

Episkeletozoans and bioerosional ichnotaxa on isolated bones of Late Cretaceous mosasaurs and cheloniid turtles from the Maastricht area, the Netherlands

John W.M. Jagt^{1*}, Mart J.M. Deckers², Magda De Leebeeck³,
Stephen K. Donovan⁴, Eric Nieuwenhuis⁵

¹Natuurhistorisch Museum Maastricht, de Bosquetplein 6-7, 6211 KJ Maastricht, the Netherlands

²Industriestraat 21, 5931 PG Tegelen, the Netherlands

³Guldensporenlaan 19, 3120 Tremelo, Belgium

⁴Naturalis Biodiversity Center, Taxonomy and Systematics Group, Postbus 9517, 2300 RA Leiden, the Netherlands

⁵Hub. Ortmanstraat 4, 6286 EA Partij-Wittem, the Netherlands

*corresponding author, e-mail: john.jagt@maastricht.nl

Abstract

Isolated bones of three taxa of marine reptiles (*Mosasaurus hoffmannii* Mantell, *Plioplatecarpus marshi* Dollo and *Allopleuron hofmanni* (Gray)) from various levels within the Maastricht Formation (upper Maastrichtian) at the former ENCI-HeidelbergCement Group quarry (Maastricht, the Netherlands) exhibit bioerosional traces and encrustation. Episkeletozoans include dimyid, ostreid and monopleurid bivalves, at least three species of cheilostome and cyclostome bryozoans and two adnate calcareous foraminifera. The bones show biting traces (*Gnathichnus pentax* Bromley, *Linichnus* cf. *serratus* Jacobsen & Bromley and *Machichnus* isp.), as well as borings. The latter may be referred to *Karethraichnus lakkos* Zonneveld, Bartels, Gunnell & McHugh, which is here considered to be a junior synonym of *Gastrochaenolites* isp.

Key words: Reptiles, epizoans, dentalites, Maastrichtian, northwest Europe

1. Introduction

In general, associated skeletal elements of mosasaurid squamates are rare, but isolated teeth, tooth crowns and elements of post-cranial skeletons have proved to be fairly common at some levels within the Gulpen and Maastricht formations in the type area of the Maastrichtian Stage (Fig. 1), of latest Cretaceous (c. 68.3–66.2 Ma) age (see Keutgen, 2018). The same holds true for chelonioid turtles, the commonest representative in the area being *Allopleuron hofmanni* (Gray, 1831). In recent years, isolated

skeletal elements of these reptilian taxa have been shown to exhibit fouling by episkeletozoans (*sensu* Taylor & Wilson, 2002; see also Taylor & Wilson, 2003) and/or boreholes, pits of commensals(?) and biting traces of predators and scavengers (dentalites; *sensu* Hunt & Lucas, 2019). A number of examples are here briefly discussed and illustrated in the hope that more material will be forthcoming when a detailed search for these episkeletozoans and bioerosional traces is conducted in museum, university and private collections. Most of the material described here is contained in the collections of the

Natuurhistorisch Museum Maastricht (abbreviation: NHMM) or will be transferred here shortly.

During the past few decades, numerous papers on ichnofossils (burrows and bioerosional traces) have appeared in print, all stressing their importance for interpretations of palaeoenvironments, interactions between organisms and substrates, ichnodisparity and the need for a uniform ichnotaxonomy (e.g., Santos & Mayoral, 2006; Glaub et al., 2007; Hasiotis et al., 2007; Wilson, 2007; Buatois & Mángano, 2011; Buatois et al., 2017). Bioerosional traces on bony material include scratches, grooves and puncture marks, reflecting either predation or scavenging, or both. Such traces have received ample attention in the literature (Schwimmer et al., 1997; Avilla et al., 2004; Mikuláš et al., 2006; Pobiner, 2008; Jacobsen & Bromley, 2009; Noto et al., 2012; Janssen et al., 2013; Pirrone et al., 2014; Zonneveld et al., 2016; Godfrey et al., 2018; Neumann & Hampel, 2018; Hunt & Lucas, 2019; Wisshak et al., 2019 and de Valais et al., 2020). Broadly comparable biting traces have also been described from abiotic

substrates and other ichnotaxa (Chumakov et al., 2013; Collareta et al., 2019).

From these papers it appears that ichnotaxonomy is still a moot point where such biting traces are involved, a fact which is illustrated in a paper by Jacobsen & Bromley (2009). In their discussion of tooth impressions on bones in general, Jacobsen & Bromley (2009, p. 373) rightly observed that, 'Using similar ichnological terminology for both theropod and mammalian feeding traces, and even those of selachian sharks preying on whales or scavenging their corpses, will help coordinate biting strategies, jaw mechanism and feeding behaviour for both recent and ancient carnivores and scavengers'. However, the same authors (Jacobsen & Bromley, 2009, p. 375) also noted that, '[...] the vast majority of biting trace fossils that [have] no inherent characteristics for the basis of ichnotaxonomic treatment. Random biting angles and biting strength on varying bone substrates offer a wealth of structures that show no coherent morphology'. In short, there will always be a measure of uncertainty in assign-

