Santonian – Campanian (Upper Cretaceous) inoceramids from the Houthalen mineshaft, NE Belgium

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Abstract

The Santonian and Campanian inoceramids from the Houthalen mineshaft (Limburg, NE Belgium) are described. Four successive faunas were distinguished: the *Sphenoceramus pachti* fauna, dated for the Middle Santonian, the *Sphenoceramus patootensiformis* fauna, of the upper Upper Santonian – lower Lower Campanian, the *Cordiceramus paraheberti* fauna, possibly of the upper Lower Campanian, and the "*Inoceramus*" *tenuilineatus* fauna, characteristic for the middle Upper Campanian. The appearance of the latter fauna marks one of the main turnover events in the evolution of the Campanian inoceramids.

Key-words: Inoceramids, Santonian, Campanian, biostratigraphy, Inoceramid zonation

Résumé

Les inocéramidés du Santonien et du Campanien récoltés dans les puits du charbonnage de Houthalen (Limbourg, Nord-Est de la Belgique) ont été étudiés. Quatre faunes successives ont été reconnues: la faune à *Sphenoceramus pachti,* du Santonien moyen, la faune à *Sphenoceramus patootensiformis* de la partie supérieure du Santonien supérieur au Campanien basal, la faune à *Cordiceramus paraheberti* probablement de la partie supérieure du Campanien inférieur, et la faune à "*Inoceramus*" *tenuilineatus*, caractéristique de la partie moyenne du Campanien supérieur. L'apparition de cette dernière faune indique un changement majeur dans l'évolution des inocéramidés du Campanien.

Mots-clefs: Inocéramidés, Santonien, Campanien, biostratigraphie, zonation inocéramide

Introduction

Relatively rich inoceramid material from the Santonian – Campanian of the Houthalen mineshaft, NE Belgium (Fig. 1), is housed in the collections of the Royal Belgian Institute of Natural Sciences at Brussels. Although the material was collected before the WW II, from rough successive intervals, and consequently particular specimens cannot be precisely located in the succession, it still enables the stratigraphical ordering of successive faunas, revealing the inoceramid record in the area in an interval spanning the Middle Santonian through middle Upper Campanian well. The best represented is the material from the stratigraphically highest parts of the section, dated for the "*Inoceramus*" *tenuilineatus* Zone of the middle Upper Campanian, the next successive assemblage above the *Cataceramus haldemensis* fauna, being usually the youngest inoceramid assemblage found in that part of Europe (GIERS 1964, WALASZCZYK 1997).

There is little previous work on the Santonian – Campanian inoceramids from the area. SORNAY (1982) described *Inoceramus borilensis* JOLKICEV, 1962, *Inoceramus sarumensis* WOODS, 1912, and listed *Inoceramus balticus* BÖHM, 1907, from the Campanian of the Houthalen mineshaft. He also mentioned that the Campanian assemblage in the section is dominated by platyceramids. Two Santonian species, *Cordiceramus brancoiformis* (SEITZ) and *Platyceramus* cf. *cycloides* (WEGNER), were shortly commented in a recent report by JAGT *et al.* (1995).

Houthalen section

No precise geological log of the Houthalen mineshaft exits. The succession and inoceramid distribution as pre-

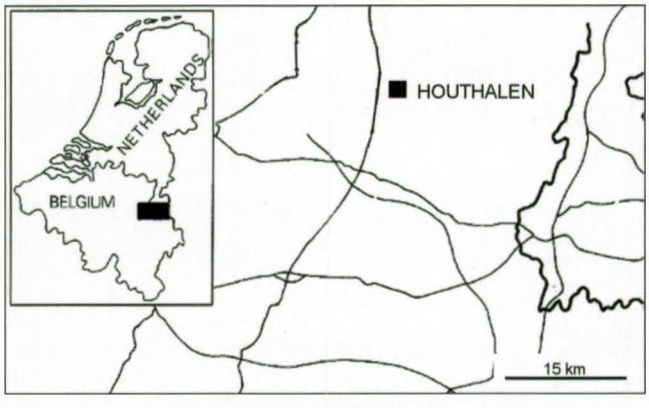

Fig. 1 — Locality map showing the location of the Houthalen mineshaft.

sented herein (Fig. 2) is based exclusively on the labels given to the palaeontological material collected during the construction of the shaft. The particular intervals mark the successive intervals dug out during mine construction, and searched for fossils when got up to the surface. The distribution lines continuing through the whole of particular intervals show the potential range and do not necessarily indicate an actual range of respective taxa.

Inoceramid distribution and stratigraphy

Seven intervals are represented by inoceramids in the Houthalen mineshaft material (Fig. 2). The lowest intervals yield usually only single specimens; the best represented are two stratigraphically highest intervals, with altogether 26 specimens to hand.

Four inoceramid faunas are distinguished: the *Sphenoceramus pachti,* the *Sphenoceramus patootensiformis*, the *Cordiceramus paraheberti*, and the *Inoceramus tenuilineatus* faunas. Their total stratigraphical range is Middle Santonian through middle Upper Campanian.

