The ichnofossil genera *Radulichnus* and *Renichnus* in the Maastrichtian of The Netherlands and Belgium

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JAGT, J.W.M., 2003. – The ichnofossil genera *Radulichnus* and *Renichnus* in the Maastrichtian of The Netherlands and Belgium. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **73**: 175-184, 1 fig., 2 pls; Bruxelles-Brussel, March 31, 2003. – ISSN 0374-6291.

Abstract

The tuffaceous chalk facies (biocalcarenites) of the Maastricht Formation (Late Maastrichtian) in its type area (SE Netherlands, NE Belgium) has yielded numerous ichnofossil taxa; however, the genera *Radulichnus* and *Renichnus* were not yet recorded. Here, examples of these two taxa are described and illustrated. *Radulichnus* traces are left on a lithified substrate by the radula of certain gastropod and/or polyplacophoran (chitonid) molluscs, while *Renichnus* are etched traces of shells of vermetid gastropods. Vermetids from the Maastricht Formation are briefly discussed; an example of *Vermetus clathratus* BINKHORST, 1861 is illustrated. In addition, the ichnofossil *Centrichnus eccentricus* BROMLEY & MARTINELL, 1991, the byssal etching trace of anomiid bivalves which bears a superficial resemblance to *Renichnus*, is also documented.

Key words: Ichnofossils, Maastrichtian, the Netherlands, Belgium.

Résumé

Le faciès tuffeau (biocalcarénites) de la Formation de Maastricht (Maastrichtien terminal) dans sa région type (SE des Pays-Bas, NE de la Belgique) a livré de nombreux taxa d'ichnofossiles. Les genres *Radulichnus* et *Renichnus* n'y avaient cependant pas encore été signalés. Des exemplaires de ces deux taxa sont décrits et figurés dans cette note. *Radulichnus* groupe des traces laissées sur un substrat lithifié par la radula de certains gastéropodes et/ou de mollusques polyplacophores (chitonidés). *Renichnus* correspond à des traces gravées par des coquilles de gastéropodes vermétidés. Les vermétidés de la Formation de Maastricht sont brièvement discutés. Un exemplaire de *Vermetus clathratus* BINKHORST, 1861 est figuré. De plus l'ichnofossile *Centrichnus eccentricus* BROMLEY & MARTINELL, 1991, trace laissée par le byssus de bivalves anomiidés et ressemblant superficiellement à *Renichnus*, est également documenté.

Mots-clefs: Ichnofossiles, Maastrichtien, Pays-Bas, Belgique.

Introduction

Although both the Kunrade limestone facies and the so-called tuffaceous chalk facies of the Maastricht Formation in its type area (southern Limburg, the Netherlands, and the Belgian provinces of Limburg and Liège) have yielded numerous ichnofossil taxa, these have so far received comparatively little attention. References to particular ichnofossil taxa from Campanian-Maastrichtian strata in this area are scattered widely in the literature and, with very few exceptions, descriptions are rarely detailed. Forms represented (see Appendix) include soft-sediment (burrows) and bioerosional taxa (*e.g.*, borings) as well as numerous micro-endoliths. Although many ichnofossil taxa may potentially yield a lot of data concerning depositional rates, palaeo-waterdepth, substrate conditions and trophic guilds, museum collections rarely comprise more than a handful of taxa. Only in recent years have palaeontologists and stratigraphers in the Maastrichtian type area come to appreciate trace fossils, and proper documentation is now underway.

Two taxa not previously recognised are here presented. For one of them, *Radulichnus*, the lack of earlier records is especially puzzling. At shallow depositional depths and with a surprisingly high number of ''patelliform'' gastropod species represented, in particular in the Nekum and Meerssen members (Maastricht Formation), radular traces could have been expected to rank amongst the commonest trace fossil taxa; in fact, they do not. In part this may be explained by collection failure. For the second it should be noted that vermetid gastropods, whose (initial) whorls leave etchings in calcareous substrates, are never common in the Maastricht Formation, which implies that examples of *Renichnus* are rare. Superficially similar traces are left by the byssus of anomiid bivalves (*Centrichnus*); an example of this type is illustrated for comparison.

To denote the repositories of material referred to or illustrated here, the following abbreviations are used:

DGUS Departamento de Geología, Universidad de Sevilla;
GPIUH Geologisch-paläontologisches Institut der Universität Hamburg;
NHMM Natuurhistorisch Museum Maastricht (JJ – J.W.M. Jagt Colln; MD - M.J.M. Deckers Colln).