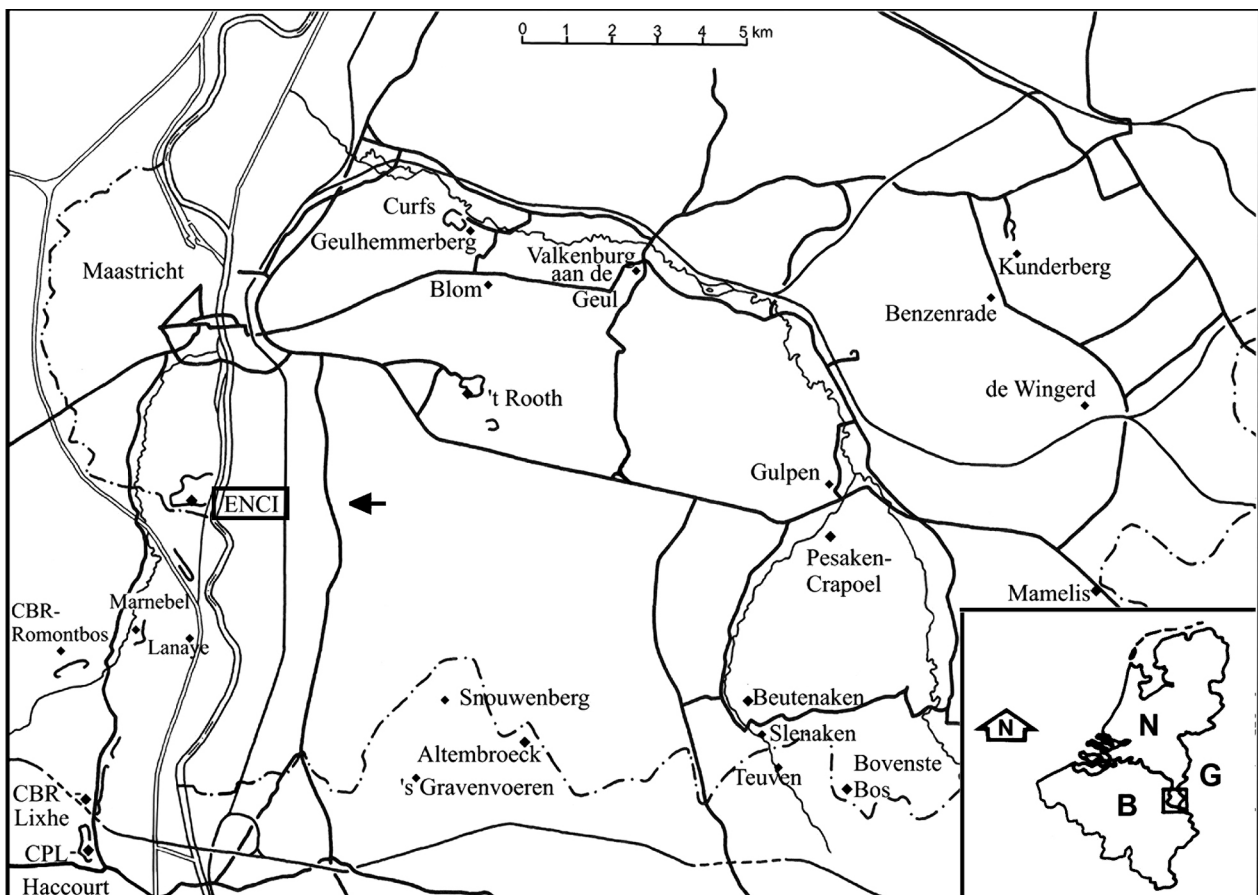


Fig. 1. Schematic map of southern Limburg (the Netherlands - see inset: N, the Netherlands; B, Belgium; G, Germany), showing the location of the former ENCI quarry (Sint-Pietersberg, south of Maastricht), as well as principal localities (natural exposures, outcrops, working and disused quarries) at which Upper Cretaceous and lower Paleogene siliciclastics and carbonates are exposed

ing biting traces, puncture traces or punch holes to particular ichnofossil taxa. Despite this drawback, Jacobsen & Bromley (2009) erected two new ichnogenera and ichnospecies to accommodate such traces on bony substrates.

With regard to biting traces in bones from the Maastrichtian type area (southeast Netherlands, northeast Belgium; Fig. 1), only very examples have been recorded in the literature. Traces illustrated by Bardet et al. (1998), occurring on the neural arch of a dorsal vertebra of the mosasaur *Plioplatecarpus marshi* would be best referred to *Linichnus* cf. *serratus*, although serrations are not really apparent. Those authors suggested a squalid shark to have produced these biting traces during scavenging on the carcass. There is a wide range of shark and ray taxa in the Maastrichtian type area (see, for example, Herman, 1977), reflecting various tooth types (serrated and unserrated). This also means that we are far from understanding what type of traces are produced by what type of shark or ray when they feed on live (predation) or dead prey (scavenging) (compare Pobiner, 2008). Biting experiments, using genuine teeth, are called for to try and document such traces.

