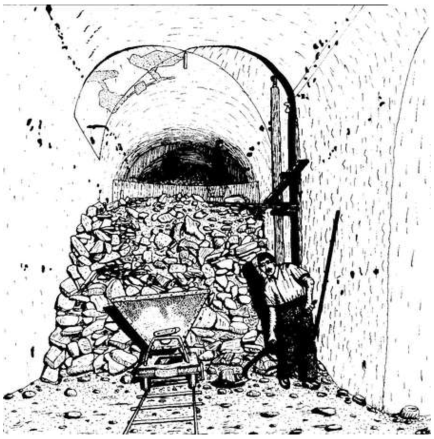
The first underground galleries were chaotic in organizations and relatively small (2-3 meters high). Some of the sustaining pillars possessed at their basement large cavities named *Fosses à Blanc* (White pits), used as storage.



Later, due to stricter Engineering rules to reduce accidents, new requirements were demanded to exploite a quarry, such as a more regular gallery network (see left figure), maximum dimensions for the galleries (6 m high and 5m wide), minimum size for pillars (6 m wide), no "White pits" into the pillars, etc.

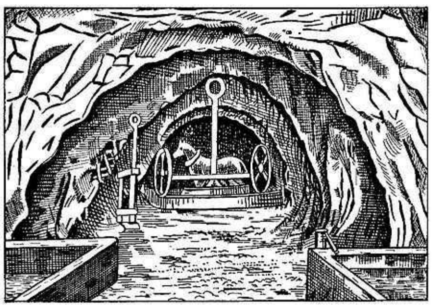
In the 19th century, the quarry exploitation reached its apogee in the Meudon region, with several factories functioning, and a network of underground galleries developed on four levels and more than 8 km.

The methods used to extract the chalk were very basical: it was removed by hand with peaks and crushed with large hammers. The crushed chalk was then put into water to eliminate sands and coarser particles by simple decantation. The same process was applied to the resulting milky water, in order to finally recover the thinnest chalk particles. When this chalk was plastic enough to be manipulated, it was molded into small rolls named "breads" that were clumps against the walls of the galleries. This strange process permitted to extract the final extra-moisture of the rolls. The rolls were let under this form or crushed into power.



With time, the only improvement of the method was the replacement of hand-grinding by a large stone roller driven by a horse.

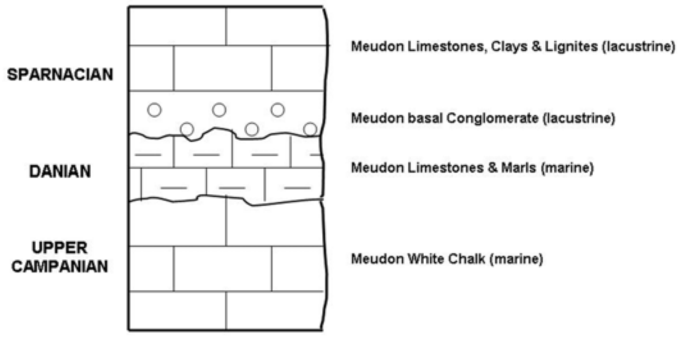
The carriers had a simple view of the fossils they founded into the chalk as they were referred to familiar objects such as chesnuts for echinids and candies for belemnites.



The “Meudon White” had a lot of primary utilities: decorative (painting, gilding, molding), industrial (lime, putty) or domestic (cleaner for windows, clothes and silverware) but also enter in several secondary productions of glass, porcelain, etc.

All these activities ended around 1930 in Meudon area. Later, these underground quarries were reused either for cultivation of Paris mushrooms (until the 1950s) or as wine cellars. Today, although some of the quarries in neighbouring towns are still used as wine cellars or storage spaces, those at Meudon are abandoned and closed to the public.