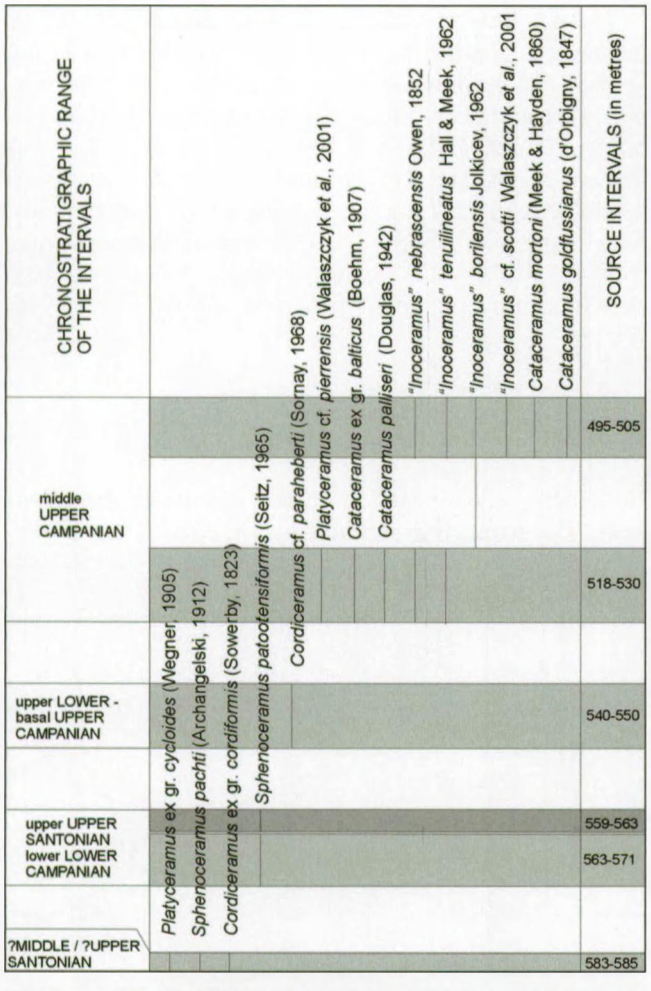

Fig. 2 — The stratigraphic succession and inoceramid ranges in the Santonian and Campanian of the Houthalen mineshaft.

The particular intervals are shortly characterised below (in stratigraphically ascending order):

583-585 m: The interval is represented by four specimens; two are *Sphenoceramus pachti* (ARKHANGELSKY, 1912), a single *Platyceramus* cf. *ahsenensis* (SEITZ, 1961) and a single specimen of *Cordiceramus* ex gr. *cordiformis* (J. DE C. SOWERBY, 1823). JAGT *et al.* (1995) reported from that interval *Cordiceramus brancoiformis* (SEITZ, 1961) and *Platyceramus* cf. *cycloides* (WEGNER, 1905).

Critical for age assignment are *Sphenoceramus pachti* and *Cordiceramus* ex gr. *cordiformis*. The latter dates the interval as not older than the Middle Santonian. *S. pachti*, although it may range as high as Upper Santonian (SEITZ 1965), rarely only ranges that high, and usually characterises the Lower and Middle Santonian. Following the new definition of the base of the Santonian, with the FO of *Cladoceramus undulatoplicatus* (ROEMER, 1852) (LAMOLDA & HANCOCK 1996) also includes the topmost Coniacian. Concluding, based on inoceramids the interval 583-585 m may range from the Middle to the Upper Santonian although the most probable age is the Middle Santonian. It corresponds well to the age diagnosis based on belemnites (CHRISTENSEN *in* JAGT *et al.* 1995).

559-563 m and 563-571 m: There are only two specimens from that interval, both representing members of the *Sphenoceramus patootensiformis* (SEITZ, 1965) – *S. angustus* (BEYENBURG, 1936) group.

Stratigraphically, members of the *S. patootensiformis* – *S. angustus* group range from the upper Upper Santonian (the *Marsupites* Zone) up to the top of the lower Lower Campanian.

540-550 m: There are three specimens from that interval all referred invariably to *Cordiceramus paraheberti* (SORNAY, 1968). The species does not give a precise stratigraphical dating; it may range through the whole upper Lower Campanian and the lower Upper Campanian.

518-530 m and 495-505 m: The interval 518-530 m is represented by eleven specimens belonging to "*Inoceramus*" *nebrascensis* OWEN, 1852, *Cataceramus palliseri* (DOUGLAS, 1942), *Ca.* ex gr. *balticus* (BOEHM, 1907), "*Inoceramus*" *tenuilineatus* HALL & MEEK, 1856, and *Platyceramus* cf. *pierrensis* (WALASZCZYK *et al*, 2001). The taxonomically most diverse assemblage occurs in the higher interval, 495-505 m. Among recognised species are: "*Inoceramus*" *scotti* WALASZCZYK *et al.*, 2001, "*Inoceramus*" *nebrascensis* OWEN, 1852, "*Inoceramus*" *borilensis* JOLKICEV, 1962, *Cataceramus mortoni* MEEK, 1876, "*Inoceramus*" *tenuilineatus* HALL & MEEK 1856, *Ca. goldfussianus* (D'ORBIGNY, 1847), and *Platyceramus* sp. A single specimen of "*I.*" *borilensis* comes from an interval between, i.e. 505-518 m.

Inoceramids from the two latter intervals, 518-530 m and 494-505 m, form an assemblage characteristic for the "*Inoceramus*" *tenuilineatus* Zone fauna, and possibly

also for the succeeding *Sphaeroceramus pertenuiformis* Zone fauna. Unfortunately because of the relatively thick succession represented by these two intervals (more than 30 m thick) and the lack of precise data on inoceramid distribution, the details of the inoceramid succession here cannot be gained.

The significance of the "*Inoceramus*" *tenuilineatus* Zone fauna

The appearance of the "*Inoceramus*" *tenuilineatus* fauna marks one of the main turnover events in the evolution of inoceramid faunas during the Campanian. It is still relatively poorly known, particularly at the generic level, and it follows directly the *Cataceramus subcompressus* (= *Ca. haldemensis*) assemblage dominated by the cataceramids. It is the starting point of most of the lineages characterising the inoceramid bivalves in the late Late Campanian. In ammonite terms this change may roughly be dated for the boundary between the *Bostrychoceras polyplocum* and the *Didymoceras donezianum* zones, as demonstrated in the Tercis (WALASZCZYK *et al.* 2002) and Vistula sections (WALASZCZYK 2004). It was first demonstrated in the material from the US Western Interior where, in the tripartite US Campanian subdivision (COBBAN 1994) it is dated for the middle *Baculites gregoryensis* Zone of the late Middle Campanian, (WALASZCZYK *et al.* 2001).

Material

All specimens are housed in the collections of the Royal Belgian Institute of natural Sciences in Brussels and bear the registration numbers IRSN – TC - MI 10938 to 10972.