In their description of the type specimen of the mosasaur *Prognathodon saturator* (NHMM 1998 141), Dortangs et al. (2002) noted a few episkeletozoans (bivalves and serpulid worms) on skull bones that provided the most elevated point of attachment of the skull when this was lying left side up in the 'soupy', fine-grained, biocalcarenic substrate. A few scratches, of a type comparable to the one described below ('Specimen 4'), were also noted on the posterior margin of the pterygoid.

Janssen et al. (2013) documented various bioerosional traces on carapace elements of *Allopleuron hofmanni*, including radular traces of gastropods (ichnogenus *Radulichnus* Voigt, 1977), and pit-like and circular lesions of various types. One of these types (Janssen et al., 2013, figs. 3–5) may well be assigned to *Karethraichnus lakkos* Zonneveld, Bartels, Gunnell & McHugh, 2016. The ichnogenus *Karethraichnus* was diagnosed as follows, 'Circular or subcircular holes bored into a bone substrate. Holes may penetrate fully though [*sic*] the substrate or terminate within the bone. Penetrative holes may have straight or convex vertical margins. Non-penetrative pits terminate within the substrate as a shallow, bowl-shaped pit or as a deeper shaft with a rounded, blunt, or pointed terminus.' (Zonneveld et al., 2016, p. 5). The size range indicated by those authors was '0.5 to 8.0 mm with 1 to 5 mm being typical'. It should be noted that they specifically referred to the nature of the substrate (i.e., bone)

when comparing this new ichnogenus to similar ones. The type ichnospecies, *K. lakkos*, was defined as follows, 'Shallow (non-penetrating) *Karethraichnus* having a simple hemispherical profile with a rounded or flattened hemispherical terminus.' (Zonneveld et al., 2016, p. 6). Wisshak et al. (2019, pp. 20, 24) considered *K. kulindros* Zonneveld, Bartels, Gunnell & McHugh, 2016 to be synonymous. We concur, but also wish to go one step further and point out that, as we see it, the original examples of *Karethraichnus* illustrated by Zonneveld et al. (2016) are nothing more than incomplete examples of *Gastrochaenolites* isp.

The 'multiple shallow lesions' in carapace material of *Allopleuron hofmanni* that were described and illustrated by Janssen et al. (2013, p. 154, fig. 2) are comparable in overall form to the 'score marks' in Cenomanian turtles from Texas recorded by Noto et al. (2012, fig. 4A, B).

2. Stratigraphy

At the former ENCI-HeidelbergCement Group quarry (Fig. 1), the lower and middle portions of the Maastricht Formation (Valkenburg, Gronsveld, Schiepersberg and Emael members) are well exposed. A level of generally coarse-grained fossil hash (directly overlying the Lichtenberg Horizon) separates the Gulpen and Maastricht formations and comparable levels are known from the base of the Gronsveld and Emael members. The Valkenburg Member is a poorly indurated, white yellowish to yellowish grey, fine- to coarse-grained biocalcarenic, with greyish brown flint nodules of varying sizes. The overlying Gronsveld Member consists of poorly indurated, white yellowish to yellowish grey, fine- to coarse-grained biocalcarenic, with small, light to dark greyish brown flint nodules of varying sizes and shapes occurring in the lower part. In the higher portion they are arranged in more or less regular beds of light-grey to greyish blue nodules. The Emael Member is a slightly more coarse-grained biocalcarenic unit, with increased macrofossil content.

Based on the most recent cyclostratigraphical and chronostratigraphical age models for the type Maastrichtian (Keutgen, 2018), the base of the Valkenburg Member (Lichtenberg Horizon) can be dated as 66.8 Ma, and the base of the overlying Gronsveld Member as 66.7 Ma. The Lichtenberg Horizon represents the early stages of a transgression from a relative lowstand during a phase of tectonic inversion, whereas the overlying Gronsveld Member represents a relative highstand during tectonic re-

laxation, with the maximum flooding surface situated around the middle of this unit.

The lower part of the Maastricht Formation has been considered to represent a gravelly intrabiomicrosparite, with regional currents that were constant enough to displace sediment particles horizontally over the entire platform, at depths of 20 to 40 metres and free from oceanic influence. Sediment reworking led to homogenisation over depths of a few decimetres, resulting in a relatively firm sea floor and clear waters. This setting has been interpreted as middle sublittoral, with subtropical temperatures and seagrass communities.

The entire Maastricht Formation is of late Maastrichtian age, as demonstrated on the basis of coleoid cephalopods and bivalves (Christensen et al., 2005; Keutgen et al., 2017; Jagt & Jagt-Yazykova, 2018).

3. Description of material

3.1. Specimen 1

Material – A cervical vertebra (Fig. 2), with a reniform distal condyle, lacking peduncle, neural arch and spine, zygapophyses and one synapophyse. It is ascribed to a small-sized, piscivorous mosasaur species, the plioplatecarpine *Plioplatecarpus marshi* Dollo, 1882 (see also Lingham-Soliar, 1994). The preservation of the bone is very good, both at the surface and internally (Fig. 2a, b).