General stratigraphy around Meudon



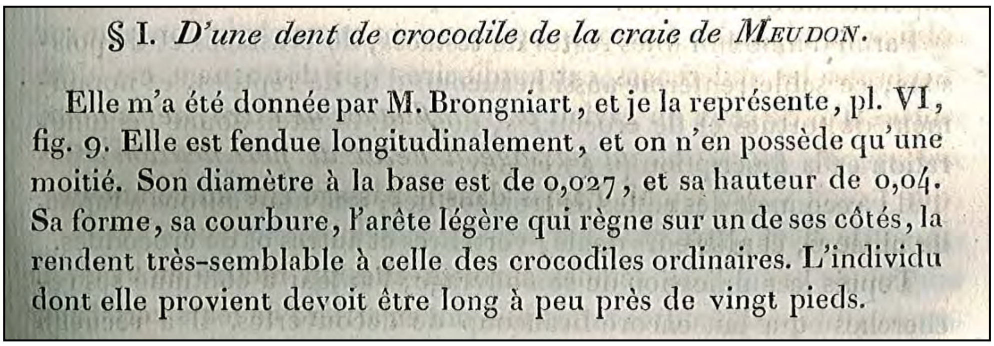
Here is a synthetic stratigraphical column of the series that is available in the underground quarries at Meudon and that we will see during the visit:

- The Upper Campanian White Chalk (marine environment)
- The Danian Limestones and Marls (marine environment), deposed in discontinuity above the Chalk (note the complete absence of Maastrichtian stage in this area).
- The Sparnacian Meudon limestones, clays and lignites (lacustrine and continental environments). This level begins by a basal conglomerate very rich in vertebrate remains, especially mammals. This level was found by Charles d'Orbigny and was considered at its time as the oldest Tertiary level from France.

The Meudon Chalk

The Meudon Chalk is a very pure white chalk, with layers of black flints. During the visit, various aspects of the mineralogy, sedimentology (paramoudra-type flints, etc.), tectonics (faults linked to the Meudon anticline) and hydrogeology (karstic network with dissolution features, stalactites) of the Chalk will be examined. **The Meudon Chalk is Late Campanian in age (*B. mucronata* Zone)**. It contains abundant invertebrate fossils, including sponges, annelids, echinids, brachiopods, bryozoans, bivalves, belemnites and ammonites. The vertebrate remains identified by Hebert (1855) include fish (*Pycnodus parallelus*, *Corax pristodontus*, *Sphryna plana*, *Otodus appendiculatus*, *Lamna subulata*, *Onchosaurus radicalis*) and reptiles (crocodilians, mosasaurs). Reports of an *Iguanodon*-like dinosaur have never been substantiated. The vertebrate fauna from the Meudon Chalk is much in need of revision as it has not been studied since the end of the 19th century. Various invertebrate fossils, as well as fish remains, will be visible during the visit.

Several mosasaurids remains, mainly isolated teeth and jaw fragments, were found in the Meudon Chalk. The first one was found by

