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Aspects of clavate borings in the type Maastrichtian (Upper Cretaceous) of the Netherlands and Belgium•

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Abstract

We describe a collection of borings in carbonate and xylic substrates (*Gastrochaenolites* ispp., *Teredolites longissimus* Kelly & Bromley), some of them containing their producers, from the Maastricht and Houthem formations (late Maastrichtian and early Danian) in the type area of the Maastrichtian Stage, but mainly from the ENCI-HeidelbergCement Group quarry, St. Pietersberg (southern Limburg, the Netherlands). Included are specimens of *Gastrochaenolites dijugus* Kelly & Bromley, showing different modes of formation of the figure-of-eight aperture, either as part of the lining, incorporating the substrate or both. *Gastrochaenolites lapidicus* Kelly & Bromley was produced by the gastrochaenid bivalve *Gastrochaena*, whereas *G. orbicularis* Kelly & Bromley is the trace of *Jouannetia supracretacea* (De Ryckholt). Bioglyph-like infills of *G. orbicularis* and *G. torpedo* Kelly & Bromley rather represent external moulds of the producing bivalves; they are termed pseudobioglyphs herein. *Teredolites longissimus* is preserved as clusters of *in situ*, parallel to sub-parallel tubes, although the woody substrate has decayed, and disarticulated fragments of calcareous tubes have been released from rotten wood. The latter include some specimens filled by flint and show good three-dimensional preservation. Some notes on the taxonomy of the producing bivalve taxa are added.

Keywords: Trace fossils, Bivalvia, bioglyph, pseudobioglyph, *Gastrochaenolites*, *Teredolites*

Introduction

Clavate borings are a distinctive feature of the rock record, particularly of the Mesozoic and Cenozoic. They are mainly classified within two ichnogenera that are, in part, defined on substrate: *Teredolites* Leymerie, 1842 (xylic (wood) substrates) and *Gastrochaenolites* Leymerie, 1842 (lithic substrates). Both are produced by boring bivalves, although 'other trace-makers may be involved' (Bromley, 2004, p. 462) in making *Gastrochaenolites*-like structures, such as sipunculan worms (Bromley, 1994, p. 142). Examples of both ichnogenera are locally common in the uppermost Cretaceous and lowermost Paleocene of the Netherlands and Belgium, but well-preserved specimens are rather rare. By 'well-preserved' we mean those specimens that are unusually complete (preserving features such as the neck and aperture, and linings), that retain the producing bivalve or a bioglyph thereof (sensu Bromley, 1996, p. 156), or a combination of these features.

Herein, we present observations on a new collection of *Gastrochaenolites* and *Teredolites* from the type area of the Maastrichtian Stage (Upper Cretaceous; see Fig. 1). Most of these specimens fit at least one of our criteria of 'well preserved'. The identififcation of these clavate borings follows Kelly & Bromley (1984). Our philosophy of open nomenclature follows Bengtson (1988). Specimens are deposited in the Natuurhistorisch Museum Maastricht, Maastricht (NHMM), and at the Museum Het Land van Valkenburg (MLV), Valkenburg aan de Geul, the Netherlands.

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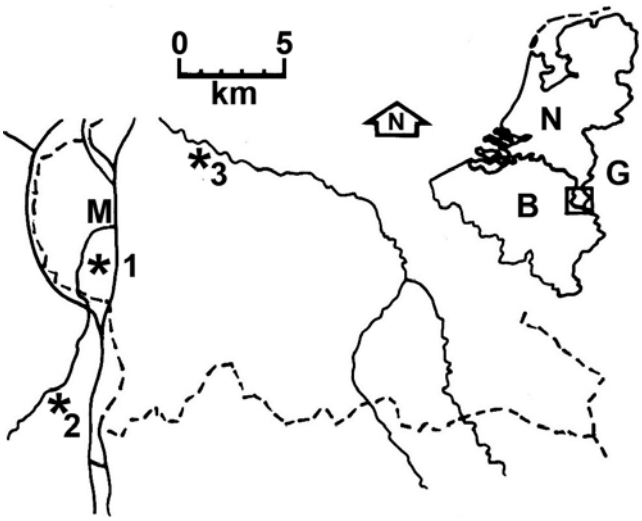

Fig. 1. Outline map of the study area (modified after Donovan & Jagt, 2004, fig. 1; Van der Ham et al., 2011, fig. 1), showing political boundaries (dashed lines), rivers and canals (solid lines), and the city of Maastricht (M). Key: ∗ = locality; 1 = ENCI-HeidelbergCement Group quarry, St. Pietersberg, southern Limburg, the Netherlands; 2 = CBR-Romontbos quarry, Eben Emael, Belgium; 3 = former Ankerpoort-Curfs quarry, Geulhem, southern Limburg, the Netherlands. The insert map of the Netherlands (N), Belgium (B) and Germany (G) shows the approximate position of the main map (box).

Systematic ichnology

Ichnogenus Gastrochaenolites *Leymerie, 1842*

Type ichnospecies

Gastrochaenolites lapidicus Kelly & Bromley, 1984, p. 797, by subsequent designation.

Other ichnospecies

Gastrochaenolites ampullatus Kelly & Bromley, 1984; *Gastrochaenolites anauchen* Wilson & Palmer, 1998; *Gastrochaenolites cluniformis* Kelly & Bromley, 1984; *Gastrochaenolites cor* Bromley & D'Alessandro, 1987; *Gastrochaenolites dijugus* Kelly & Bromley, 1984; *Gastrochaenolites hospitium* Kleemann, 2009; *Gastrochaenolites oelandicus* Ekdale & Bromley, 2001; *Gastrochaenolites orbicularis* Kelly & Bromley, 1984; *Gastrochaenolites ornatus* Kelly & Bromley, 1984; *Gastrochaenolites pickerilli* Donovan, 2002; *Gastrochaenolites torpedo* Kelly & Bromley, 1984; *Gastrochaenolites turbinatus* Kelly & Bromley; 1984, and *Gastrochaenolites vivus* Edinger & Risk, 1994. Note that *G. hospitium* may be a junior synonym of *G. pickerilli* (S.K.D. and D.J. Blissett, research in progress).

