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RECENT ADDITIONS TO THE LATE MAASTRICHTIAN MOSASAUR FAUNAS OF LIÈGE-LIMBURG (THE NETHERLANDS, BELGIUM)

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Rezumat

Completări recente la fauna maastrichtiană târzie de mosaszauri din Liege-Limburg (Olanda, Belgia)

Elementele predominante ale faunei de vertebrate marine din stratotipul maastrichtianului sunt reprezentate de mosazauri şi chelonieni, mult mai rari fiind plesiozaurii, crocodilii eusuchieni şi dinozaurii.

In ultimul timp au avut loc numeroase descoperiri de resturi de mosazauri, bine documentate stratigrafic, câteva dintre acestea fiind discutate pe scurt în aceasta lucrare. Cele mai notabile descoperiri reprezintă un fragment de dentar de Leiodon sectorius COPE 1871 găsit "in situ" în Membrul Lanaye din complexul de cariere de la Marnebel (Eben Emael, Belgia), cât şi un individ mare, destul de bine conservat al unui ? mosasaurin în acelasi nivel stratigrafic în cariera ENCI-Maastricht BV (Maastricht, Olanda).

Introduction

The predominant elements amongst late Maastrichtian marine vertebrate faunas from the type area of the Maastrichtian Stage (Fig. 1) known to date are mosasaurid lizards and cheloniid turtles. In comparison, representatives of other groups such as plesiosaurs, eusuchian crocodiles and dinosaurs are extremely rare (MULDER 1998; MULDER et al. 1998, 2000; WEISHAMPEL et al. 1999). In recent years, numerous stratigraphically well-documented mosasaur finds have been made, a few of which are briefly discussed in the present paper. The most notable recent additions are *in situ* finds of a fragmentary dentary of the mosasaurine *Leiodon sectorius* COPE 1871 in the Lanaye Member at the Marnebel quarry complex (Eben Emael, NE Belgium), and of a fairly well-preserved, large individual of a ?mosasaurine in the same stratigraphic unit at the ENCI-Maastricht BV quarry (Maastricht, the Netherlands).

Recent additions

On belemnite evidence (Fig. 2), the Lanaye Member of the Gulpen Formation, as well as all members of the overlying Maastricht Formation are of late/latest Maastrichtian age (*Belemnitella junior* and *Belemnella kazimiroviensis* zones; see CHRISTENSEN 1996, 1997a, b).

Most of the recent mosasaur finds are either from the Lanaye, Valkenburg or Emael members, and are thus of *B. junior* Zone age. Selected for illustration and brief discussion here are the most notable of these recent additions. To denote the repository of material referred to in the text, the following abbreviations are used:

AMNH - American Museum of Natural History, New York

ANSP - Academy of Natural Sciences, Philadelphia

NHMM - Natuurhistorisch Museum Maastricht, Maastricht

YPM - Yale University/Peabody Museum of Natural History, New Haven

Specimens currently housed in the private collections of two of us (RWD, MMMK) will be transferred to the NHMM in due course.

Leiodon sectorius COPE 1871

Figs. 3, 4

COPE (1871, p. 41) based this taxon on fragments of a maxilla, a dentary, a coronoid and a surangular, as well as a single incomplete vertebra, collected by J.C. Gaskill from marl pits of the Pemberton Marl Company at Birmingham (Burlington Co.), New Jersey (USA).

The type material (AMNH 1401) is probably from the Navesink Formation, which on ammonite evidence (KENNEDY et al. 1995) is late Campanian-early Maastrichtian in age. GALLAGHER (1993, p. 103) noted that RUSSELL's (1967, p. 143) referred specimens ANSP 9669-9670 might be from the Hornerstown Formation of Vincentown (Burlington Co.), New Jersey, which is a younger unit ranging in age from latest Maastrichtian to basal Palaeocene (GALLAGHER 1993).