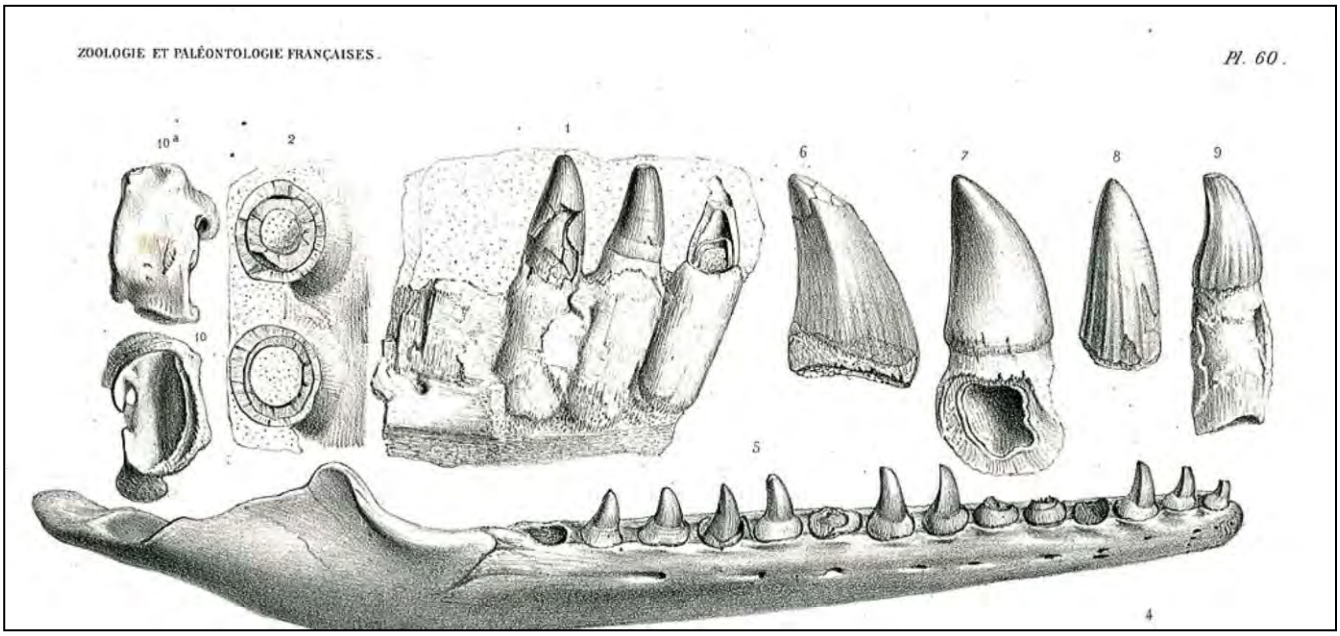


§ I. *D'une dent de crocodile de la craie de* MEUDON.

Elle m'a été donnée par M. Brongniart, et je la représente, pl. VI, fig. 9. Elle est fendue longitudinalement, et on n'en possède qu'une moitié. Son diamètre à la base est de 0,027, et sa hauteur de 0,04. Sa forme, sa courbure, l'arête légère qui règne sur un de ses côtés, la rendent très-semblable à celle des crocodiles ordinaires. L'individu dont elle provient devoit être long à peu près de vingt pieds.

Brongniart and described by Cuvier in his *Recherche sur les Ossements Fossiles* and referred to a crocodile (text right).

Several others were later described by Gervais (1848-1852), Hébert (1855) and Gaudry (1892) and referred to either *Leiodon* or *Mosasaurus*. Currently, only the teeth described by Cuvier and Gaudry has been recovered in the collections of the MNHN of Paris, as well as other unpublished teeth.



From Gervais (1848-1852). Beside the jaw and quadrate of *Mosasaurus hoffmanni* type specimen are figured several mosasaurid specimens found at Meudon. **1-2**: jaw fragments found by D'Orbigny. **6**: tooth described by Cuvier (1824) as a crocodile. **7-9**: other teeth.

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The Meudon Conglomerate

The Meudon Conglomerate is interpreted as the filling of a fluvial channel carved in an underlying Palaeocene limestone**. It is Sparnacian (basal Eocene) in age (MP7 Zone)**. In the 19th century, the Meudon Conglomerate (and the immediately overlying sandy clay rich in lignite) became famous for the abundant vertebrate remains they contained, especially the mammal one, like the large *Coryphodon*.

In 1855, the young physicist Gaston Plante discovered remains of a giant flightless bird at Meudon; it was named *Gastornis parisiensis* by Hébert, and attracted much attention. At the end of the 19th century, the Meudon Conglomerate became inaccessible, and remained so for about a century.

In 1984, it was rediscovered by Mr. Alain Galoyer in a slump ("fontis") in one of the underground chalk quarries at Meudon, and later in a temporary outcrop on a building site. Screenwashing by Donald Russell and Marc Godinot (MNHN, Paris), led to the discovery of a number of vertebrate remains, including mammal teeth, which have significantly improved our knowledge of the fauna from the Meudon Conglomerate. The mammal assemblage from Meudon characterises reference level MP7 (Schmidt-Kittler, 1987) and zone PE II (Hooker, 1996). The vertebrate fauna from the Meudon Conglomerate includes fishes (Selachii indet, Pristidae, Batoidea indet., Pycnodontidae, Lepisosteidae, Amiidae, Percoidei indet., Phyllodontidae), amphibians (Urodela indet., Anura indet.), turtles (Trionychidae, Carettochelyidae), lizards (Agamidae, Anguidae), crocodilians (Crocodylidae, Alligatoridae), birds (Aves indet., Gastornithidae), and mammals (Didelphidae, Ischyromyidae, Erinaceidae, Nyctitheriidae, Apatemyidae, Icaronycterididae, Microsyopidae, Paromomyidae, Plesiadapidae, Omomyidae, Adapidae, Equidae, Miacidae, Viverravidae, Oxyaenidae, Hyopsodontidae, Coryphodontidae).

The Meudon Conglomerate is still exploited for palaeontological purposes by Mr. Alain Galoyer in the underground quarry visited by the field trip, in a timbered narrow gallery which will be seen during the visit. Samples of conglomerate and lignite will be available for examination and sampling.