Taxonomy

Ichnogenus *Radulichnus* VOIGT, 1977, p. 339

Fig. 1 — *Centrichnus eccentricus* near the umbo of a pycnodonteine oyster [*Pycnodonte vesicularis* (LAMARCK, 1806)], NHMM JJ 12110 (leg./don. Y. Coole); CPL SA quarry, Haccourt (Liège, Belgium); Gulpen Formation, base of Vijlen Member + 2-6 m (upper Lower Maastrichtian), x 10.

TYPE ICHNOSPECIES

Radulichnus inopinatus VOIGT, 1977, p. 340, by original designation (holotype GPIUH TK1847).

Radulichnus inopinatus VOIGT, 1977
(Pl. 1, Figs. 1-4; Pl. 2, Figs. 1, 2)

* 1977 *Radulichnus inopinatus* VOIGT, p. 340, pl. 3a-c.
1987 *Radulichnus* sp. - MAYORAL, p. 54, pl. 2, figs. 9-11; text-fig. 2.
1993 *Radulichnus* - PALMER & PLEWES, p. 141, fig. 9B.
1993 *Radulichnus inopinatus* Voigt, 1977 - BROMLEY & ASGAARD, table 1.

Material:

Radular traces have been recognised on an isolated left coracoid (NHMM 003915) of the mosasaurid *Mosasaurus hoffmanni* MANTELL, 1829 (see KUYPERS *et al.*, 1996, p. 7) from the Maastricht Formation (level unknown, but probably Nekum Member) at St Pietersberg (Maastricht), and on the roots of NHMM MD 1005, an anterior tooth of the lamnid *Archaeolamna kopingensis* (DAVIS, 1890) from the upper Nekum Member (Maastricht Formation) at the Ankerpoort-Marnebel Noord quarry, Eben Emael (Bassenge, Liège, Belgium).

Description:

The concave portion of the inner surface of the coracoid (Pl. 1, Fig. 1), which measures 300 mm in width and 270 mm in length, shows various patches of radular traces between the coracoid foramen and the anterior margin. The largest concentration of individual traces shows a sinuous course (Pl. 1, Figs. 1, 2), which also records at least two "generations" of traces. Individual scratches or grooves in one of these, excavated deeper into the bony substrate, appear more or less blurred, but still two to three adjoining rows may be recognised (Pl. 1, Fig. 3). Traces produced subsequently are seen at the margins of this more deeply excavated area, some of which consist of single "scoops" only, while others are more irregularly distributed and partially overlap. In contrast to adjacent "scoops" where no ridges of bony material are left, adjoining rows are separated by straight to concave ridges of varying width (Pl. 1, Figs. 3, 4). Individual markings (*i.e.*, sets of grooves of a single "scoop"), which are 1.8-2.5 mm wide and 1.5-1.8 mm long, apparently consist of seven grooves of variable width and depth, separated by wider ridges. The central grooves generally, but not invariably, are deeper, longer and wider than those to the left and right. Sets of subparallel grooves predominate, whose orientation is more consistent in some sets than in others. As almost all markings partially overlap or coalesce it is difficult to judge whether or not all of them have the same number of grooves. In some places, both the margins and bottom of existing furrows in the bony material itself show radular traces. Presumably, encrustation by algae or infestation by boring thallophytes was especially prominent in those places.

The traces left on the labial side of the roots of the shark tooth (Pl. 2, Figs 1, 2) are closely comparable in structure, partial overlap and distribution. However, there is variation in depth and width of individual grooves, which are markedly unparallel and in places are almost convergent. This is undoubtedly due to the convex nature of the substrate.

Discussion:

This type of trace closely corresponds to radular traces that are produced by various groups of gastropods and chitonid polyplacophorans. The first examples from the fossil record were illustrated by BOEKSCHOTEN (1966, p. 368, fig. 11; 1967, fig. 17); other sources, documenting both extant and fossil radular traces, include RICHTER (1962), JÜCH & BOEKSCHOTEN (1980), BROMLEY & HANKEN (1981), HILLMER & MUNDLOS (1981), VOIGT (1981, 1996), AKPAN *et al.* (1982), BROMLEY *et al.* (1990), BRETON (1993) and MELLOR & SCHÜLKE (1996).