Occurrence – Former ENCI-HeidelbergCement Group quarry (Maastricht, the Netherlands); Maastricht Formation, base of Gronsveld Member.

Description – There are only few episkeletozoans on this vertebra; both surfaces of the right synapophysis show thin-shelled bivalves (Fig. 2a, b). On the centrum, halfway between peduncular base and synapophysis, two small colonies of cheilostome bryozoans are seen. In one of these there are no frontal walls, the other retains a few.

Discussion – On account of the near-pristine quality of the bony material and the limited number and low diversity of episkeletozoans, this vertebra is interpreted to have been available for fouling on the sea floor for a short time only, implying comparatively rapid burial after elements of this skeleton had been dispersed. At the site, there was no other bone associated with this vertebra, which suggests that the present specimen was carried away from a decomposing carcass, either by currents or by a scavenger. The thin-shelled bivalves lack any vesicular shell structure, ruling out identification as the pycnodonteine oyster *Pycnodonte vesicularis* (Lamarck,

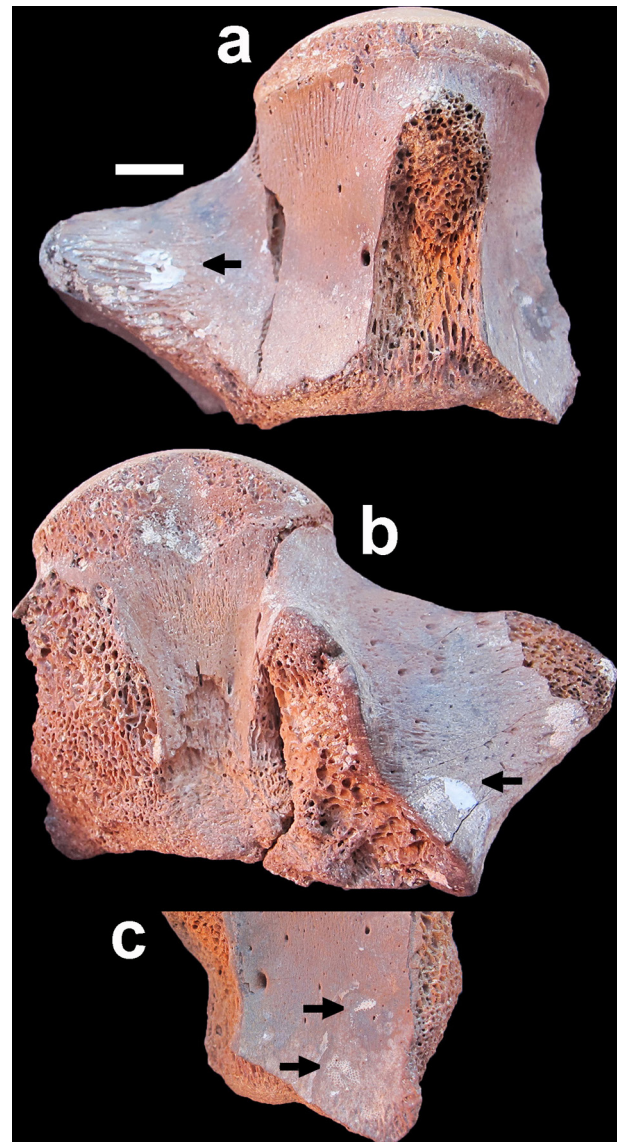


Fig. 2. Cervical vertebra (NHMM JJ 11964) of *Plioplatecarpus marshi* Dollo, 1882, in ventral (a) and dorsal (b) aspects, and detail of the lower right-hand surface of the centrum shown in ventral (c) view. Two indeterminate oysters (arrows in Figure 2a, b) are visible on the synapophysis; two cheilostome bryozoan colonies (arrows in Fig. 2c) foul the area between the bases of the peduncle and the synapophysis. Scale bar equals 10 mm

1806). In addition, the shell is too thin and lustrous to be assignable to *Atreta nilssonii* (von Hagenow, 1842), a dimyid (*sensu* Waller, 2012). For the time being, we consider these to be indeterminate oysters.

3.2. Specimen 2

Material – A large, ill-preserved vertebral centrum (Fig. 3), showing signs of abrasion, corrosion and

decortication. Proportions suggest this to be a dorsal vertebra of the mosasaurine *Mosasaurus hoffmannii* Mantell, 1829, the largest mosasaur species in the area (see Lingham-Soliar, 1995; Grigoriev, 2013; Street & Caldwell, 2016).

Occurrence – Former ENCI-HeidelbergCement Group quarry (Maastricht, the Netherlands); Maastricht Formation, base of Valkenburg Member.