RUSSELL (1967) noted that some of the fragments which constituted the type material of the present species, were lost. During a recent re-examination by one of us (EWAM), it appeared that of the type material (AMNH 1401) only a small jaw fragment with a single anterior tooth and a tooth socket survives (Fig. 3). The remaining tooth is virtually identical to the anterior teeth in NHMM 004104, and would corroborate LINGHAM-SOLIAR's (1993) assignment of that specimen to *L. sectorius*.

Having previously been referred by MEIJER (1980) with a query to *Liodon* [sic] *compressidens* GAUDRY 1892, Lingham-Soliar (1993) reassigned NHMM 004104, a fragmentary left dentary with ten preserved teeth, to *L. sectorius*, which thus represented the first specimen of this taxon to be recorded from outside North America. Since this specimen allows anterior and posterior dentary teeth to be described in detail, a number of isolated teeth have subsequently been demonstrated

to be also referable to this taxon (KUYPERS *et al*., 1998, p. 31, pl. 4, figs 1-9). Data on geographic and stratigraphic provenance of NHMM 004104 are lacking; however, an analysis of the benthic foraminiferal content of small matrix samples suggest it to have come from the basal portion of the Maastricht Formation (benthic foraminiferal zone Mb).

KUYPERS et al. (1998, text-fig. 11) have recently shown *L. sectorius* to range from the upper Gulpen Formation to the upper Maastricht Formation.

The newly collected material (Fig. 4A-G) is from the Lanaye Member at the Marnebel quarry complex (Eben Emael- Bassenge, NE Belgium) and consists of various fragments of a right dentary with six preserved teeth, all remarkably well preserved. There are slight differences between these teeth and those of NHMM 004104, but these are considered to be size related, the new specimen being of a larger size. Both carinae (cutting edges) are well developed, and teeth show faint signs of facetting. Colour banding on all teeth (Fig. 4D-G) corresponds to growth zones, and occurs at variable tooth crown heights along the jaw.

A detailed description of this specimen and an analysis of these growth zones will appear elsewhere.

Mosasaurus hoffmanni MANTELL 1829

Figs. 5, 6

This species, the largest mosasaur taxon known to date (Lingham-Soliar, 1995), is undoubtedly the commonest species in the area.

Many isolated teeth (crowns) and vertebrae have been collected in recent years, and associated remains have been shown to be comparatively common as well. However, owing to quarrying activities most of these run the risk of being seriously damaged and scattered over the quarry floor prior to discovery.

Notable for their state of preservation are a few associated cervical vertebrae of a comparatively small-sized (?subadult) individual of *M. hoffmanni* (Fig. 5) from the Valkenburg Member (Maastricht Formation) at the CBR-Romontbos quarry (Eben Emael-Bassenge). Although the neural arches are partially broken, the anterior and posterior zygapophyses (Fig. 5A), hypapophyses, synapophyses, zygosphenes and associated peduncles are remarkably well preserved.

Of another individual (NHMM 1998140; Fig. 6), from the Emael Member at the same quarry, portions of the vertebral column, numerous associated broken and scattered ribs, and a highly fragmented skull, have been collected. Tooth size shows this to have been a large, fully-grown specimen.

?Mosasaurine (?Globidensini) mosasaur

Fig. 7

The most recent find (NHMM 1998141) is from the upper Lanaye Member (flint level 18) at the ENCI-Maastricht BV quarry (Maastricht). Upon discovery in early August 1998, five dorsal vertebrae (Fig. 7), still articulated, were collected. On the basis of these it was decided to first remove the overburden using heavy machinery down to a discontinuous level of flint nodules, and excavate the skeleton by hand from then on. In a number of trenches, the skeleton was subsequently shown to be scattered over an area of at least 20 square metres.

Apparently, dorsal vertebrae and ribs were scattered by wave action and/or scavenging, since a number of teeth of the sharks *Squalicorax pristodontus* (AGASSIZ 1843), *'Palaeohypotodus' bronni* (AGASSIZ, 1843) and *Plicatoscyllium minutum* (FORIR 1887), a few vertebrae and pieces of cartilaginous bone have been collected from directly above the skeleton.