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Thanks to Mr. A. Galoyer, Mrs. A. Derradji, Mr. S. Brisson and all the owners of the property at 15 route des Gardes for the opportunity to visit the underground quarries.

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TROISIEME CONGRES SUR LES MOSASAURES

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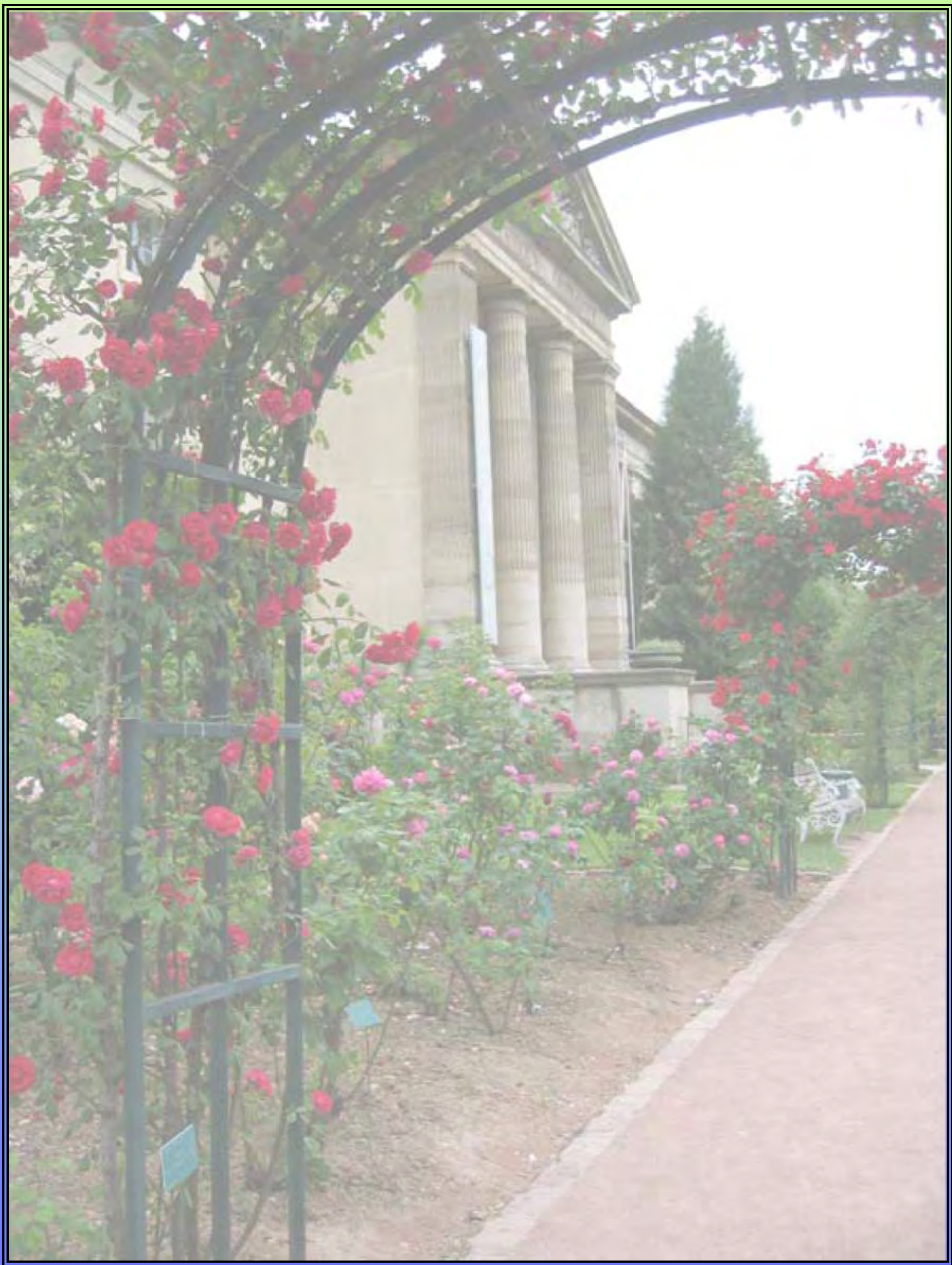

(Rose Garden and Palaeobotany Building, MNHN, Paris)