Description – Episkeletozoans and bioerosional traces on the various surfaces of this centrum comprise bivalves, worms, bryozoans, foraminifera and scraping traces of the lantern of regular echinoids. Bivalves include *Atreta nilssoni* (= *Ostrea podopsidea* Nyst, in Thielens, 1872; Fig. 3a, e), cheilostome bryozoan taxa (Fig. 3a, b, e), two gryphaeid oysters

(i.e., the pycnodonteine *Pycnodonte vesicularis* [Fig. 3a] and indeterminate juvenile exogyrines [Fig. 3c–e]) and the monopleurid *Gyropleura* ex gr. *inequirostrata* (Woodward, 1833) (Fig. 3c). Bryozoans are variably sized colonies of indeterminate cheilostomes on all surfaces, while the single adnate worm tube is assignable to the sabellid genus *Glomerula* Brünnich Nielsen, 1931 (see Jäger, 2005). Attached foraminifera include a single specimen of *Planorbulinella cretae* (Marsson, 1878) (see Hofker, 1966) and an indeterminate form. Only a single bioerosional trace, *Gnathichnus pentax* Bromley, 1975, has been recognised on this centrum.

Discussion – Signs of abrasion, corrosion and decortication are the result of prolonged exposure on

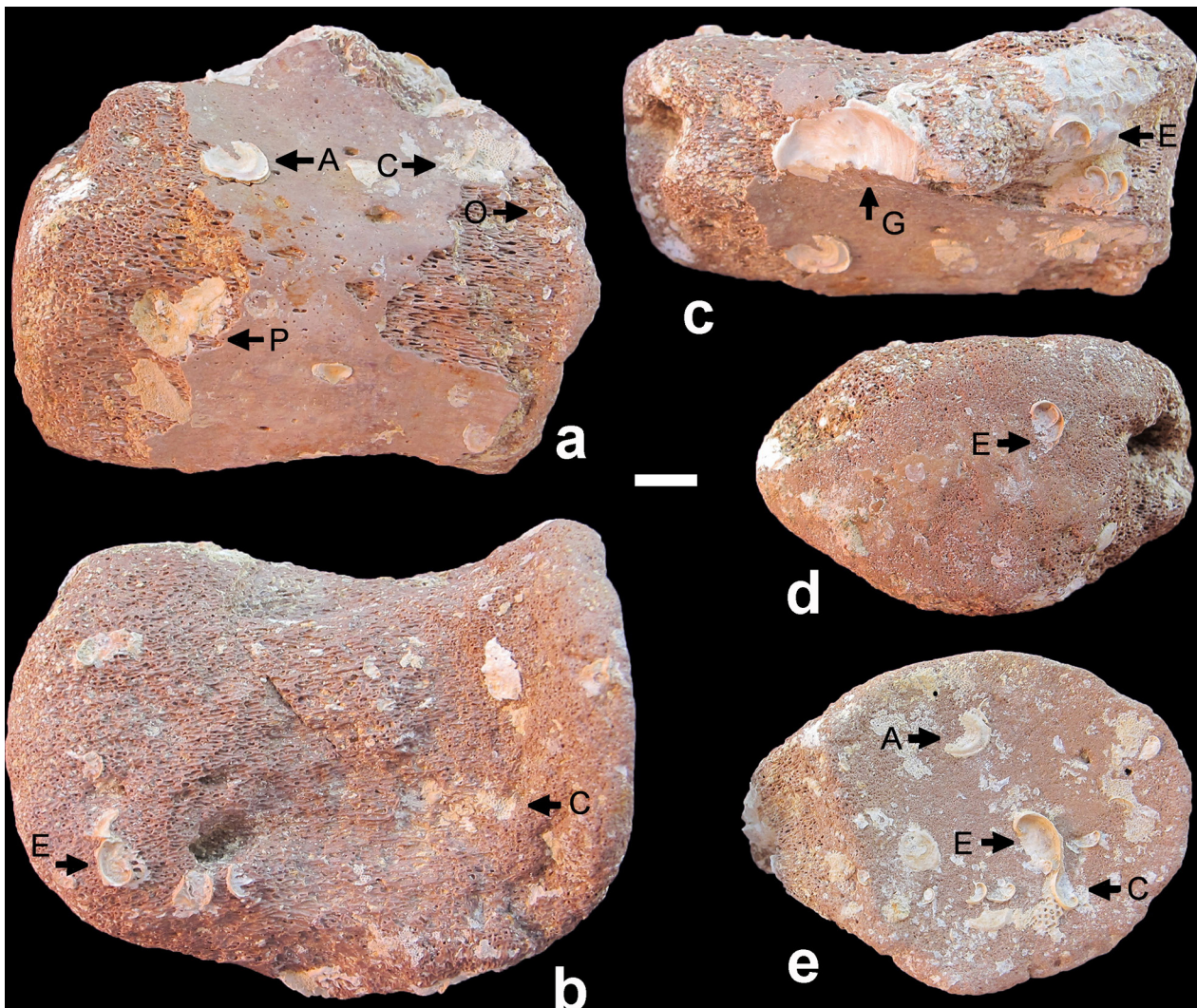


Fig. 3. Dorsal vertebra (NHMM MD 5256.01), probably of *Mosasaurus hoffmannii* Mantell, 1829, in ventral (a), dorsal (b), lateral (c), posterior (d) and anterior (e) views. Episkeletozoans and bioerosional traces (arrowed) include the following: *Pycnodonte vesicularis* (P; 4 specimens), *Gnathichnus pentax* (1 specimen), *Atreta nilssoni* (A; 7 specimens), cheilostome bryozoans (C; >20 specimens), juvenile exogyrine oysters (E; >40 specimens), *Glomerula* sp. (1 specimen), *Gyropleura* ex gr. *inequirostrata* (G; 1 specimen), juvenile oysters (O; >10 specimens), adnate foraminifera (1 specimen). Scale bar equals 10 mm