Mainly on the basis of the still articulated coracoid/scapula, this specimen was originally thought to be referable to the mosasaurine *Mosasaurus hoffmanni*, but now this preliminary assignment can no longer be upheld. The skull, situated close to the posterior postcranial skeleton, with the snout pointing backwards, is now revealing all kinds of features that are atypical of *M. hoffmanni* (*e.g.* structure of quadrate, frontal and parietal bones). Preparation has not yet been completed; the close association of lower and upper jaws suggests limited *post-mortem* transport, as does the series of cervical vertebrae still attached to the basioccipital unit. Mandibular and dental teeth lack the U-shaped cross section which characterises teeth of *M. hoffmanni*, and have no well-developed prisms. Moreover, when well preserved, they show apical enamel striations similar to the ones described for teeth referred to *Prognathodon giganteus* DOLLO 1904 by BARDET et al. (1997).

In many respects, NHMM 1998141 appears to be closely related to the genus *Prognathodon* DOLLO 1889, representatives of which are well known from southern Belgium (Lingham-Soliar & Nolf, 1989) and the United States (*e.g*. *Prognathodon overtoni*).

However, all these species have much smaller skulls; as preserved, the length of the lower jaw of NHMM 1998141 is 123 cm, but some 10-15 cm are missing, having fallen victim to quarrying.

Upon completion of preparation, our research is to concentrate on the taxonomic assignment of NHMM 1998141, and on providing a detailed taphonomic picture of this recent find.

Carinodens belgicus (WOODWARD 1891)

KUYPERS et al. (1998, text-fig. 11) assumed this mosasaurine to first appear in the Emael Member (Maastricht Formation), and to have been a representative of a second 'pulse' of mosasaur immigration into the Maastrichtian type area. However, in the course of 1998 two isolated tooth crowns, both contained in private collections, were collected from the base of the Valkenburg

Member. This means that mosasaur distribution and stratigraphic ranges need to be reconsidered (see JAGT et al. 2000).

Plioplatecarpus marshi DOLLO 1882

Fig. 8

In his brief discussion of *Plioplatecarpus depressus* (COPE 1869), RUSSELL (1967, p. 160) noted that the type material originally comprised a quadrate, skull fragments and dorsal vertebrae, collected by L.T. Germain in Birmingham (Pemberton; Burlington County), New Jersey, apparently from the Hornerstown Formation. On the basis of referred specimen YPM 312, the type of *Mosasaurs copeanus* MARSH 1869, RUSSELL (1967, p. 162, text-fig. 88) suggested that *P. depressus* would most closely resemble *P. marshi*, except that the former had less medially recurved mandibular teeth, and could thus be distinct. As noted by GALLAGHER (1993, p. 103) the type is missing. Although the original specimen could not be traced, an illustration of the quadrate of *P. depressus* has recently been compared by MULDER (1999) with quadrates of *P. marshi*, who suggests these taxa to be synonymous. Thus, it appears advisable to use the name *P. marshi* for both the North American and European specimens, since that taxon is based on more or less complete skeletons and is thus better characterised. This action obviously calls for an application to the ICZN to suppress *P. depressus* in favour of *P. marshi*.

Plioplatecarpus marshi is the second commonest mosasaur species in the Maastrichtian type area. In recent years, quite a number of associated finds, such as the ones described in JAGT et al. (1995, figs 1-4) and KUYPERS et al. (1998, pp. 14-16; text-fig. 6), have been made. Still undescribed material in the Dortangs and Kuypers collections, which includes the associated remains of a very large specimen preserving both quadrates, as well as sets of teeth (Fig. 8A), skull remains, fragmentary ribs and dorsal/pygal vertebrae (Fig. 8B) is assignable to *P. marshi* and adds considerably to our knowledge of this species.

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REFERENCES

BARDET N., BARBIN V., LAURAIN M. & JANIN M.-C. 1997. Première découverte du mosasaure *Prognathodon giganteus* (Squamata) dans le Campanien (Crétacé supérieur) de Champagne, France. Rev. Paléobiol., 16, pp. 225-230.