Diagnosis

'Clavate borings in lithic substrates. The apertural region of the boring is narrower than the main chamber and may be circular, oval, or dumb-bell shaped. The aperture may be separated from the main chamber by a neck region which in some cases may be widely flared. The main chamber may vary from subspherical to elongate, having a parabolic to rounded truncated base and a circular to oval cross section, modified in some forms by a longitudinal ridge or grooves to produce an almond- or heart-shaped section' (after Kelly & Bromley, 1984, p. 797).

Remarks

Gastrochaenolites borings are excavated principally by endolithic bivalves (such as mytilids and pholadids), but also by Recent coralliophilid gastropods and some sipunculan worms (Bromley, 2004, p. 462). However, direct evidence and informed inference suggests that all of the borings discussed herein are the spoor of boring bivalves.

Gastrochaenolites dijugus *Kelly & Bromley, 1984*

Figs 2A, B, E, 3C.

Material

Four specimens: NHMM JJ 10551a (Fig. 2A, B; two individuals), JJ 13380 (Fig. 3C) and JJ 14571 (Fig. 2E).

Locality and stratigraphy

All specimens are from the ENCI-HeidelbergCement Group quarry, St. Pietersberg (Fig. 1). NHMM JJ 10551a is from the upper Meerssen Member (above subunit IVf-4), and NHMM JJ 13380 from the same member (subunit IVf-5), while NHMM JJ 14571 is from the underlying uppermost Nekum Member (subunit IVe-7). All Maastricht Formation; uppermost Maastrichtian.

Description

NHMM JJ 10551a is a fragmentary valve of an exogyrine ostreid with a clean internal surface, encrusted by serpulid worms and perforated by borings. The most prominent of the latter are a pair of *G. dijugus* which are incomplete (but which presumably penetrated the underlying firm sediment or rock substrate; Fig. 2B), but preserve the figure-of-eight-shaped apertures in the oyster shell (Fig. 2A, starred). Both borings are lined with calcite.

NHMM JJ 13380 is large, about 60 mm in maximum length, but incomplete, preserving one side of the boring only (Fig. 3C). The interior of the boring is smooth and the upper half coated with calcite. The central plate of the aperture is formed of limestone substrate coated with calcite.

NHMM JJ 14571 has been broken longitudinally; the boring is not filled. The counterpart is not preserved. The borer has lined the cavity with calcite, where its smooth appearance contrasts to the adjacent broken rock surface (Fig. 2E). The specimen unusually preserves evidence of the neck separating into two siphonal canals. These, too, are coated with calcite; a central plate of the lining separated the two siphons in life.

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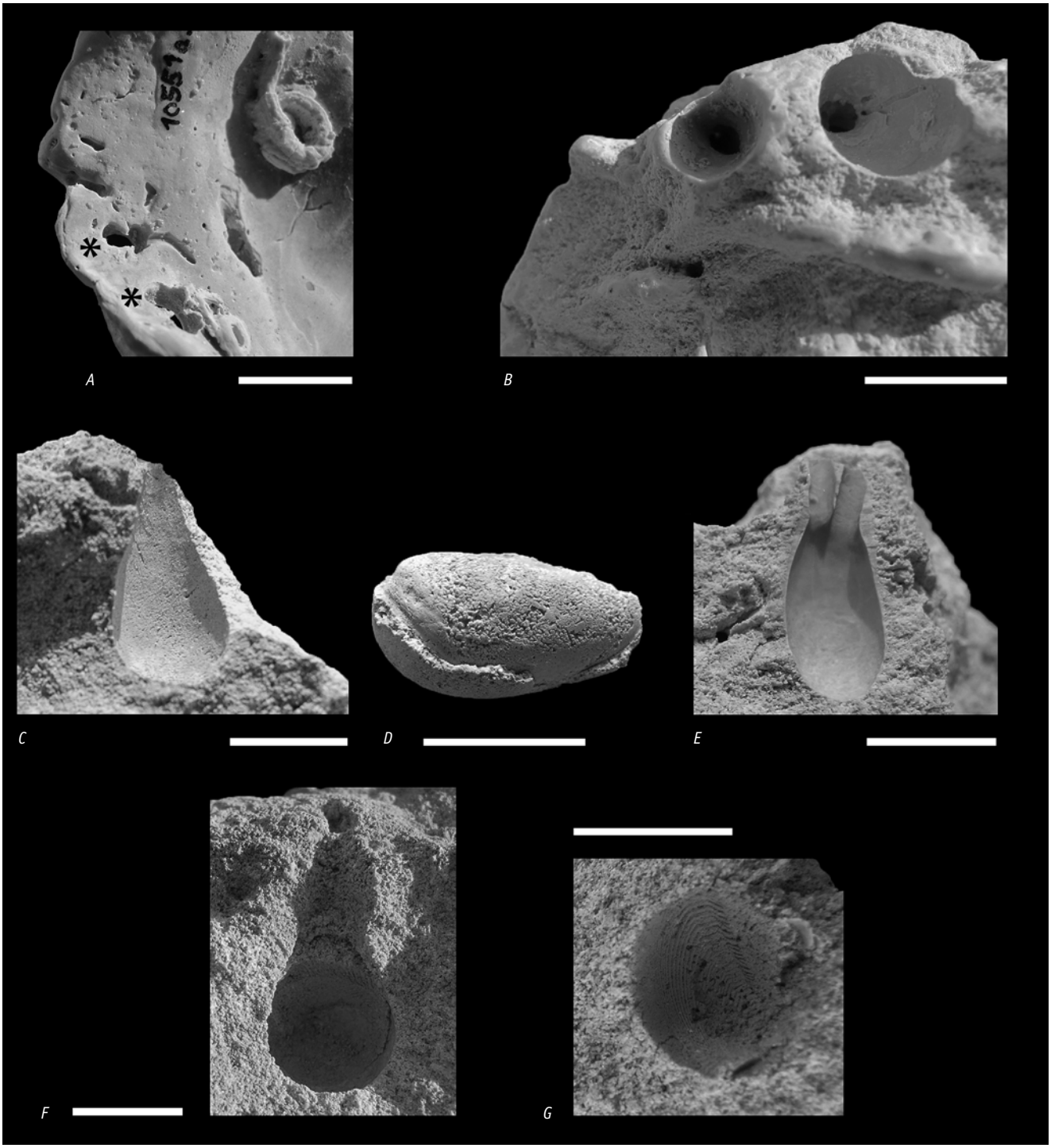