Abbreviations
AMNH: American Museum of Natural History, New York, USA.
GSC: Geological Survey Canada, Ottawa, Canada.
IRSN-TC-MI: Royal Belgian Institute of Natural Sciences (Type Collection - Mesozoic Invertebrates), Brussels, Belgium.
MNHN: Lab. de Paléontologie, Département Histoire de la Terre, Muséum National d'Histoire naturelle, Paris, France.
USNM: Paleobiology, United States National Museum of Natural History, Smithsonian Institution, Washington DC, USA.

Taxonomy

In the following chapter the descriptive terms and measurements are taken after HARRIES *et al.* (1996). Abbreviations used are as follows: LV - left valve; RV - right valve; δ - angle of obliquity (angle between the axis of growth and the hinge axis); h - axial length (length along the axis of growth); hmax - maximum axial growth.

Bivalvia LINNÉ, 1758
Pteriomorphia BEURLEN, 1944
Pterioida NEWELL, 1965
Pterioidea GRAY, 1847
Inoceramidae ZITTEL, 1881 (ICZN 473)

Genus *Cordiceramus* HEINZ, 1932
Type species: *Inoceramus cordiformis* J. DE C. SOWERBY (1823, p. 61, pl. 440), from presumably Santonian deposits of Gravesend (Kent, England).

Cordiceramus ex gr. *cordiformis* (J. DE C. SOWERBY, 1823)
(Pl. 1, Fig. F)

MATERIAL: a single specimen; IRSN-TC MI 10944

DESCRIPTION AND REMARKS
The specimen is a single internal mould of the RV. The valve is small (hmax = 54 mm) and incomplete; it lacks the dorsal and postero-ventral margins. The specimen is doubly geniculated, dividing the valve into juvenile, adult and gerontic stages. The juvenile stage is small (h = 26 mm), oblique (with δ = 40°), strongly prosocline. The beak is small and pointed antero-dorsally. The surface covered with irregularly spaced, asymmetrical commarginal rugae. The adult growth stage contacts the juvenile one along the geniculation line with the geniculation angle approximately 60°. The gerontic geniculation step is much smaller, about 25°. Both the adult and gerontic stages are covered with irregularly spaced rugae. The growth lines are not visible. The radial sulcus is weakly developed; it is absent in the juvenile stage.

Because of incomplete preservation, the final specific determination of the specimen is difficult. It resembles strongly inflated (with one or two geniculation steps) forms such as *Cordiceramus koeplitzi* (SEITZ, 1961) or *Co. brancoiformis* (SEITZ, 1961), or the weakly sulcate representative of *Co. cordiformis* (J. DE C. SOWERBY).

OCCURRENCE: Middle through Upper Santonian and possibly even the lowermost Campanian.

Cordiceramus cf. *paraheberti* (SORNAY, 1968)
(Pl. 1, Figs. C, E)

*v. 1968 *Inoceramus* (*Cordiceramus*) *paraheberti* n.sp.; SORNAY, p. 38, pl. G; pl. H, figs 1-2; text-figs 7-10.
1978 *Inoceramus* (*Cordiceramus*) *paraheberti* Sornay; NODA & KANIE, p. 24, pl. 2, fig. 1.
v. 2001 *Cordiceramus paraheberti* (Sornay); WALASZCZYK *et al.*, p. 134, pl. 2, figs 5-6; pl. 4, fig. 1.

TYPE: the holotype, by original designation, is MNHN R61298 (specimen no 722 BA) the original of SORNAY (1968, pl. G, figs 1-2) from the Lower Campanian of Ampamba – Antsirasira, Madagascar Republic.

MATERIAL: three specimens: IRSN-TC MI 10942, 10967, 10943.

DESCRIPTION
All three specimens are internal moulds of more or less complete single valves. Only IRSN-TC MI 10943 shows the general subquadrate outline of the valve well; the other two specimens are deformed and/or incomplete. Well seen is the ornament composed of regular commarginal rugae, sharp-topped, with relatively wide interspaces, growing gradually ventrally. The radial sulcus, characteristic for the species, rather weakly developed. In the antero-ventral parts of the valves the growth lines obliquely cross the rugae.

REMARKS
As mentioned already by SORNAY (1968), in the original description of his new species, *Cordiceramus paraheberti* belongs to the *Co. muelleri* group and is very similar to forms like *Co. muelleri recklingensis* or originals of *Co. heberti* (FALLOT, 1885) and *Inoceramus crippsi* var. *regularis in* ZITTEL (1866, pl. 14, fig. 3). Although some of the specimens referred to *Co. muelleri recklingensis* are really very close to *Co. paraheberti* (e.g. SEITZ 1961, pl. 8, fig. 4 ; pl. 15, fig. 2) the type of the species differs slightly, being more obliquely ovate rather than subquadrate, as in the case of SORNAY's species. FALLOT's species seems to be more ventrally elongated. We refer the Houthalen specimens to SORNAY's species, admitting however, that the relationship between these particular species is not clear.

OCCURRENCE: SORNAY (1968) described *Cordiceramus paraheberti* from the Lower and lower Middle Campanian of Madagascar. Also the species was reported from the upper Lower Campanian of the US Western Interior (WALASZCZYK *et al.* 2001).

Genus *Sphenoceramus* BOEHM, 1915
Type species: *Inoceramus cardissoides* GOLDFUSS (1836, p. 112, pl. 110, fig. 2) by subsequent designation of VIALOV *et al.* (1960).

Sphenoceramus pachti (ARKHANGELSKY, 1912)
(Pl. 1, Figs. B,G)

* 1912 *Inoceramus pachti* sp.n., ARKHANGELSKY, p. 171.
1916 *Inoceramus cardissoides* subsp. *pachti* Arkhangelsky ; ARKHANGELSKY, p. 18, pl. 3, figs 2-4.
v. 1965 *Inoceramus* (*Sphenoceramus*) *pachti* Archangelski; SEITZ, p. 48, pls 5-9. (and literature cited therein).
v. 1992 *Sphenoceramus pachti* (Archangelski); WALASZCZYK, p. 59, pl. 41, figs 5-7.

TYPE: the lectotype, by subsequent designation of SEITZ (1965), is the original of ARKHANGELSKY (1912, pl. 3, fig. 2) from Chembar, Pensa Oblast, European Russia (SEITZ did not interpret the text of ARKHANGELSKY correctly – nowhere did ARKHANGELSKY indicate that Chembar is situated in Turkestan).