the sea floor and reworking; thus, there was ample time for attachment and growth of episkeletozoans. The monopleurid bivalve *Gyropleura* ex gr. *inequirostrata* (Fig. 3c) is of the finely ribbed variety that Abdel-Gawad (1986) distinguished from *G. cipllyana* (de Ryckholt, 1851); in general, species of this genus are in need of a modern revision (compare also Holzapfel, 1889). The association with other, non-adnate taxa is more or less accidental, since these became taphonomically lodged between the cellular structure of the bony material. For instance, there are columnal and brachial ossicles of the bourgueticrinid crinoid *Dunnocrinus aequalis* (d'Orbigny, 1841) (see Jagt et al., 1998; Jagt, 1999), and a single valve of the craniid brachiopod *Danocrania hagenowi* (Davidson, 1853), which is a typical form at this particular level (Krutzler, 1969; Jagt & Donovan, 2016). In addition, the faecal pellet ichnofossil taxon *Coprulus maastrichtensis* van Amerom, 1971 is represented. On account of the heavily worn nature of

this centrum, and the rich and diverse episkeletozoan assemblages, this vertebra is interpreted to have been available for fouling on the sea floor for an extensive period of time.

3.3. Specimen 3

Material - A dorsal vertebra, of mediocre preservation (Fig. 4), apparently is conspecific with specimen 2 (see above).

Occurrence - Former ENCI-HeidelbergCement Group quarry (Maastricht, the Netherlands); Maastricht Formation, base of Valkenburg Member.

Description - Articular surfaces are relatively well preserved and show on the distal side (condyle) typical scratches in a regular pattern (Fig. 4c, d). Many, partially overlapping, stellate scratches are seen. The other articular surface (cotyle; Fig. 4b) reveals the contorted calcareous tube of a sabellid