Fig. 2. The ichnofossil Gastrochaenolites *and a producing bivalve from the type Maastrichtian (Upper Cretaceous) of ENCI-HeidelbergCement Group quarry, St. Pietersberg. A, B –* Gastrochaenolites dijugus *Kelly & Bromley, 1984, NHMM JJ 10551a; A – detail of inner surface of infested oyster valve, both encrusted and bored, the latter including two figure-of-eight apertures of* G. dijugus *(*); B – outer surface, rotated 90° counter clockwise with respect to (A) (that is, right-hand specimen is the upper boring in A), showing incomplete, smooth-sided chambers; C, D –* Gastrochaenolites lapidicus *Kelly & Bromley, 1984, and producing bivalve; C – NHMM JJ 12820a, boring; D –* Gastrochaena *sp., NHMM JJ 12820b, internal mould of bivalve, anterior to left; E –* Gastrochaenolites dijugus *Kelly & Bromley, 1984, NHMM JJ 14571, boring showing the smooth lining of calcite and the neck, separated into two diverging canals for siphons by a central plate formed as part of the lining; F, G –* Gastrochaenolites orbicularis *Kelly & Bromley, 1984, NHMM JJ 12329a, b, respectively, part and counterpart, the latter preserving the chamber only, and both preserving the pseudobioglyph (= external mould) of the producing bivalve,* Jouannetia supracretacea. *All scale bars represent 10 mm.*

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Remarks

The borings in NHMM JJ 10551a indicate that the oyster valve was resting with the external surface in intimate contact with the seafloor, probably in or on a firmground or hardground. The inner surface (= upper surface when bored) was infested by borers and serpulids, so it was not blanketed by sediment at that time. The distinctive apertures of *G. dijugus* provide a way-up structure, the producing bivalve having bored into the inner and through the outer surface of the oyster valve.

Kelly & Bromley (1984, p. 800) diagnosed this ichnospecies as, 'Smooth *Gastrochaenolites* in which neck region is constricted in the form approaching a figure of eight by two opposed ridges.' These ridges sensu stricto are not apparent in NHMM JJ 14571; rather, it is the lining of the boring that produced the bifurcation of the neck. NHMM JJ 13380 is of an intermediate morphology, the limestone substrate forming an incomplete central vein that is coated with the calcite lining the boring.

Gastrochaenolites lapidicus *Kelly & Bromley, 1984*

Figs 2C, 3B, H.

Material

NHMM JJ 12820a (Fig. 2C), preserved with the internal mould of the producing bivalve, *Gastrochaena* sp. (Fig. 2D); JJ 8453b (Fig. 3H), infill of boring; and JJ 12270 (Fig. 3B), at least four such borings in a hardground surface.

Locality and stratigraphy

All from the ENCI-HeidelbergCement Group quarry, St. Pietersberg (Fig. 1). NHMM JJ 12820a is from the lower Meerssen Member (subunit IVf-1); JJ 8453b and JJ 12270 from the same member (subunit IVf-4, 'bioherm'; and subunit IVf-1, respectively). All Maastricht Formation; uppermost Maastrichtian.

Description

Although the boring lacks a counterpart, NHMM JJ 12820a is teardrop-shaped and rounded in section throughout with a rounded, unsculptured base to the chamber. It is undoubtedly *G. lapidicus* (compare with Kelly & Bromley, 1984, text-figs 3A, 4A, B). NHMM JJ 8453b is a teardrop-shaped limestone filling a main chamber, the infill consisting of rather coarse-grained bryozoan debris and a fragment of the producing bivalve, a possible lithophagine. The borings in Figure 3B (NHMM JJ 12270) are the two best examples of *G. lapidicus* in a heavily bored hardground surface; note that the right-hand specimen has itself been bored or crosscuts an earlier borehole.

Remarks

NHMM JJ 12820a is one of the rare specimens of *Gastrochaenolites* documented herein from the ENCI quarry to preserve an internal mould of the producing bivalve (see also *G. orbicularis* and *G. torpedo*). Kelly & Bromley (1984, p. 800) noted that *Gastrochaena* typically excavated *G. dijugus* borings, with the neck and aperture modified to a figure-of-eight section. There is no evidence for such a modification in NHMM JJ 12820a. Assuming that our identification of the bivalve, preserved as an internal mould (Fig. 2D), is correct, this is a further boring morphology that can be made by *Gastrochaena*. Kelly & Bromley (1984, p. 798) noted that, '(b)orings of this type (i.e., *G. lapidicus*) are produced by several species of *Lithophaga* and *Hiatella* today.'

Gastrochaenolites orbicularis *Kelly & Bromley, 1984*

Figs 2F, G, 3A, E.

Material

NHMM JJ 12329a-c, both halves of the boring (Fig. 2F, G) and the internal mould of the producing bivalve, *Jouannetia supracretacea* (De Ryckholt, 1852); JJ 12182 (Fig. 3A), incomplete main chamber with pseudobioglyph; JJ 12220a-c, chamber and neck with internal mould of *J. supracretacea* (Fig. 3J); JJ 12221-12223, matrix block with multiple incomplete chambers, one retaining an internal mould of *J. supracretacea*, and two further moulds of the same; JJ 12428 (Fig. 3E, I), tubular clast, presumed to be an intraformational lithified burrow, reworked and bored; and JJ 14558a, half of the main chamber with a prominent pseudobioglyph.