MATERIAL: two specimens from the interval 583-585 m: IRSN-TC MI 10941 and 10940.

DESCRIPTION
IRSN-TC MI 10940 is an incomplete internal mould of the RV, with the antero-dorsal part missing, whereas IRSN-TC MI 10941 is a somewhat more complete internal mould of the LV, with not-exposed/not preserved ? postero-dorsal part. Both specimens show long antero-ventral margin, passing into narrow, rounded ventral margin. Well seen is the radial sulcus in the posterior part of the disc. The posterior auricle is partly preserved in IRSN-TC MI 10940.

The main commarginal rugae are well preserved in both specimens, the ribs up to 3 in inter-rugae spaces, are seen in IRSN-TC MI 10941. The radial ornament weakly visible; both specimens show the crenulation of the rugae ridges.

REMARKS
The details of the ornament are poorly preserved, hindering a more precise taxonomic discussion. Both specimens seem to have rather weak radial ornament; IRSN-TC MI 10941 shows the type of ornament resembling the subspecies *S. pachti reticulus* HEINZ, as discussed by SEITZ (1965, p. 61).

OCCURRENCE: SEITZ (1965) marked the species *Sphenoceramus pachti* almost throughout the whole Santonian (and in the current definition of the Coniacian / Santonian boundary through the topmost Coniacian). The species, however, is usually absent (or extremely rare) in the Upper Santonian, as already shown by TRÖGER (1989).

Sphenoceramus patootensiformis (SEITZ, 1965)
(Pl. 1, Figs. A, D)

*v. 1965 *Inoceramus* (*Sphenoceramus*) *patootensiformis* n.sp.; SEITZ, p. 107, pl. 20, figs 1-2;, pl. 21, fig. 2; pl. 22, fig. 2; pl. 23, figs 2-3; pl. 24, figs 1-2, 4; pl. 25, fig. 2. (and literature cited therein).
v. 1992 *Sphenoceramus patootensiformis* (Seitz); WALASZCZYK, p. 61, pl. 39, figs 2-3; pl. 40, fig. 3.

TYPE: the holotype, by original designation, is the specimen of WEGNER (1905, pl. 10, fig. 1; re-illustrated by SEITZ 1965, pl. 25, fig. 2) from the *patootensiformis* Zone (lower Lower Campanian) of Haltern (Westphalia, northern Germany).

MATERIAL: two specimens: IRSN-TC MI 10938 and 10939.

DESCRIPTION AND REMARKS
IRSN-TC MI 10938 is a very incomplete outer cast of the juvenile part, with umbo and anterior part missing; shell-fragments are still attached. The characteristic ornament and the general outline enable, in spite of the very frag-

mentary preservation, a convincing taxonomic determination of this specimen. The second specimen, IRSN-TC MI 10939 is much better preserved. It is a 120 mm long LV, with the anterior and dorsal parts missing. The preserved ventral part preserves the ornament with main and secondary rugae, characteristic for SEITZ' species, and forming a broad and long antero-ventral curve, that distinguishes the species from the very similar *Sphenoceramus angustus* (BEYENBURG, 1936).

OCCURRENCE: the species appears at the base of the *Marsupites* Zone and ranges to the top of the lower Lower Campanian (e.g. SEITZ, 1965; TRÖGER, 1989; WALASZCZYK, 1992; REMIN, 2004).

Genus *Platyceramus* HEINZ, 1932
Type species: *Inoceramus mantelli* (DE MERCEY) BARROIS, 1879, p. 454, pl. 4, fig. 1.

Platyceramus* ex gr. *cycloides (WEGNER, 1905)
(Pl. 1, Fig. H)

TYPE: the lectotype is the original of WEGNER (1905, text-fig. 6) from the Santonian of the Blumenthal mineshaft near Recklinghausen (Ruhr, northern Germany).

MATERIAL: a single specimen, IRSN-TC MI 10945.

DESCRIPTION
IRSN-TC MI 10945 is an incompletely preserved internal mould of a RV, with the ventral and postero-ventral parts missing. Preserved is the ligamental plate, clearly showing fine ligamental pits and ridges. The valve is prosocline, with the umbo curved dorsally; it does not project above the hinge line. The hinge line is long and straight. The anterior margin is not completely preserved; as may be inferred from the preserved part, it is broadly convex and relatively long. The valve is weakly inflated, with maximum inflation in the dorsal part. The posterior auricle is not separated from the disc. The ornament is composed of fine, closely and seemingly regularly spaced, round-topped rugae; the increase of interspaces ventralwards is very slow.

REMARKS
It is a single and incomplete specimen and a more precise identification is not possible.

OCCURRENCE: the group of *Platyceramus cycloides* appears very low in the Santonian and ranges high into the Campanian (SEITZ 1961, 1967) at least up to the top of the *Bostrychoceras polyplocum* Zone (see WALASZCZYK, 2004).

Platyceramus* cf. *pierrensis
(WALASZCZYK, COBBAN & HARRIES, 2001)
(Pl. 2, Figs B,C;? Text fig.3 A)

1896 *Inoceramus sagensis* Owen; GILBERT, p. 56, fig. 2.

*v. 2001 "*Inoceramus*" *pierrensis* sp. nov., WALASZCZYK *et al.*, p. 206, pl. 12, fig. 14; pl. 14, figs 1, 3, 5; pl. 15, fig. 4; pl. 16, fig. 1

v. 2004 *Platyceramus* cf. *pierrensis* (Walaszczyk, Cobban & Harries); WALASZCZYK, p. 133, text-fig. 27.

TYPE: by original designation, the holotype is USNM 507740, the original of WALASZCZYK *et al.* (2001, pl. 14, fig. 1) from the *Baculites scotti* ammonite Zone of the Red Bird section, Wyoming, Western Interior, USA.

MATERIAL: three specimens: IRSN-TC MI 10948, 10947 and 15.518-530 (10964).