VOIGT (1977, p. 339) suggested the ichnofossil taxon *Radulichnus* for, "Minute patches or shallow grooves with parallel or subparallel tiny striae arranged side by side in transverse rows or irregularly distributed", to be used for traces commonly interpreted to have been left by both gastropods and polyplacophorans.

The large surface area of the coracoid may be assumed to have been covered by endolithic algae. Infestation probably was fairly low, since "radular scoops" are more or less clearly defined and feeding does not seem to have occurred in a "sweeping" fashion. These algae were browsed upon by patelliform gastropods and/or polyplacophorans. Although evidence for the presence of the latter group of molluscs in the Maastrichtian type area is still lacking, R.G. Bromley (pers. comm., August 2002) noted that the grooves are arranged at right angles to the direction of movement of the tracemaker. This suggests that the radular teeth moved laterally and not axially, which in turn would indicate that the tracemaker was a polyplacophoran and not a gastropod. The present *Radulichnus* traces are large and the tracemaker would therefore have been sizable.

The comparatively small surface area of the roots of the shark tooth (NHMM MD 1005) may also have been infested by algae, but there might be an alternative explanation. HILLMER & MUNDLOS (1981, fig. 15) illustrated radular traces of ?muricid (carnivorous) gastropods on the lower surface of rajid placoid scales from the Eocene of Helmstedt (Germany). These authors suggested that tissue material might have been left in the shallow pulpa which served as food for muricids which are known to carrion-feed at times. However, traces illustrated by these authors include a few clear "triple traces", which are not represented in NHMM MD 1005.

Isolated scratches, *i.e.* those not occurring in sets (*e.g.*, Pl. 1, Figs. 3, 4), might be confused with traces left by the biting action of the lantern in regular (*e.g.*, cidarid, saleniid, phymosomatid) echinoids, *Gnathichnus*. Examples of this taxon (see BROMLEY, 1975; BRETON *et al.*, 1992) are quite common at various levels in the Cretaceous succession of the study area, but these generally are stellate and never occur in discrete adjoining rows of the type illustrated here (Pl. 1, Figs. 2, 3).

Ichnogenus *Renichnus* MAYORAL, 1987, p. 56

TYPE ICHNOSPECIES

Renichnus arcuatus MAYORAL, 1987, p. 56, by original designation (holotype DGUS $BO_2/1/2$).

Renichnus arcuatus MAYORAL, 1987
(Pl. 2, Fig. 3)

* 1987 *Renichnus arcuatus* MAYORAL, p. 56, pl. 2, fig. 13; text-fig. 3.

1993 *Renichnus arcuatus* Mayoral, 1987 - BROMLEY & ASGAARD, table 1.

1999 *Renichnus arcuatus* Mayoral, 1987 - TADDEI RUGGIERO, p. 171, fig. 10-P.

Material:
A single trace on the inner surface, close to the shell margin, of a fragment of a large exogyrine oyster (NHMM JJ 12130) from the basal metre of the Meerssen Member (Maastricht Formation, Late Maastrichtian, *Belemnitella junior* Zone of authors), as exposed at the Ankerpoort-'t Rooth quarry (Bemelen, the Netherlands).

Description:
The comparatively small trace (total length of main row being *c.* 9 mm) consists of a row of seven consecutive, kidney-shaped impressions, slightly sinuous in the lower portion and more or less straight for the remainder. The first impression (see Pl. 2, Fig. 3, between two abraded serpulid tubes) is very faint and contours are barely visible. The second measures *c.* 1 mm in width and shows subequal limbs, while the third, wider and laterally more compressed ("pinched"), is symmetric. The width of the fourth to sixth impressions increases gradually, but the depth of impression is more or less similar. They are symmetric and have well-rounded ends. Interspaces between the consecutive impressions are (near) equal. The seventh impression, which is slightly asymmetric, measures 2.8 mm in width.

Two additional impressions, with much less well-marked symmetric limbs, may be seen to one side of the main row, separated from each other by a wider interspace (Pl. 2, Fig. 3). Their depth is comparable to that of the impressions in the main row. Whether or not these two impressions were produced by the same individual that etched the main row is difficult to tell. If so, the shell may be assumed to have changed the direction of growing rather suddenly, for whatever reason.