CHRISTENSEN W.K. 1996. A review of the Upper Campanian and Maastrichtian belemnite biostratigraphy of Europe. Cret. Res., 17, pp. 751-766.

CHRISTENSEN W.K. 1997 a. The Late Cretaceous belemnite family Belemnitellidae: Taxonomy and evolutionary history. Bull. geol. Soc. Denmark, 44, pp. 59-88.

CHRISTENSEN W.K. 1997b. Palaeobiogeography and migration in the Late Cretaceous belemnite family Belemnitellidae. Acta palaeont. pol., 42, pp. 457-495.

COPE E.D. 1871. Supplement to the 'Synopsis of the extinct Batrachia and Reptilia of North America'. Proc. Am. philos. Soc., 12, pp. 41-52.

GALLAGHER W.B. 1993. The Cretaceous/Tertiary Mass Extinction Event in the Northern Atlantic Coastal Plain. The Mosasaur, 5, pp. 75-154.

JAGT J.W.M., KUYPERS M.M.M. & Peeters, H.H.G. 1995. Mosasauriers in het Natuurhistorisch Museum Maastricht opnieuw onder de loep genomen. Natuurhist. Maandbl., 84, pp. 47-59.

JAGT J.W.M., DORTANGS R.W. & MULDER, E.W.A. 2000. First appearance of the mosasaur *Carinodens belgicus* (Woodward, 1891) in the type Maastrichtian. *In*: 5th European Workshop on Vertebrate Palaeontology, Karlsruhe, 27.06-01.07.2000, Program, Abstracts, Excursion guides, p. 37.

KENNEDY W.J., JOHNSON R.O. & COBBAN W.A. 1995. Upper Cretaceous Ammonite Faunas of New Jersey. *In*: BAKER, J.E.B. (ed.). Proceedings of a symposium, field trips and teacher workshop on the topic Contributions to the Paleontology of New Jersey. Geol. Assoc. New Jersey, 12, pp. 24-55.

KUYPERS M.M.M., JAGT J.W.M., PEETERS H.H.G., DE GRAAF D.T., DORTANGS R.W., DECKERS M.J.M., EYSERMANS D., JANSSEN M.J. & ARPOT L. 1998. Laat-kretaceische mosasauriers uit Luik-Limburg: nieuwe vondsten leiden tot nieuwe inzichten. Publ. Natuurhist. Gen. Limburg, 43, pp. 5-47.

LINGHAM-SOLIAR T. 1993. The mosasaur *Leiodon* bares its teeth. Modern Geol., 18, pp. 443-458.

LINGHAM-SOLIAR T. 1995. Anatomy and functional morphology of the largest marine Upper Cretaceous reptile known, *Mosasaurus hoffmanni* (Mosasauridae, Reptilia) from the Upper Cretaceous, Maastrichtian of The Netherlands. Phil. Trans. r. Soc. London, B347, pp. 155-180.

LINGHAM-SOLIAR T. and NOLF, D. 1989. The mosasaur *Prognathodon* (Reptilia, Mosasauridae) from the Upper Cretaceous of Belgium. Bull. Inst. r. Sci. nat. Belg., Sci. Terre, 59, pp. 137-190, pls 1-7.

MEIJER A.W.F. 1980. Voorlopige mededeling over het voorkomen van een kleine mosasaurier met zijdelings afgeplatte tanden in Limburgse Krijtafzettingen. Natuurhist. Maandbl., 69, pp. 157-159.

MULDER E.W.A. 1998. Thoracosaurine vertebrae (Crocodylia; Crocodylidae) from the Maastrichtian type area. Proc. Kon. Ned. Akad. Wet., 100 (1997), pp. 161-170.