DESCRIPTION
All three specimens are internal moulds of single valves; only small fragments of the ligamental plate are preserved in IRSN-TC MI 10947 and 15.518-534.

IRSN-TCMI 10947 is a huge LV, with maximum preserved h = 140 mm, and the interpolated axial length above 250 mm. The valve is prosocline, with the beak curved dorso-anteriorly, projecting slightly above the hinge line, and moderately oblique, with adult δ approximately 50°. Anterior margin is straight and relatively short; its length consists approximately of 45% of the respective axial length. It passes then into broadly rounded antero-ventral margin. Posterior margin not preserved. As may be observed in these large specimens, up to the axial length of around 100 mm the anterior face is very low; then it starts to grow perpendicularly to the lateral surface. The posterior auricle is not separated from the disc. The valve is covered with widely spaced and low commarginal rugae. Further details of the ornament are not preserved.

15.518-534 is a RV of moderate size with maximum axial length preserved h = 95 mm. The valve is moderately oblique, with adult δ approximately 50°. Similarly as IRSN-TC MI 10947 it possesses a relatively short anterior margin, comprising less than 50% of the respective axial length, and passing into a broadly rounded antero-ventral margin. The ventral and posterior margins are not preserved. The valve is laterally compressed, but this does not influence the external valve outline. The anterior face is low because the specimen is relatively small-sized. The valve ornament is composed of low, widely spaced rugae; as seen in the part of the valve, the rugae were superimposed by evenly and closely spaced growth lines.

The third specimen, 105 mm in preserved axial length, is referred to here with a question mark. It is of similar valve outline and apparently it is similarly ornamented. However, its poor preservation does not allow an unequivocal determination.

REMARKS
Distinctly oblique outline and widely spaced low rugae, with flat-floored interspaces are the most characteristic features of the species.

OCCURRENCE: the species is known from the *Baculites scotti* through *Exiteloceras jennyi* ammonite zones of the upper Middle and lower Upper Campanian of the US Western Interior. Recently reported from the lower part of the "*Inoceramus*" *tenuilineatus* Zone (=lower part of the *Didymoceras donezianum* ammonite Zone) of the Middle Vistula section, central Poland.

Genus *Cataceramus* HEINZ, 1932
Type species: *Inoceramus balticus* BÖHM (1909, pl. 11, fig. 2) from the Lower Campanian of Dülmen (Westphalia, northern Germany).

Cataceramus goldfussianus (D'ORBIGNY, 1847) (Pl. 3, Fig. D)

*v.	1847	*Inoceramus Goldfussianus* D'ORBIGNY, p. 517, pl. 411, figs 1-2.
v.	2004	*Cataceramus goldfussianus* (D'ORBIGNY); WALASZCZYK, p. 115, text-figs 9S-E, 10A-C, ?11A, 12A-C, E-F (and literature cited therein).

TYPE: the lectotype, by subsequent designation (SORNAY 1957) is the original to D'ORBIGNY (1847, pl. 411, figs 1-2), MNHN d'Orbigny coll. 7593, from the Upper Campanian of Royan (Charente-Maritime, SW France).

MATERIAL: two specimens: IRSN-TC MI 10968 and 10962.

DESCRIPTION AND REMARKS
Both specimens are internal moulds of single LV. IRSN-TC MI 10962 is slightly deformed; a pseudogeniculation is developed in the juvenile stage. Both specimens show the characteristic of the species well: the subquadrate to postero-ventrally elongated outline, commarginal rugae, with rugae growing gradually ventralwards. The valves are prosocline with the umbo slightly curved posteriorly.

OCCURRENCE: The species is known from the upper Upper Campanian of Europe and North America.

Cataceramus mortoni (MEEK & HAYDEN, 1860) (Pl. 2, Fig A, Text fig 3 C)

non	1856	*Inoceramus proximus* TOUMEY, p. 171 [*nomen nudum*]
*v.	1876	*Inoceramus proximus* Toumey?; MEEK, p. 53, pl. 12, fig. 7a, b.
non	1984	*Inoceramus proximus* Toumey; BALAÑOS & BUITRON, p. 411, pl. 1, fig. 5.
v.	2001	*Cataceramus mortoni* (Meek & Hayden, 1860); WALASZCZYK *et al.*, p. 150, pl. 7, figs 2-3, 6; pl. 11, figs 6-8, 10, 12.
v.	2002	*Cataceramus mortoni* Meek; WALASZCZYK *et al.*, p. 282, pl. 1, fig. 4.
v.	2004	*Cataceramus* cf. *mortoni* (Meek & Hayden); WALASZCZYK, p. 117, text-fig. 22B.