Discussion:
The present trace is closely comparable to examples of vermetid etching traces illustrated in the literature (MAYORAL, 1987; SAVAZZI, 1996; TADDEI RUGGIERO, 1999). That this type is rare in the type Maastrichtian may be explained by the scarcity of vermetid gastropods in these strata.

The earliest undoubted vermetids are of Late Cretaceous age, with earlier records probably referring to serpulids. TRACEY *et al.* (1993, p. 148) remarked that, because of convergence, Mesozoic vermetids were difficult to identify from the adult shells. SAVAZZI (1996) noted that vermetids were cemented to hard substrates, had internal septa and a shell morphology that was largely under environmental control, generally conforming to the topography of substrate. The fact that these gastropods have a protoconch and usually show internal septa or internal longitudinal ridges, distinguishes them from serpulid tubes. SAVAZZI (1996) also suggested that substrate-etching in vermetids was likely to improve shell attachment to the substrate; alternatively it might be a way to economise on the amount of shell material secreted, or could be a source of calcium carbonate allowing an increased shell growth rate.

As noted above, vermetid gastropods in the Maastrichtian type area are never common and are in need of revision. Apparently, most occurrences are linked with bryozoan/scleractinian coral patch reefs, in particular in the lower half of the Meerssen Member (see, *e.g.* BINKHORST, 1861; KAUNHOWEN, 1898). A partially preserved septum in NHMM JJ 12389 demonstrates that *Vermetus clathratus* BINKHORST, 1861 (p. 35, pl. 5a2, fig. 3) is indeed a vermetid. Moreover, it might well be a representative of *V.* (*Vermetus*) since it is irregularly and loosely coiled and is cemented to the substrate over its entire length (see Pl. 2, Fig. 4). The status of the other species recorded from the type Maastrichtian needs to be determined. KAUNHOWEN (1898, p. 49) noted for *V. clathratus* that that species was confined to the indurated, coral-rich levels accompanying the bryozoan-rich intervals, an observation substantiated here. That author added two other vermetids, *V. nodosus* KAUNHOWEN, 1898 (p. 49, pl. 4, figs 6-10), from the Kunrade limestone facies at Kunrade, and *V. alternans* KAUNHOWEN, 1898 (p. 49, pl. 4, fig. 11), based on a single specimen only, from the indurated levels accompanying the bryozoan layers. *Vermetus nodosus* has subsequently been reassigned by ABDEL-GAWAD (1986, p. 98) to the genus *Lemintina* RISSO, 1826.

Renichnus arcuatus shows a superficial resemblance to etching traces of anomiid bivalves, named *Centrichnus eccentricus* BROMLEY & MARTINELL, 1991, which are also known from the Maastrichtian type area (NHMM JJ 7274, NHMM 1997098), mostly occurring on echinoids, but also on pycnodonteine oysters (NHMM JJ 12110) (see Text-fig. 1). So far, *C. eccentricus* has only been recorded from the Vijlen Member (lower Gulpen Formation). Despite the fairly common occurrence of anomiids in the upper Gulpen Formation and Maastricht Formation, examples of *Centrichnus* have not yet been recognised, which is puzzling in view of the large number of echinoid tests and other substrates in these strata.

Acknowledgements

I thank R.W. Dortangs (Amstenrade) for preparation of photographs, Yvonne Coole (Stramproy) and M.J.M. Deckers (Tegelen) for donation of material, Ankersmit NV Holding (Maastricht) and ENCI-Maastricht bv for allowing access to their quarries over recent years, G.J. Boekschoten (Amsterdam) and E. Voigt (Hamburg) for supplying items of literature, and S.K. Donovan (Leiden) and R.G. Bromley (Copenhagen) for commenting on an earlier typescript.

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Typescript submitted: 23 July 2002.
Revised typescript received: 22 October 2002.

Appendix

List of ichnofossil genera represented in the Vaals, Gulpen and Maastricht formations of the type area of the Maastrichtian Stage, as based on personal observations and on literature sources (UMBGROVE, 1925; BROMLEY, 1967; VOIGT, 1971; BROMLEY & FREY, 1974; BROMLEY & EKDALE, 1984; HOFMANN, 1996; ZIJLSTRA, 1994; JAGT *et al.*, 1997; JAGT & DORTANGS, 2000, 2003).