MULDER E.W.A. 1999. Transatlantic latest Cretaceous mosasaurs (Reptilia, Lacertilia) from the Maastrichtian type area and New Jersey. *In*: JAGT J.W.M., LAMBERS P.H., MULDER E.W.A. and SCHULP A.S. (eds). Proceedings of the Third European Workshop on Vertebrate Palaeontology, Maastricht, 6-9 May 1998. Geol. Mijnbouw, 78, pp. 281-300.

MULDER E.W.A., BARDET N., GODEFROIT P. & JAGT J.W.M., 2000. Elasmosaur remains from the Maastrichtian type area and a review of Maastrichtian plesiosaurs. Bull. Inst. r. Sci. nat. Belg., Sci. Terre (in press).

MULDER E.W.A., JAGT J.W.M., KUYPERS M.M.M., PEETERS H.H.G. & ROMPEN P. 1998. Preliminary observations on the stratigraphic distribution of Late Cretaceous marine and terrestrial reptiles from the Maastrichtian type area (SE Netherlands, NE Belgium). Oryctos, 1, pp. 55-64.

RUSSELL, D.A. 1967. Systematics and Morphology of American Mosasaurs (Reptilia, Sauria). Bull. Peabody Mus. nat. Hist., 23, vii + 241 pp.

WEISHAMPEL D.B., MULDER E.W.A., JAGT J.W.M., JIANU C.-M., DORTANGS R.W., KUYPERS M.M.M., PEETERS H.H.G. and SCHULP A.S. 1999. Dinosaur remains in the type Maastrichtian: An update. *In*: JAGT J.W.M., LAMBERS P.H., MULDER, E.W.A. & SCHULP, A.S. (eds). Proceedings of the Third European Workshop on Vertebrate Palaeontology, Maastricht, 6-9 May 1998. Geol. Mijnbouw, 78, pp. 357-365.

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Captions

Fig. 1: Southern Limburg (The Netherlands) and contiguous areas, with location of quarries referred to in the text: 1 - ENCI-Maastricht BV; 2 - Marnebel quarry complex; 3 - CBR-Romontbos.

Fig. 2: Lithostratigraphy and belemnite zonation of the uppermost Gulpen Formation (Lanaye Member) and Maastricht Formation.

Fig. 3: A fragmentary jaw with single tooth and tooth socket, AMNH 1401 (ex Cope Collection); the surviving portion of type material of Leiodon sectorius (Cope, 1871), Burlington Co., New Jersey (USA), Maastrichtian, previously illustrated by Russell (1967, text-fig. 82). Scale bar equals 50 mm.

Fig. 4A-G: Leiodon sectorius, fragments of right dentary (A-C: lengths 270 mm and 300 mm, respectively) and isolated teeth (D-G: heights 100 mm and 88 mm, respectively); Marnebel quarry complex, Eben Emael-Bassenge; Gulpen Formation, Lanaye Member (NHMM LV 150).

Fig. 5A, B: Three cervical vertebrae of a subadult (?) individual of *Mosasaurus hoffmanni*, with associated peduncles (length of largest vertebra 70 mm). Note the pristine state of preservation of anterior and posterior zygapophyses; CBR-Romontbos quarry; Maastricht Formation, Valkenburg Member (Dortangs Collection).

Fig. 6: Two small teeth of *Mosasaurus hoffmanni* (height of larger specimen 75 mm); CBR-Romontbos quarry; Maastricht Formation, Emael Member (Dortangs Collection).

Fig. 7: (Posterior?) dorsal vertebrae of a ?mosasaurine (?Globidensini) in matrix; ENCI-Maastricht BV quarry; Gulpen Formation, Lanaye Member (NHMM 1998141, leg. R. Dortangs).

Fig. 8A, B: Isolated teeth and dorsal/pygal vertebrae of Plioplatecarpus marshi; height of largest tooth 40 mm, width of largest vertebra 60 mm; CBR-Romontbos quarry; Maastricht Formation, Valkenburg Member (Dortangs Collection).