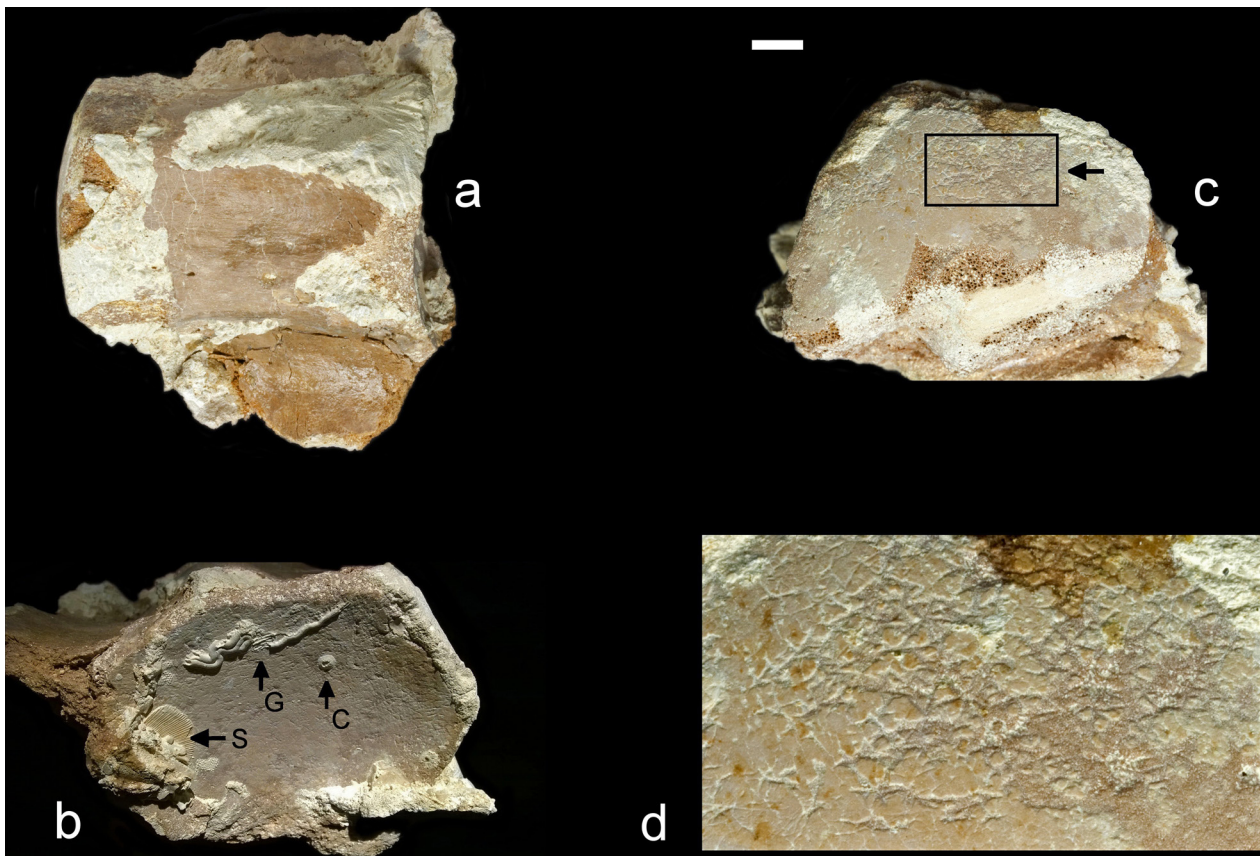


Fig. 4. Dorsal vertebra (NHMM 2019 003, leg. M. De Leebeeck), probably of *Mosasaurus hoffmannii* Mantell, 1829, in ventral (a), anterior (b) and posterior (c) views (photographs: J.W. Stroucken). The condylar surface (c) reveals close-set *Gnathichnus pentax*, while the other articular surface (cotyle, b) has the contorted calcareous tube of a sabellid worm, *Glomerula lombricus* (arrow G; see Jäger, 2005), a partial valve of an indeterminate spondylid bivalve (arrow S), two small colonies of cheilostome bryozoans and a *Lichenopora*-like cyclostome bryozoan (arrow C). In addition, there are numerous examples of *Gnathichnus pentax*, some isolated, other partially overlapping (see detail [box, d] of Fig. 4c). Scale bar equals 10 mm

worm, *Glomerula lombricus* (DeFrance, 1827) (Fig. 4b; see Jäger, 2005), a partial valve of an indeterminate spondylid bivalve, two small colonies of cheilostome bryozoans and a *Lichenopora*-like cyclostome, as well as *Gnathichnus pentax*.

Discussion – The stellate scratches represent the ichnotaxon *Gnathichnus pentax* Bromley, 1975, which is produced by the repetitive scraping action of the teeth in the lantern of regular echinoids on algae-covered biotic and abiotic substrates. Members of the families Cidaridae, Saleniidae and Phymosomatidae are common in the Upper Cretaceous of Liège-Limburg (Jagt, 2000). In view of the relatively shallow depth of deposition of these strata (Keutgen, 2018), there must have been ample opportunities for algal growth and consequent echinoid browsing.

On account of mediocre preservation of this centrum and low-diversity episkeletozoan fouling, this vertebra is interpreted to have been available for fouling for a limited period of time. The fairly good preservation of the bone suggests it resided on the sea floor for a shorter time than Specimen 2, but for longer than Specimen 1.

3.4. Specimen 4

Material – A set of associated bones of skull and post-cranial skeleton (NHMM 2012 073) of the mosasaur *Plioplatecarpus marshi* Dollo, 1882, nicknamed ‘Kristine’, includes a number of fragmentary ribs, one of which shows biting traces.

Occurrence – Former ENCI-HeidelbergCement Group quarry (Maastricht, the Netherlands); Maastricht Formation, upper part of Emael Member.

Description – One rib fragment reveals two sets of partially overlapping traces; one comprises five near-parallel scratches oblique to the long axis of

the bone and the other a single, longer scratch with an opposite trend. Depth, width and length of individual scratches vary, suggesting a multicuspated dentition, with teeth arranged in consecutive rows. In transverse section, the scratches are faintly V-shaped and at their margins coarse serrations can be noted.

Discussion – The ichnotaxon *Linichnus serratus* Jacobsen & Bromley, 2009 (p. 376) was diagnosed as, ‘Single elongate groove of biogenic origin on skeletal material (e.g., bones, teeth). The groove, U- or V-shaped in transverse section, may only affect the surface of the bone, or bone-fibres may be cut through, recurved or broken with the groove. The groove has a serrated morphology.’ The ichnotaxon was linked to theropod dinosaurs with serrated teeth (see also Noto et al., 2012). With the exception of not being ‘single’, the biting traces in NHMM 2012 073 correspond to this, but because traces of tooth serration are not sharply defined and clearly symmetrical in the latter, we refer to it as *Linichnus* cf. *serratus*. However, Jacobsen & Bromley (2009, fig. 5) also illustrated ‘groupings’ of *L. serratus*; these are closely similar to what is seen here (Fig. 5).

The same authors also illustrated (Jacobsen & Bromley, 2009, fig. 6) tooth scraping by sharks, which have multicuspated dentitions with teeth arranged in consecutive files, on ribs of a mosasaur from the Niobrara Formation (Campanian) of Kansas (USA), under the name of *Knethichnus parallelum* Jacobsen & Bromley, 2009 [emended to *K. parallelus* by Wisshak et al., 2019, p. 27]. Only sharks with serrated teeth, such as anacoracids, could have produced such traces (Schwimmer et al., 1997). In the Maastrichtian type area, the anacoracid *Squalicorax pristodontus* (Agassiz, 1843) is common (see Herman, 1977), but traces such as *K. parallelus* have not (yet) been recognised.