Suggested tracemakers [in brackets] are after VOIGT (1972, 1975), BROMLEY (1975), EKDALE *et al.* (1984), BROMLEY & D'ALESSANDRO (1984), KELLY & BROMLEY (1984), PLEYDELL & JONES (1988), VOSSLER & PEMBERTON (1989), BRETON *et al.* (1992), BROMLEY & ASGAARD (1993), BROMLEY (1991, 1999) and others.

Arachnostega BERTLING, 1992 [polychaetes]
Bathichnus BROMLEY *et al.*, 1975 [pogonophores, nemertineans and/or holothurians?]
Burrow type D *sensu* KENNEDY, 1967 [?decapod crustaceans]
Caulostrepsis CLARKE, 1908 [spionid polychaetes]
Centrichnus BROMLEY & MARTINELL, 1991 [anomiid bivalves and verrucid cirripedes]
Chondrites STERNBERG, 1833 [?worms, sipunculids]
Dendrina QUENSTEDT, 1849 [?]
Dodecaceria, *sensu* VOIGT, 1971 [polychaetes]
Entobia BRONN, 1838 [spirastrellid and clionid sponges]
Gastrochaenolites LEYMERIE, 1842 [lithophagid and pholadid bivalves]
Gnathichnus BROMLEY, 1975 [echinoids]
Gyrolithes DE SAPORTA, 1884 [?decapod crustaceans; see DWORSCHAK & RODRIGUES, 1997]
Lapispecus VOIGT, 1970 [?polychaetes]
Lepidenteron SUHR, 1988 [?worms]
Leptichnus TAYLOR *et al.*, 1999 [cheilostome bryozoans]
Maeandropolydora VOIGT, 1965 [polychaetes]
Nygmites MÄGDEFRAU, 1937 [?polychaetes]
Oichnus BROMLEY, 1981 [muricid and naticid gastropods, octopodid cephalopods]
Ophiomorpha LUNDGREN, 1891 [decapod crustaceans]
?*Planolites* NICHOLSON, 1873 [?worms]
?*Podichnus* BROMLEY & SURLYK, 1973 [brachiopods]
Radulichnus VOIGT, 1977 [gastropods, polyplacophorans]
Ramosulcichnus HILLMER & SCHULZ, 1973 [?spionid polychaetes]
Renichnus MAYORAL, 1987 [vermetid gastropods]
Rogerella DE SAINT-SEINE, 1951 [acrothoracican cirripedes]
Spongeliomorpha DE SAPORTA, 1887 [decapod crustaceans]
?*Taenidium* HEER, 1877 [associated with *Thalassinoides*, compare BROMLEY *et al.*, 1999]
Talpina VON HAGENOW, 1840 [phoronids and bryozoans]
Teichichnus SEILACHER, 1955 [?worms]
Teredolites LEYMERIE, 1842 [teredinid bivalves]
Thalassinoides EHRENBERG, 1944 [decapod crustaceans]
Trypanites MÄGDEFRAU, 1937 (emend. BROMLEY, 1972) [cirripedes, phoronids, sipunculids or polychaetes]
?*Uniglobites* PLEYDELL & JONES, 1988 [adociid and clionid sponges]
Zoophycos MASSALONGO, 1855 [nematodes/sipunculids/?worms]
?gastropod homing scars (compare NODA, 1991)
as well as faecal pellets (*Coprulus maastrichtensis* VAN AMEROM, 1971, *Thoronetia maastrichtense* BLAU *et al.*, 1997, *Canalispalliatum trigranulatum* BLAU *et al.*, 1997) and microborings of the types described and illustrated by HOFMANN (1996).

Plate Captions

PLATE 1

Figs. 1-4 — *Radulichnus inopinatus* on lower (inner) side of left coracoid (NHMM 003915) of mosasaurid *Mosasaurus hoffmanni*; St Pietersberg, south of Maastricht (the Netherlands); stratigraphic details lacking, but probably Maastricht Formation (Nekum Member); 1: general view illustrating sinuous course of radular traces, x 0.3; 2: detail of previous picture, x 0.8; 3: variation in depth of traces, suggesting more than one phase of grazing, x 2.5; 4: detail of sets of radular traces, partially overlapping, x 7.3.

PLATE 2

Figs. 1-2 — Anterior tooth (NHMM MD 1005) of *Archaeolamna kopingensis* with *Radulichnus inopinatus* on roots; Ankerpoort-Marnebel Noord quarry, Eben Emael (Bassenge, Liège, Belgium); Maastricht Formation, upper Nekum Member (Late Maastrichtian, *Belemnitella junior* Zone of authors); 1: view illustrating labial surface of tooth and close-set radular traces on both root limbs. Scale bar equals 5 mm; 2: detail of previous picture, x 8.2.