Locality and stratigraphy

Specimens from the ENCI-HeidelbergCement Group quarry, St. Pietersberg (Fig. 1), all from the Meerssen Member (Maastricht Formation; uppermost Maastrichtian) include NHMM JJ 12329a-c from the upper part of subunit IVf-2; JJ 12428 from the base of subunit IVf-4; and JJ 14558a from subunits IVf-4/5. NHMM JJ 12182 is from the top (subunit IVe-7) of the underlying Nekum Member.

Specimens from the former Ankerpoort-Curfs quarry, Geulhem (southern Limburg; see Fig. 1) comprise NHMM JJ 12220a-c and 12221-12223, all from the lower Geulhem Member (Houthem Formation; Vroenhoven Horizon +0.3-0.5 m) of earliest Danian age (compare Jagt & Janssen, 1988).

Remarks

These specimens include several additional rare examples of borings from the study area preserving the producing organism. The bivalve genus *Jouannetia* Des Moulins in Rang & Des Moulins, 1828 (Fig. 3J) has already been recognised (Kelly & Bromley, 1984, p. 801) as a producer of *G. orbicularis*, but the interest in the present specimens lies in their preservation. The bivalves are preserved as internal moulds; apparent bioglyphs are found in several of the borings (Figs 2F, G, 3A) which provide unusually clear details of the external sculpture of the shell. However, the origin of each of these structures is not as a bioglyph. A bioglyph sensu stricto '... reflects the digging

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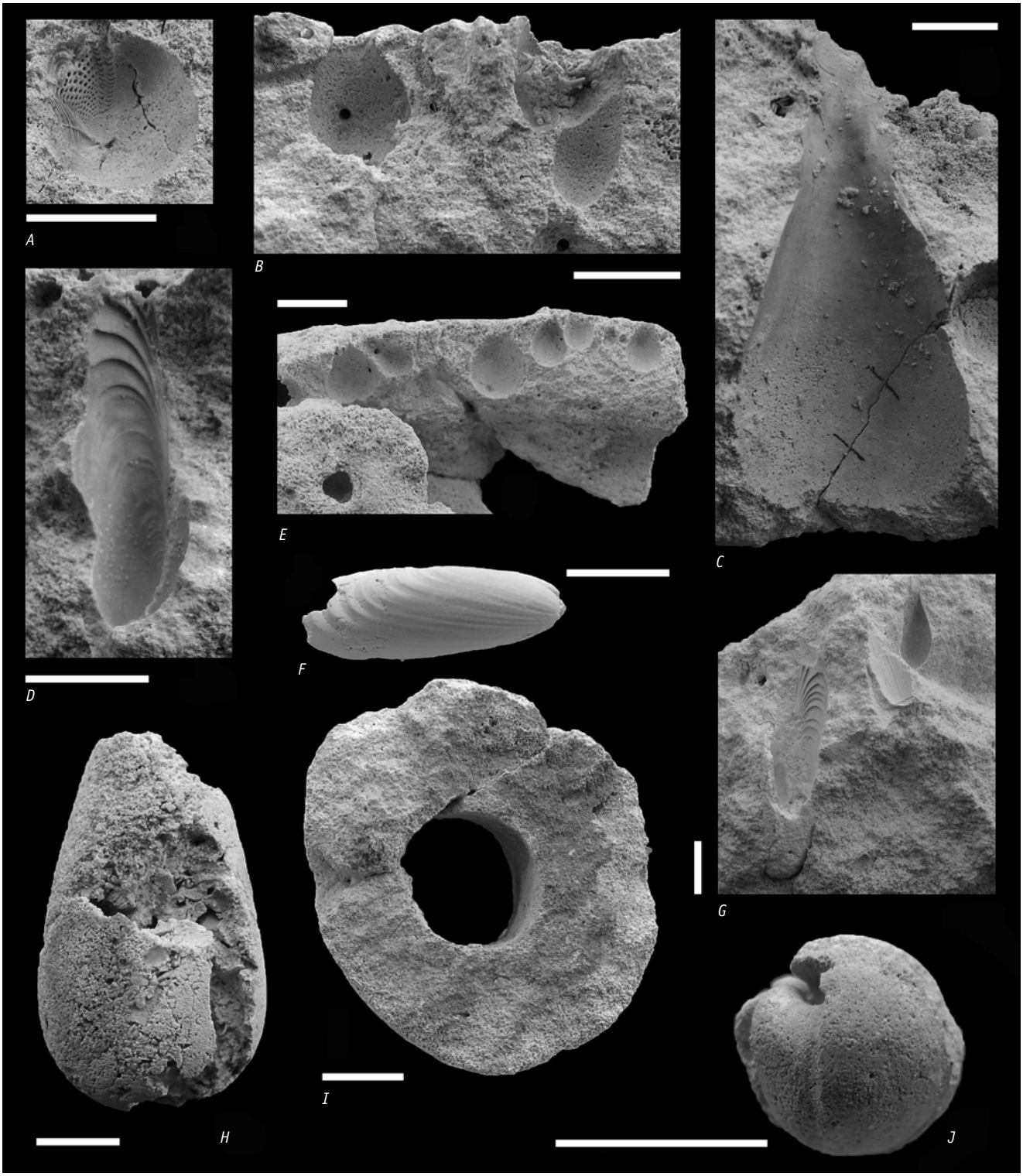