Fig. 5. Fragmentary rib (NHMM 2012 073) of *Plioplatecarpus marshi* Dollo, 1882 with *Linichnus* cf. *serratus* Jacobsen & Bromley, 2009 (photograph: D. Cornelissen). Scale bar equals 30 mm

3.5. Specimen 5

Material – A few associated peripheral carapace bones (2nd to 5th) of a cheloniid turtle (Fig. 6), assigned to the commonest taxon in the type area of the Maastrichtian Stage, *Allopleuron hofmanni*.

Occurrence – Former ENCI-HeidelbergCement Group quarry (Maastricht); Maastricht Formation, lower part of Gronsvelt Member.

Description – On the 4th peripheral, several long, slightly curved and close-set ('lined'; see Pirrone et al., 2014, fig. 3) scratches are seen; these run almost parallel to the outer margin. Individual scratches are fairly shallow and have a U- to V-shaped base; some overlap partially and then split up again.



Fig. 6. *Allopleuron hofmanni* (Gray, 1831) (NHMM EN 92s; see Nieuwenhuis, 2017), right-hand side second to fifth peripherals, with scratches (detailed view) assigned, albeit provisionally, to the ichnogenus *Machichnus* Mikuláš, Kadlecová, Fejfar & Dvořák, 2006 (photographs: E. Nieuwenhuis). Scale bars equal 100 mm

Discussion – The close proximity of the scratches would suggest a dentition of long, pointed, close-set teeth that merely scraped the surface, but did not puncture it. The shallowest of these scratches might denote the place where the teeth were first applied to the bone surface and where they were later taken off, in a single(?) bite. Possibly, enchondontid fish, common in the Maastrichtian type area (Friedman, 2012), could have produced such traces. In overall structure, there is a certain resemblance of traces illustrated here (Fig. 6) with those referred to the ichnogenus *Machichnus* Mikuláš, Kadlecová, Fejfar & Dvořák, 2006, which was diagnosed as follows, 'Shallow serial parallel or subparallel grooves in hard substrates. The groove surface is smooth or longitudinally striated. Each series consists usually of dozens of grooves which are typically uniform in shape and dimensions. The grooves are oriented perpendicular to substrate edge' (Mikuláš et al., 2006, p. 121). However, traces illustrated here (Fig. 6) are not perpendicular to the bone surface, but rather parallel. Other comparable examples of close-set scratches on bone surfaces, like those illustrated by Jagt et al. (2003b, figs. 1, 2) and Janssen et al. (2013, fig. 6), are arranged perpendicularly or obliquely to the bone surface. Thus, none of the ichnospecies of *Machichnus* recognised by Mikuláš et al. (2006) and Chumakov et al. (2013) corresponds fully to the traces illustrated here (Fig. 6), which is why we leave them in open nomenclature.

4. Conclusions

The selected specimens described above illustrate biting traces on skeletal elements of mosasaurs and turtles, inflicted either when those animals were still alive (by predators) or on carcasses (by scavengers), either still floating or already resting on the sea floor. With flesh, muscles and ligaments gone, the bare bones of these vertebrates were used almost exclusively by episkeletozoans.

The examples described are all considered to constitute *post-mortem* traces. Such should not be confused with (sub)lethal injuries and lesions inflicted by predators when their prey was still alive (see, e.g., Avilla et al., 2004; Noto et al., 2012; Bastiaans et al., 2014, 2019, 2020), a fact also stressed by Pirrone et al. (2014, p. 195). The last-named authors also noted that it was important to differentiate between genuine bioerosional structures (that is, those resulting from predation or scavenging) and bioturbation structures in contact with the bone or in the associated substrate. It is not always straightforward (compare Avilla et al., 2004) to differentiate predation

and scavenging traces (ethological class of praedichnia; compare Vallon et al., 2015), but in those cases where scar tissue and/or deformed bone growth is seen, this is clear; these must reflect injury inflicted upon a live animal (compare Pobiner, 2008).

In the Maastrichtian type area, genuine marine 'bonebeds', such as the ones described by Boessenecker et al. (2014), are unknown. Concentrations of teeth, tooth crowns and skeletal elements (vertebrae, ribs) usually indicate time-averaged, current-winnowed occurrences, representing many generations. Of note is the fact that, to date, no bivalve borings in mosasaur or turtle bone have been recorded from the area, despite their common occurrence in other biotic and abiotic substrates (Donovan & Jagt, 2013), including the odd, washed-in dinosaur bone (Jagt et al., 2003a).

The present examples allow the ichnogenera *Linichnus* and *Machichnus* to be added to the rapidly growing list of trace fossils from the Maastrichtian type area; *Gastrochaenolites* (= *Karethraichnus*) has already been recorded on numerous occasions. We hope that the examples illustrated here will stimulate the search for additional material of episkeletozoans and bioerosional traces on bones from the Upper Cretaceous of the study area.

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