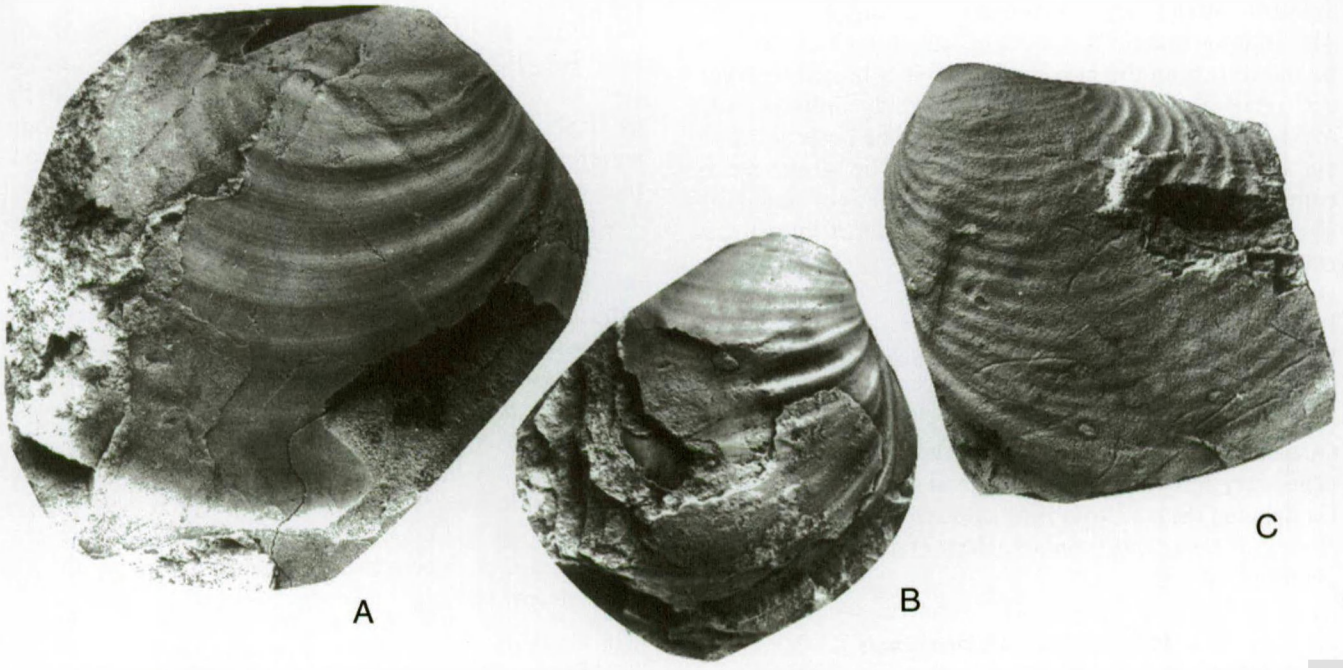

Fig. 3 — A - ? *Platyceramus* cf. *pierrensis* (WALASZCZYK, COBBAN & HARRIES, 2001), IRSN-TC MI 10964; B - "*Inoceramus*" *tenuilineatus* HALL & MEEK, 1856, IRSN-TC MI 10965; C - *Cataceramus mortoni* (MEEK & HAYDEN, 1860), IRSN-TC MI 10966. All figures are natural size.

TYPE: the holotype is the original of MEEK (1876, pl. 12, fig. 7 – USNM 481) from the *Baculites gregoryensis – Baculites scotti* ammonite Zones of the Middle/Upper Campanian boundary interval (in the American tripartite subdivsion of the stage), of the Great Bend of the Missouri River, below Fort Pierre (South Dakota, USA).

MATERIAL: a single specimen, IRSN-TC MI 10966, 10946)

DESCRIPTION AND REMARKS

IRSN-TC MI 10966 is a moderately well preserved internal mould of a LV. The valve is of moderate size (h = 68 mm), prosocline, with the beak curved antero-dorsally. The hinge line is straight and of moderate size in the juvenile stage, and seemingly of moderate size in the adult as suggests the outline of the rugae; as the hinge line is very incomplete it cannot directly be measured. The anterior margin is relatively short and convex, passing into a broadly convex antero-ventral margin. The ventral and postero-ventral margins are not preserved. The valve is covered with closely and regularly spaced fine commarginal rugae.

OCCURRENCE: in the US Western Interior the species is known from the upper Middle and basal Upper Campanian (in the tripartite American scheme) from the upper *Baculites perplexus* up to *Didymoceras nebrascense* ammonite zones. It is also known from the "*Inoceramus*" *tenuilineatus* Zone of the Middle Vistula section (WALASZCZYK 2004) and was also reported from Tercis, SW France (WALASZCZYK *et al.* 2002) presumably from the same level.

Cataceramus ex gr. *balticus* (BOEHM, 1907)
(Pl. 2, Fig. D)

MATERIAL: a single specimen, IRSN-TC MI 10949.

DESCRIPTION AND REMARKS

The studied specimen is an internal mould, of moderate size (hmax = 65 mm) of a single LV. The valve is elongated postero-ventrally, moderately oblique (d = 35°) with a small beak, projecting slightly above the hinge line. The hinge line is straight and long. It shows regularly spaced commarginal rugae, weakening in the most postero-ventral part.

When compared with the type of the species (i.e. GOLDFUSS' 1835, pl. 112, fig. 4a specimen; re-illustrated *in* BOEHM 1909, pl. 11, fig. 2) our specimen is a little bit more oblique and its ornament weakens rather quickly ventralwards. Otherwise it corresponds well even to the concept of the BOEHM species as narrowly defined by GIERS (1964, p. 238), i.e. to his *Cataceramus balticus balticus*. Because we have only a single and rather juvenile specimen we refrain, however, in giving such a very precise determination, as the specimen can easily belong to a population of any other species of the group, as e.g. *Ca. subcompressus* (MEEK & HAYDEN, 1860) or *Ca. marcki* (GIERS, 1964).

OCCURRENCE: the *balticus* group is known from the Upper Santonian and from the Lower and lower Upper Campanian of Europe and North America.

Cataceramus palliseri (DOUGLAS, 1942)
(Pl. 2, Fig E; Pl. 3, Figs. B, C)

v. 1847 *Inoceramus regularis* D'ORBIGNY, p. 516, pl. 410, figs 1-2.
. 1942 *Inoceramus palliseri* DOUGLAS, p. 62, pl. 1, fig. 2.
v. 2001 *Cataceramus ? palliseri* (Douglas); WALASZCZYK *et al.*, p. 162, pl. 27, fig. 2 ; pl. 33, fig. 2 ; pl. 37, fig. 1 [and references cited therein].
v. 2002 *Cataceramus ? palliseri* (Douglas); WALASZCZYK et al., p. 283, pl. 8, figs 1-2 ; pl. 10, fig. 4.
v. 2004 *Cataceramus palliseri* (Douglas); WALASZCZYK, p. 119, text-fig. 14.

TYPE: the holotype, by original designation is GSC 8928, the original of DOUGLAS (1942, pl. 1, fig. 2) from Boxelder Creek (Saskatchewan, Canada).

MATERIAL: at least three specimens : IRSN-TC MI 10954, 10953, 10950.

DESCRIPTION

The species is represented by three single valves, all internal moulds of moderate size. All valves are distinctly geniculated. The juvenile parts, from the umbo to the geniculation line, are weakly inflated, posteriorly elongated, with broadly convex growth axis, what causes growing obliquity during ontogeny. The umbo is small, located anteriorly, projecting very slightly above the hinge line. The hinge line is straight and long. The anterior margin is short, slightly convex and passes into broadly convex antero-ventral margin, and thence into more regularly rounded ventral margin; the posterior margin is also convex. The adult part, ventralwards of the geniculation line, is only partly preserved, best in IRSN-TC MI 10954..