Fig. 3. The ichnofossil Gastrochaenolites *and two producing bivalves from the type Maastrichtian (Upper Cretaceous) of ENCI-HeidelbergCement Group quarry, St. Pietersberg (unless stated otherwise). A –* Gastrochaenolites orbicularis *Kelly & Bromley, 1984, NHMM JJ 12182, incomplete main chamber with pseudobioglyph; B –* Gastrochaenolites lapidicus *Kelly & Bromley, 1984, NHMM JJ 12270, a pair of specimens in a strongly bored hardground; C –* Gastrochaenolites dijugus *Kelly & Bromley, 1984, NHMM JJ 13380, lined with calcite except towards the base of the main chamber; D –* Gastrochaenolites torpedo *Kelly & Bromley, 1984, NHMM JJ 5514, pseudobioglyph; E, I –* Gastrochaenolites orbicularis *Kelly & Bromley, 1984, NHMM JJ 12428; E – numerous borings in the wall of reworked, lithified burrow; I – lithified wall of reworked, intraformational circular burrow, bored during the Maastrichtian; F, G –* Gastrochaenolites torpedo *Kelly & Bromley, 1984, NHMM JJ 13380, showing pseudobioglyphs (left and upper centre), and boring (upper right) (G), and internal mould of producing bivalve,* Lithophaga *sp. (F); H –* Gastrochaenolites lapidicus *Kelly & Bromley, 1984, NHMM JJ 8453b, limestone infill of boring; J –* Jouannetia supracretacea*, NHMM 12220c, internal mould, former Ankerpoort-Curfs quarry, Geulhem. Scale bars represent 10 mm.*

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activity; a network of scratches, annulations or longitudinal striation' (Bromley, 1996, p. 156) and is not an external mould of the shell. Rather, features such as those seen in Figures 2G and 3A are post-mortem structures produced by sedimentation. The medium-grained biocalcarenite forming the bored substrate would not have been conducive to preserving such fine details as are seen on the chamber walls of these borings. Rather, and presumably after the death of the producer, the chamber of the boring was filled by lime mud. As the bivalve largely filled the chamber, the sediment infill formed a thin layer lining the cavity. After lithification of the mudrock envelope and the fine-grained limestone infill of the dead *Jouannetia*, the bivalve shell was dissolved by percolating groundwater.

The impression of *Jouannetia* in *G. orbicularis* is therefore not a bioglyph, which would have been the spoor of the living mollusc (Bromley, 1996, p. 156). Rather, it is an external mould produced by inorganic processes, but 'imitating' the situation of a bioglyph within a boring. We name this structure a pseudobioglyph and suggest that care must be taken in separating such from true bioglyphs. Further pseudobioglyphs are identified in *G. torpedo* (below).

Gastrochaenolites torpedo *Kelly & Bromley, 1984*

Fig. 3D, G.

Material

NHMM JJ 5514 (Fig. 3D), boring with pseudobioglyph and associated internal mould of producing lithophagine bivalve; NHMM JJ 13380 (Fig. 3G), six borings, all incomplete, but including one with a well-preserved pseudobioglyph and internal mould of producing lithophagine bivalve (Fig. 3F).

Locality and stratigraphy

All three examples are from the Meerssen Member at the ENCI-HeidelbergCement Group quarry, St. Pietersberg (Fig. 1). NHMM JJ 5514 is from 0-4 m above the base of the member, while JJ 13380 is from subunits IVf-4/-5. All Maastricht Formation; uppermost Maastrichtian.

Description

Borings elongate, slender, more or less pointed at base of main chamber; neck and aperture not preserved. Bases of chamber either filled with fine-grained limestone or with a geopetal infill (JJ 5514, not illustrated). External moulds of producing bivalve, *Lithophaga* sp., preserved as pseudobioglyphs.

Remarks

Both specimens preserve a pair of rare features, an internal mould of the producing bivalve and a pseudobioglyphic external mould of the same. The geopetal infill in NHMM JJ 5514 suggests that this was a reworked intraformational clast that became inverted.

A further specimen, NHMM JJ 12396, preserving at least two incomplete borings and one internal mould of a bivalve, is clearly the work of a gastrochaenid; it is from the same locality, Meerssen Member (subunit IVf-1). The borings are incomplete and their ichnospecific assignment uncertain. The boring may also be, for example, *G. lapidicus* and, at best, NHMM JJ 12396 can only be referred to *Gastrochaenolites* isp. while noting its similarities to the named ichnospecies. The bivalve, which includes part of a pseudobioglyph, is referred to *Gastrochaena*; the species appears to differ from in Figure 2D.

Gasterochaenolites *isp.*

Fig. 4.

Material

A fragmentary internal mould of a nautiloid body chamber; MLV collections (IndeBraekt, no. 4311, ex B 175).

Locality and stratigraphy

Former Ankerpoort-Curfs quarry, Geulhem, southern Limburg, the Netherlands. Maastricht Formation, definitely Meerssen Member, but exact horizon unrecorded.

Remarks

This specimen preserves an interesting juxtaposition of an internal mould of a moderately rare cephalopod and *Gastrochaenolites*. The largest boring in this nautiloid body chamber, probably of *Eutrephoceras depressus* (Binkhorst van den Binkhorst, 1862) (compare Jagt, 2012), lacks an aperture and a base to the main chamber (Fig. 4B-D); other, smaller borings only retain the rounded bases of chambers. All are left in open nomenclature in view of their incomplete preservation. But the largest specimen (greatest length, as preserved, 70 mm; upper and lower diameters 23 and 32 mm, respectively) is the most interesting, penetrating the biocalcarenitic internal mould of a partial nautiloid body chamber which was presumably embedded in a hardground or firmground surface, of which there are many within the Meerssen Member in the study area.

Ichnogenus Teredolites *Leymerie, 1842*

Type ichnospecies

Teredolites clavatus Leymerie, 1842, p. 2, pl. 2, figs 4, 5, by monotypy.

Other ichnospecies

Teredolites longissimus Kelly & Bromley, 1984.