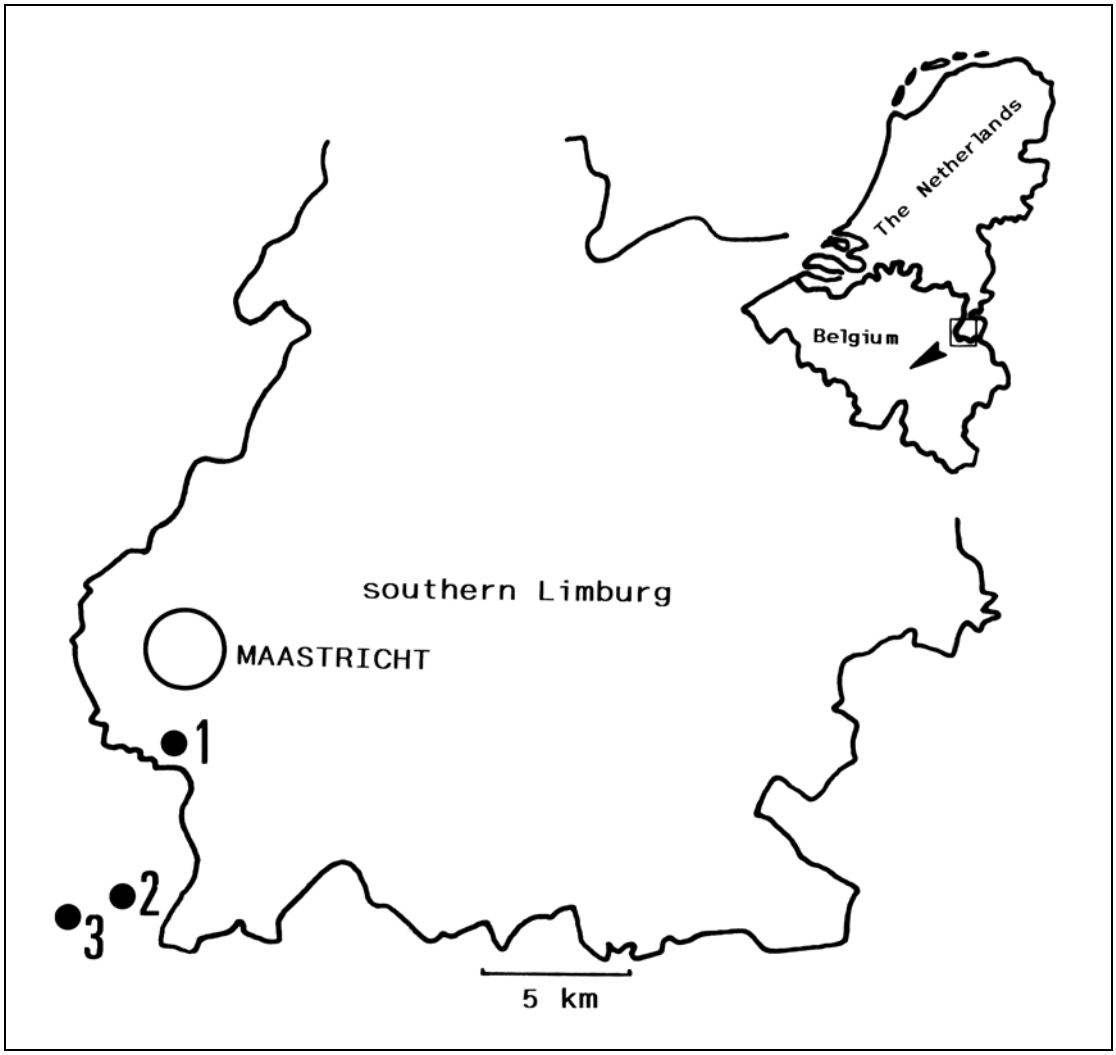

Fig. 1

MAASTRICHT Formation	Meerssen Member	*Belemnella kazimiroviensis* Zone
	Nekum Member	
	Emael Member	
	Schiepersberg Member	*Belemnitella junior* Zone
	Gronsveld Member	
	Valkenburg Member	
GULPEN Formation (*pars*)	Lanaye Member	