The juvenile stage is convered with regularly and closely spaced commarginal rugae, with interspaces increasing gradually ventralward.

REMARKS

The Houthalen specimens are identical to D'ORBIGNY's type of *Inoceramus regularis* (MNHN, d'Orbigny coll. 7594-1) (see e.g. SORNAY 1962, pl. 7, fig. 3), which falls into synonymy of DOUGLAS' species. The name *regularis* was shown to be pre-occupied by DHONDT (1993), who proposed an exchange name *Selenoceramus sornayi*. Then it was shown that D'ORBIGNY's form is conspecific with DOUGLAS' (1942) *Inoceramus palliseri* (WALASZCZYK *et al.* 2001).

OCCURRENCE: the species is known from the upper Upper Campanian of Europe and North America.

Species referred to the genus "*Inoceramus*" sensu lato

"*Inoceramus*" *borilensis* JOLKICEV, 1962
(Pl. 4, Figs B, F-G)

* 1962 *Inoceramus borilensis* nov.sp.; JOLKICEV, p. 145, pl. 7, fig. 1.
v. 1982 *Inoceramus borilensis* Jolkicev; SORNAY, p. 9. Pl. 3, fig. 2; *non* pl. 3, fig. 1.
v. 2001 "*Inoceramus*" *borilensis* Jolkicev; WALASZCZYK, p. 142, text-figs 20F, 32. (and literature cited therein).

TYPE: the holotype, by original designation, is the original of JOLKICEV (1962, pl. 7, fig. 1) from the Campanian of Medven (Bulgaria).

MATERIAL: three specimens: IRSN-TC MI 10958, 10960, 10959.

DESCRIPTION
All three specimens are internal moulds of juvenile and neck stages with attached youngest parts of the adult stages. The juveniles stages are strongly oblique, and markedly elongated postero-ventrally. The hinge-line is long and straight. Very short or short, regularly curved anterior margin passes invariably into a very long, broadly convex antero-ventral margin. Ventral margin, as seen in IRSN-TC MI 10959 and 10958 is narrow and rounded. IRSN-TC MI 10959 has a poorly preserved "holhkehle", which starts in the medium part of the juvenile stage and continues further ventralwards onto the neck stage. It is located precisely in the line of the growth axis. Minute shell fragments are attached in the ventral part of IRSN-TC MI 10959.

The juvenile ornament is composed of the regularly spaced, commarginal, closely spaced rugae; they start to weaken or disappear completely on the neck part.

DISCUSSION
More complete and better preserved specimens of "*Inoceramus*" *borilensis* from the Houthalen section were described and illustrated by SORNAY (1982, pl. 2, fig. 1; pl. 3, figs 2-3). However, the three specimens treated herein show, the juvenile and early adult stages of the species well.

OCCURRENCE: the species is widely known in the lower Upper Campanian of Europe, from the *basiplana/stobaei* Zone (in Westphalia – see WALASZCZYK 1997) up to the *Sphaeroceramus pertenuiformis* Zone, as evidenced in Tercis, SW France (WALASZCZYK *et al.* 2002) and in the Vistula section, central Poland (WALASZCZYK, 2004). The Campanian age was also suggested for the type Bulgarian material of JOLKICEV (1962) dated originally for the Early Maastrichtian (see Walaszczyk, Lees & Jolkicev in prep.).

"*Inoceramus*" cf. *scotti*
WALASZCZYK, COBBAN & HARRIES, 2001
(Pl. 3, Fig.?E; Pl. 4, Fig. E)

*v. 2001 "*Inoceramus*" *scotti* sp.nov., WALASZCZYK *et al.*, p. 204, pl. 9, figs 1-3.

TYPE: the holotype, by original designation, is USNM 507529, the original to WALASZCZYK *et al.* (2001, pl. 9, fig. 2) from the *Baculites scotti* ammonite Zone of the topmost Middle Campanian (in the tripartite North American subdivision of the stage) of Tom Hollow (Pueblo County, Colorado, USA).

MATERIAL: a single specimen, IRSN-TC MI 10963 (and perhaps 15.518-530 10955).

DESCRIPTION
The studied specimen is an internal mould of a relatively large single LV. The valve is incomplete in the antero-ventral part, and slightly deformed, what caused its 'bulbous' shape in the dorsal part. No shell fragments are attached; the surface ornament is well preserved.

The valve is large – its maximum axial length attains 126 mm – moderately oblique, with the δ angle being approximately 45°. The valve outline is obliquely subrounded, with relatively short anterior and dorsal margins, and a long and broadly convex antero-ventral margin. The ventral margin is regularly rounded. The outline and original shape of the umbonal area was changed due to subsequent deformation, but the umbo itself is apparently small, projecting slightly above the straight and relatively short hinge line. The posterior auricle is small and weakly separated from the disc.

The valve is covered with relatively widely and evenly spaced rugae, which are round-topped, and symmetrical in cross sections. In the juvenile and adult stages well preserved on the mould surface are regular, fine growth lines; they disappear at the most ventral part.

REMARKS
The general outline and the ornament in the studied specimen are identical to the American type (see WALASZCZYK *et al.* 2001, pl. 9, fig. 2). Some differences in the general architecture are due to subsequent deformation of the Houthalen specimen. To this species belongs possibly also 10955 (Pl. 3,Fig. E). It shows a very similar outline and the type of the ornament. Its much weaker inflation and much less vigorous ornament may easily be because of subsequent lateral compression.

OCCURRENCE: it is known from the *Baculites scotti* ammonite Zone of the topmost Middle Campanian (in the tripartite American subdivision of the stage) and from the Houthalen section.