Diagnosis

'Clavate borings in woody substrates, acutely turbinate, evenly tapered from aperture to base of main chamber; neck region not

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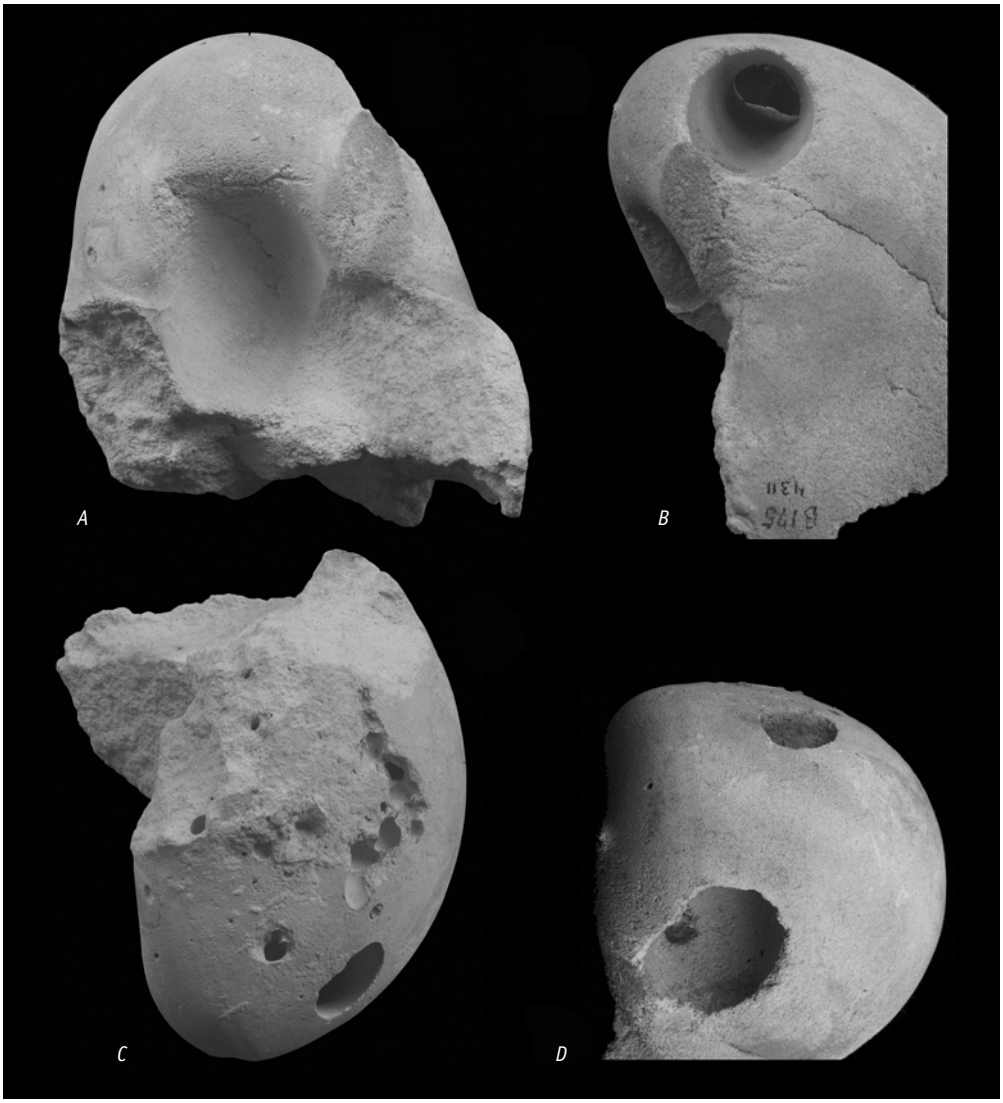

Fig. 4. Gastrochaenolites *isp. in an incomplete internal mould of a nautiloid, MLV collections (IndeBraekt Collection, no. 4311), from an unknown level within the Meerssen Member (Maastricht Formation) at the former Ankerpoort-Curfs quarry, Geulhem. A, septal view of the youngest phragmocone chamber, borings not apparent; B-D,* Gastrochaenolites *isp. seen in oblique-lateral (B), lateral (C) and ventral (D) aspects. D is presumably the approximate orientation of the nautiloid when bored. The greatest whorl width (A) is 93 mm.*

separated from main chamber; cross-sections at all levels more or less circular; elongate to short' (after Kelly & Bromley, 1984, p. 804).

Remarks

The diversity of patterns of preservation of *Teredolites* is larger than that of *Gastrochaenolites* because of the differences in their substrates. The woody substrate of *Teredolites* may be mineralized and preserved enclosing the bivalve borings (for example, Donovan et al., 2009). If the wood is lost during diagenesis, it is still possible for *Teredolites* borings to be preserved in their life association and in three dimensions, assuming that the substrate decayed after burial (for example, Pickerill et al., 1996; Donovan, in press; Fig. 5E, F herein). If the wood rots before burial, the calcareous linings of *Teredolites* will be released and, although fragile, may be preserved as fragmentary tubes (such as Donovan et al., 1998, pl. 1, figs 4-6; Pickerill et al., 2003; Fig. 5A-D herein).

Teredolites longissimus *Kelly & Bromley, 1984*

Fig. 5.

Material

NHMM JJ 9202/1-4 (Fig. 5C, D), JJ 11884a, b (Fig. 5E) and JJ 12568a, b (Fig. 5A, B, F).

Locality and stratigraphy

NHMM JJ 9202/1-4 is from the CBR-Romontbos quarry, Eben Emael, Gronsveld Member; JJ 11884a, b, from the ENCI-HeidelbergCement Group quarry, St. Pietersberg, base of Nekum Member (just above Laumont Horizon); JJ 12568a, b, from the same locality, base of Nekum Member, Laumont Horizon +0.5 m. All Maastricht Formation; uppermost Maastrichtian.