Fig. 2

Fig. 3

Fig. 4 A

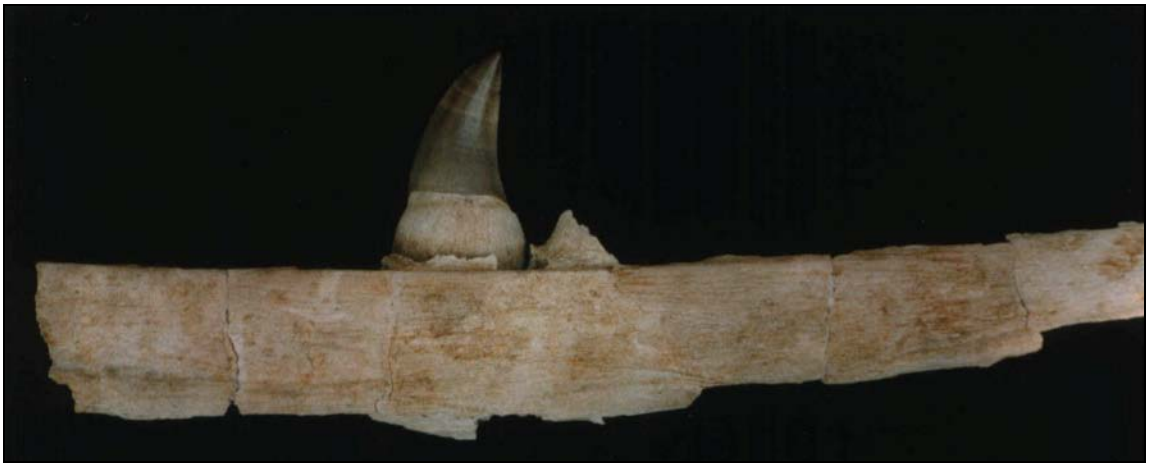

Fig. 4 B

Fig. 4 C

Fig. 4 D

Fig. 4 E

Fig. 4 F

Fig. 4 G

Fig. 5 A

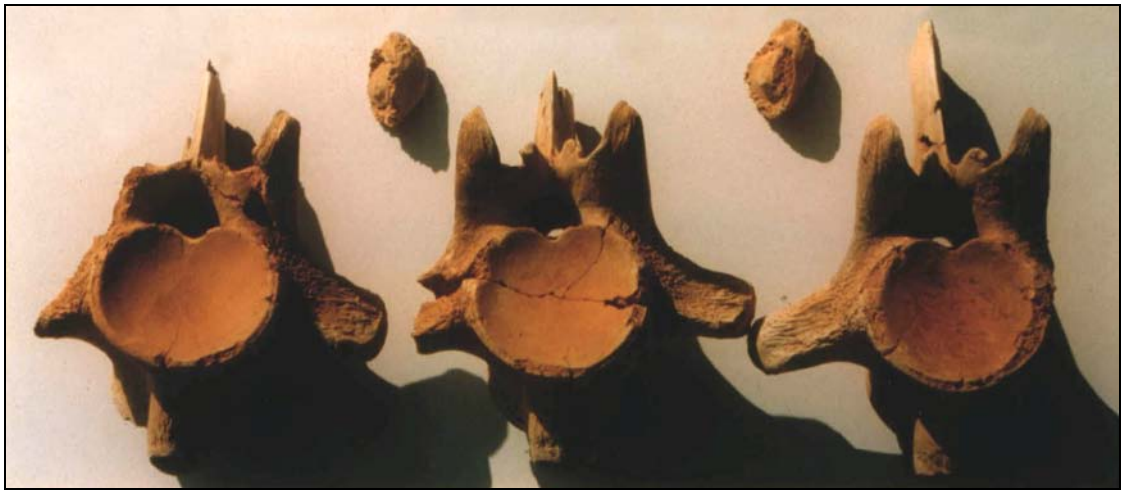

Fig. 5 B

Fig. 6

Fig. 7

Fig. 8 A

Fig. 8 B