Fig. 3 — *Renichnus arcuatus* on the inside of a large exogyrine oyster (NHMM JJ 12130); Ankerpoort-'t Rooth quarry (Bemelen, the Netherlands); Maastricht Formation, basal metre of Meerssen Member (Late Maastrichtian, *Belemnitella junior* Zone of authors). Scale bar equals 1 mm.

Fig. 4 — *Vermetus clathratus* (NHMM JJ 8456); ENCI-Maastricht bv quarry, Maastricht; Maastricht Formation, Meerssen Member, base IVf-3 (Late Maastrichtian, *Belemnitella junior* Zone of authors). Scale bar equals 5 mm.

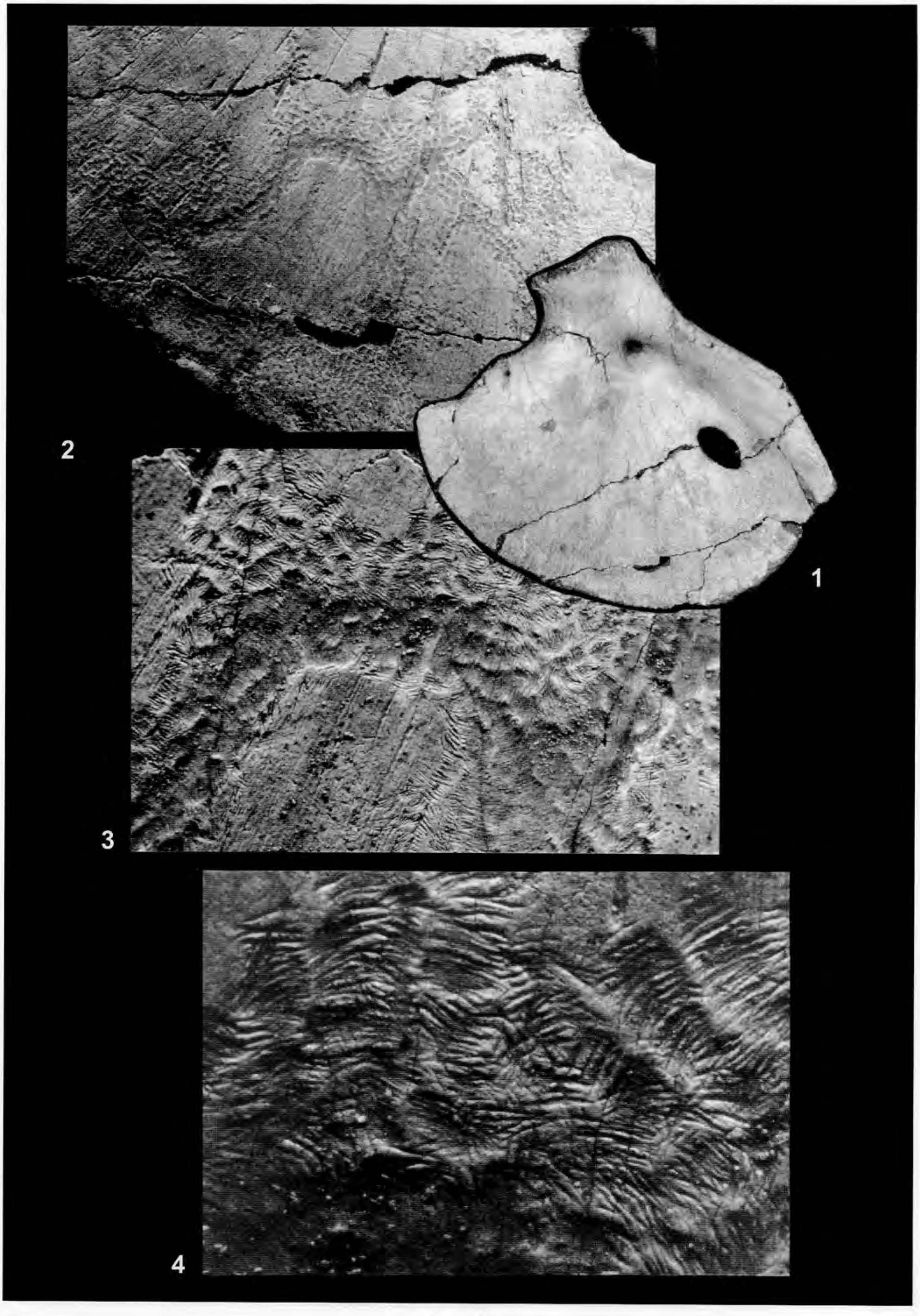

PLATE 1

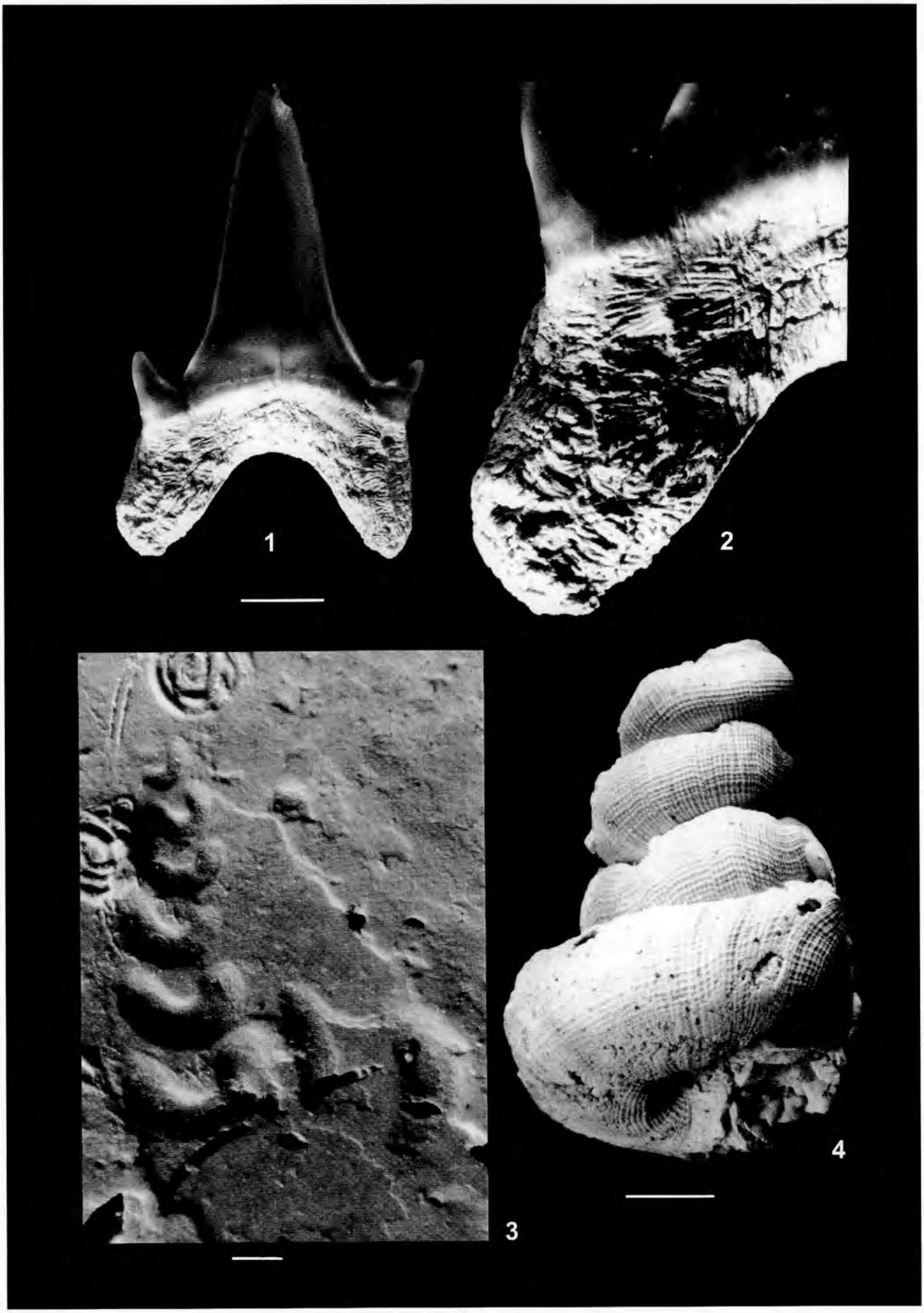

PLATE 2