Description

This small suite of specimens shows two styles of preservation. Short, thin-walled, incomplete calcareous tubes (Fig. 5A-D) are infilled by biocalcarenitic matrix (JJ 12568b) or flint. The latter

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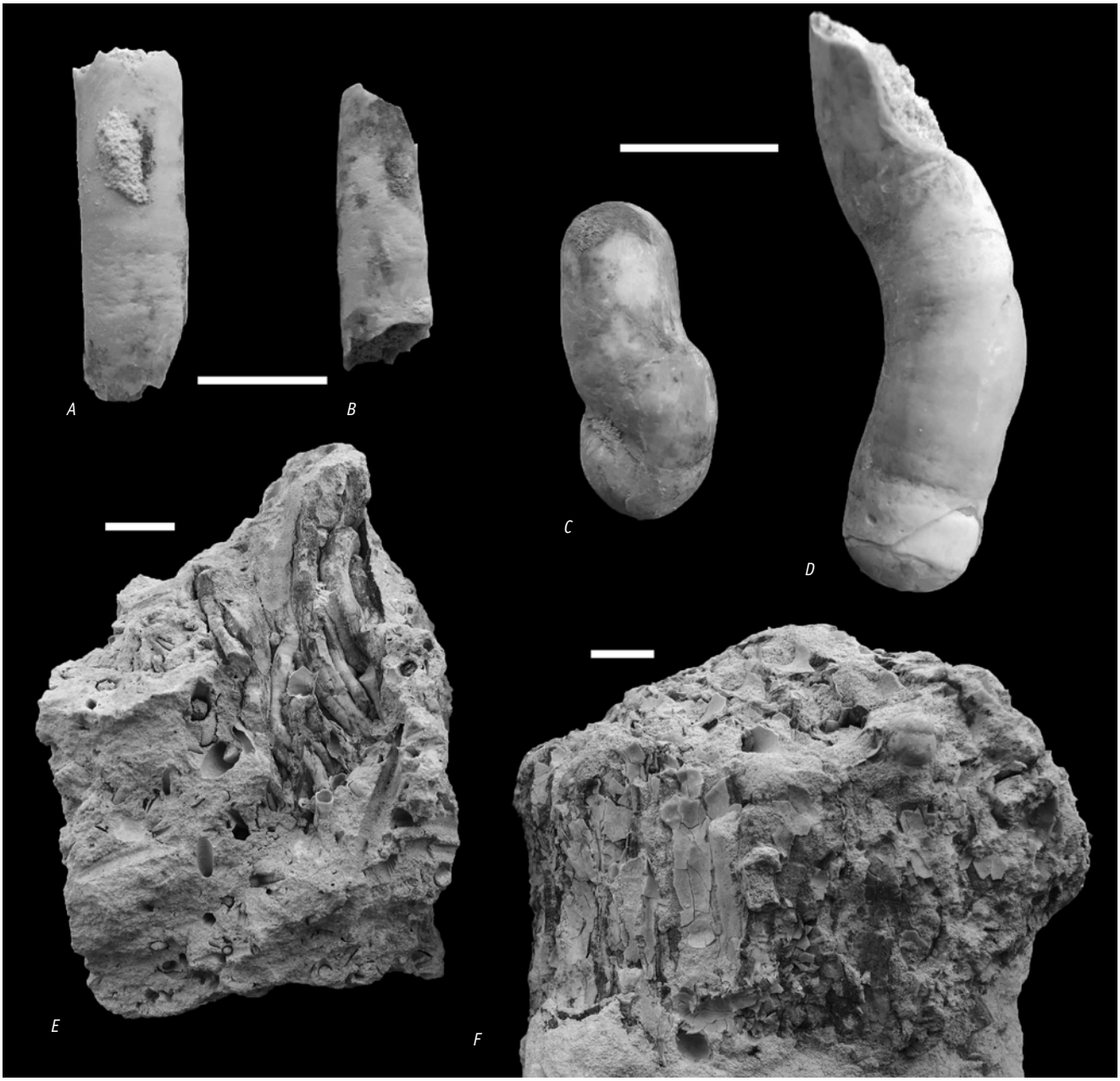

Fig. 5. The xylic boring Teredolites longissimus *Kelly & Bromley, 1984, from the type Maastrichtian (Upper Cretaceous), southern Limburg, the Netherlands. A, B – NHMM JJ 12568b (two specimens out of many), short fragments of lining to shaft of borings; C, D – NHMM JJ 9201/1, 2 (out of four), short fragments of lining to distal terminations of borings; E – NHMM JJ 11884a,* in situ *cluster of borings (xylic substrate decayed); F – NHMM JJ 12568a,* in situ *cluster of borings (xylic substrate decayed). All scale bars represent 10 mm.*

include the longest specimen (Fig. 5D; about 40 mm in length) and two tubes with rounded distal terminations. Tubes smooth, mainly straw brown in colour, of constant diameter to slightly tapered, with rounded distal terminations and growth lines poorly apparent in some specimens.

Clusters of closely packed tubes are found preserved mainly parallel to subparallel in biocalcarenites. Calcareous tubes, with limestone fills (Fig. 5E, F), are longer than most free tubes, over 45 mm in some examples, but incomplete; flattened in NHMM JJ 12568a and cracked longitudinally (Fig. 5F).

Remarks

A flint infill appears to favour superior preservation of tubes released from the rock (Fig. 5C, D). Both specimens preserving *T. longissimus in situ* (Fig. 5E, F) are densely infested. It is probable that the xylic substrate, now decayed, but with the resulting cavity infilled by limestone, lost buoyancy due to the extreme density of infestation by boring bivalves destroying the wood. This compares well with a record of '*Teredolites* sp.' (*sic*) in a log of driftwood from the Gronsveld Member (Maastricht Formation) at the CBR-Romontbos quarry (Eben Emael, Liège, Belgium) by Jagt & Collins (1999, p. 101, fig. 8).

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Notes on boring bivalves

Although not intended to be exhaustive, some notes on the taxonomy of the bivalve taxa that produced the borings described above are added here. Boring bivalves, lithophagine mytilids to be precise, preserved within their boreholes in scleractinian coral taxa from the higher portion of the Maastricht Formation, were first illustrated by Faujas de Saint Fond (1798/1799-1803), but not named. Bosquet (1868, p. 15) listed for the 'Maestrichtien', that is, the Maastricht Formation of current usage, three species of boring bivalves, in original nomenclature: *Lithodomus ciplyanus* de Ryckholt, *L. similis* de Ryckholt and *L. contortus* d'Orbigny. The first-named was referred with a query to the genus *Lithophaga* Röding, 1798, by Kleemann (1983, p. 6), on the basis of the original material from the upper Maastrichtian of Ciply (Mons Basin, southern Belgium) as illustrated by De Ryckholt (1852, p. 127, pl. 7, figs 1, 2). The morphology is close to the larger-sized lithophagines from the type Maastrichtian (see, for example, Nieuwenhuis, 2006, p. 113, fig. 1), so this may be the same species, although other forms appear to be represented as well (see Fig. 3G). De Ryckholt (1852) recorded *Lithodomus ciplyanus* from the 'Sénonien supérieur' of Ciply (southern Belgium), which would in all likelihood correspond to the late Maastrichtian Saint-Symphorien Calcarenite Formation (see Robaszynski et al., 2002, p. 128).

The second species is a possible member of the mytilid *Botula* Mörch, 1853 (see also Vincent, 1930, p. 75; Soot-Ryen, 1969, p. N278; Kleemann, 1983, p. 22). Identical specimens are fairly common, mostly preserved *in situ*, in the Nekum and Meerssen members of the Maastricht Formation (see Nieuwenhuis, 2006, p. 114, fig. 3). The last-named, *Lithodomus contortus*, might be another species of *Botula* (see Kleemann, 1983, p. 6), but appears to include various taxa that range in age from Late Cretaceous to Neogene (Miocene). Vogel (1895) revised Bosquet's (1868) records, noting (p. 31, pl. 2, fig. 9) a single internal mould of '*Lithodomus*' *similis* from the St. Pietersberg (upper part of the Maastricht Formation inferred), and confirming assignment to '*Lithodomus*' *ciplyanus* of another specimen.

Amongst pholadids, *Jouannetia supracretacea* appears to be the commoner form. This species was originally recorded, as *Pholas supracretacea*, by De Ryckholt (1852, p. 115, pl. 5, figs 14-16), in particular from the 'le silex à Ciply', and mostly in the form of internal moulds. Glibert & Van de Poel (1973, p. 61) recorded it from the 'Poudingue' and the 'Tufeau (*sic*) de Ciply', noting that the term 'silex' as used by De Ryckholt (1852, p. 115) referred to the indurated basal levels of the 'Tufeau de Ciply'. In current terminology this is the middle to late Danian Ciply Formation (see Laga et al., 2002). For the time being, the latest Maastrichtian (Maastricht Formation, Nekum and Meerssen members) and early Paleocene (Houthem Formation, Geulhem Member) specimens from the type area of the Maastrichtian Stage are considered to be conspecific. Vincent (1930, p. 108, pl. 6, fig. 10) recorded *J. supracretacea*, lodged within a perfect example of *Gastrochaenolites orbicularis*, from the 'Poudingue de Ciply' and the 'Tuffeau durci' from Ciply, southern Belgium, remarking (p. 109) that in the upper Maastrichtian of the type area of that stage another related, yet smaller, form occurred of which only internal moulds were known to Vincent. For the time being, these forms are lumped, although another pholadid appears to be present as well. This might in fact turn out to be conspecific with *J.* ('*Pholadopsis*') *montensis* Vincent, 1930 (p. 110, pl. 6, fig. 11), from the Ciply Formation.

Boring bivalves in (silicified) wood have been recorded since the early days of palaeontological studies in the type area of the Maastrichtian Stage (e.g., Faujas de Saint-Fond, 1798/1799-1803; compare Felder, 1961). However, contrary to material on record from the Santonian Aken (Aachen) Formation which can be referred to the martesiine pholadid *Opertochasma* (compare Turner, 1969; Kelly, 1988), no bivalves have yet been documented from inside such borings. These were probably pholadids.

Of gastrochaenids, Bosquet (1868, p. 17) listed two species, in original nomenclature, *Gastrochaena amphisbaena* Goldf. sp. and *G. voracissima* Mull. (*sic*). The latter (Müller, 1851, p. 63), which was never illustrated, appears to refer to wood-boring pholadids, such as *Opertochasma*, which infest wood in huge numbers. Vogel (1895, p. 49) recorded it, as *Teredo voracissima*, from silicified wood from Maastricht and the St. Pietersberg, although it is clear that the taxa that he listed, and under various names, in fact refer to the ichnogenus *Teredolites*. With regard to *G. amphisbaena*, Müller (1851, p. 63) remarked that boring bivalves in silicified wood from the Aachen Formation would almost certainly comprise various species, but that distinction was a moot point. These forms have never been formally described. De Ryckholt (1852, pp. 117, 119, pl. 5, fig. 19) described and illustrated, as *Fistulana amphisbaena*, tubes of wood-boring bivalves that are here referred to as *Teredolites longissimus*; he also noted loose specimens from the Maastrichtian type area.

NHMM JJ 12820b (Fig. 2D) clearly is an internal mould of a gastrochaenid; it is associated with a borehole lacking a neck and an aperture modified to figure-of-eight section. This implies that this is a further boring morphology that can be made by *Gastrochaena*; Pisera (1987, fig. 11) illustrated a similar example from the Upper Jurassic of northern Poland. In shell outline, there is a close resemblance to Late Jurassic and latest Cretaceous material described and illustrated by Carter (1978, figs 54, 57) and Pisera (1987). Kelly & Bromley (1984, p. 798) noted that, '(b)orings of this type (*G. lapidicus*) are produced by several species of *Lithophaga* and *Hiatella* today'.

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