"Inoceramus" tenuilineatus HALL & MEEK, 1856
(Pl. 3, Fig F; Pl. 4, Fig C; Text fig, 3 B)

*v. 1856 *Inoceramus tenuilineatus* HALL & MEEK, p. 387, pl. 2, fig. 3.
v. 2004 *"Inoceramus" tenuilineatus* HALL & MEEK; WALASZCZYK, p. 157, text-fig. 20D [and literature cited therein]

TYPE: the lectotype, by subsequent designation of WALASZCZYK *et al.* (2001) is AMNH 0362/1, from the topmost Middle Campanian (in the North American tripartite Campanian substage subdivision) *Baculites gregoryensis – Baculites scotti* ammonite Zones of the Great Bend of the Missouri River (South Dakota, USA).

MATERIAL: five specimens: IRSN-TC MI 10956, 10969, 10961, 10965, 10970

DESCRIPTION
All five specimens are internal moulds of single valves. Small shell fragments are attached to IRSN-TC MI 10965 and to 10969. The species is inequilateral, ?equivalve, of small to moderate size. The valve is prosocline, with the beak projecting moderately above the hinge line. The hinge line is short and straight. The anterior margin is short, convex or straight, passing into a very long, broadly convex antero-ventral margin, and thence into a rounded ventral margin. In the studied specimens the posterior margin is either incomplete or deformed. The posterior auricle is small, weakly separated from the disc.

The valve is ornamented with irregularly spaced rugae; more regular ornament occurs only in the juvenile stage. IRSN-TC MI 10961 shows a weak geniculation.

REMARKS
"Inoceramus" tenuilineatus HALL & MEEK resembles *Sphaeroceramus sarumensis* (WOODS, 1912). Compressed specimens, preserved as internal moulds, are difficult to separate. The American species has a more slender disc, a straight to concave anterior margin, and lacks the anterior ear. The latter, however, is a delicate part and may be lacking to due to secondary detachment.

OCCURRENCE: *"I." tenuilineatus* appears in the latest Middle Campanian of the US Western Interior, and is known from the basal *Didymoceras donezianum* ammonite Zone of Europe.

"Inoceramus" nebrascensis OWEN, 1852
(Pl. 3, Figs A, D; Pl. 4, Fig. A)

*v. 1852 *Inoceramus Nebrascensis* (N.S.); OWEN, p. 582, pl. 8A, fig. 1.
v. 2004 *"Inoceramus" nebrascensis* OWEN; WALASZCZYK, p. 151, text-figs 38-39 [and references therein]

TYPE: by monotypy, the holotype is the original of OWEN (1852, pl. 8A, fig. 1), USNM 20247, from the Campanian of Sage Creek (Pennington County, South Dakota, USA).

MATERIAL: three specimens: IRSN-TC MI 10951, 10952, 10957.

DESCRIPTION AND REMARKS
All three specimens are represented by single valve internal moulds; tiny shell fragments are attached to the dorsal part of IRSN-TC 10957. The specimens belong to juvenile and early adult fragments. The valves are moderately prosocline with subquadrate to subrectangular outline, moderately inflated. The ornament is composed of irregular, low rugae in the juvenile part and the valves are almost smooth in later stages. Often the geniculation step (with closely spaced positive and negative geniculation following) is observed at approximately the juvenile/ adult stage junction (see e.g. Pl. 3, Fig. D).

OCCURRENCE: the species is known from the lower Upper Campanian of the US Western Interior (in the tripartite American subdivision of the stage). Also reported from the upper part of the *Didymoceras donezianum* Zone of the Middle Vistula section, central Poland.

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Explanation of plates

PLATE 1

Figures A, D — *Sphenoceramus patootensiformis* (SEITZ, 1965); A – IRSN-TC MI 10938; D – IRSN-TC MI 10939;
Figures B, G. — *Sphenoceramus pachti* (ARKHANGELSKY, 1912); B – IRSN-TC MI 10940; G – IRSN-TC MI 10941;
Figures C, E — *Cordiceramus* cf. *paraheberti* (SORNAY, 1968); C – IRSN-TC MI 10942; D – IRSN-TC MI 10943;
Figure F — *Cordiceramus* ex gr. *cordiformis* (J. DE C. SOWERBY, 1823), IRSN-TC MI 10944;
Figure H — *Platyceramus* ex gr. *cycloides* (WEGNER, 1905), IRSN-TC MI 10945.
All figures are natural size

PLATE 2

Figure A — *Cataceramus mortoni* (MEEK & HAYDEN, 1860), IRSN-TC MI 10946;
Figures B, C — *Platyceramus* cf. *pierrensis* (WALASZCZYK, COBBAN & HARRIES, 2001); B – IRSN-TC MI 10947; C – IRSN-TC MI 10948;
Figure D — *Cataceramus* ex gr. *balticus* (BOEHM, 1907), IRSN-TC MI 10949;
Figure E — *Cataceramus palliseri* (DOUGLAS, 1942), IRSN-TC MI 10950.
All figures are natural size

PLATE 3

Figures A, D — "*Inoceramus*" *nebrascensis* OWEN, 1852; A – IRSN-TC MI 10951; D – IRSN-TC MI 10952;
Figures B, C — *Cataceramus palliseri* (DOUGLAS, 1942); B – IRSN-TC MI 10953; C – IRSN-TC MI 10954;
Figure E — ?"*Inoceramus*" cf. *scotti* WALASZCZYK *et al.*, 2001, IRSN-TC MI 10955;
Figure F — "*Inoceramus*" *tenuilineatus* HALL & MEEK, 1856, IRSN-TC MI 10956.
All figures are natural size

PLATE 4

Figure A — "*Inoceramus*" *nebrascensis* OWEN, 1852, IRSN-TC MI 10957;
Figures B, F, G — "*Inoceramus*" *borilensis* JOLKICEV, 1962; B – IRSN-TC MI 10958; F – IRSN-TC MI 10959; G – IRSN-TC MI 10960;
Figure C — "*Inoceramus*" *tenuilineatus* HALL & MEEK, 1856, IRSN-TC MI 10961;
Figure D — *Cataceramus goldfussianus* (D'ORBIGNY, 1847), IRSN-TC MI 10962;
Figure E — "*Inoceramus*" cf. *scotti* WALASZCZYK *et al.*, 2001, IRSN-TC MI 10963.
All figures are natural size

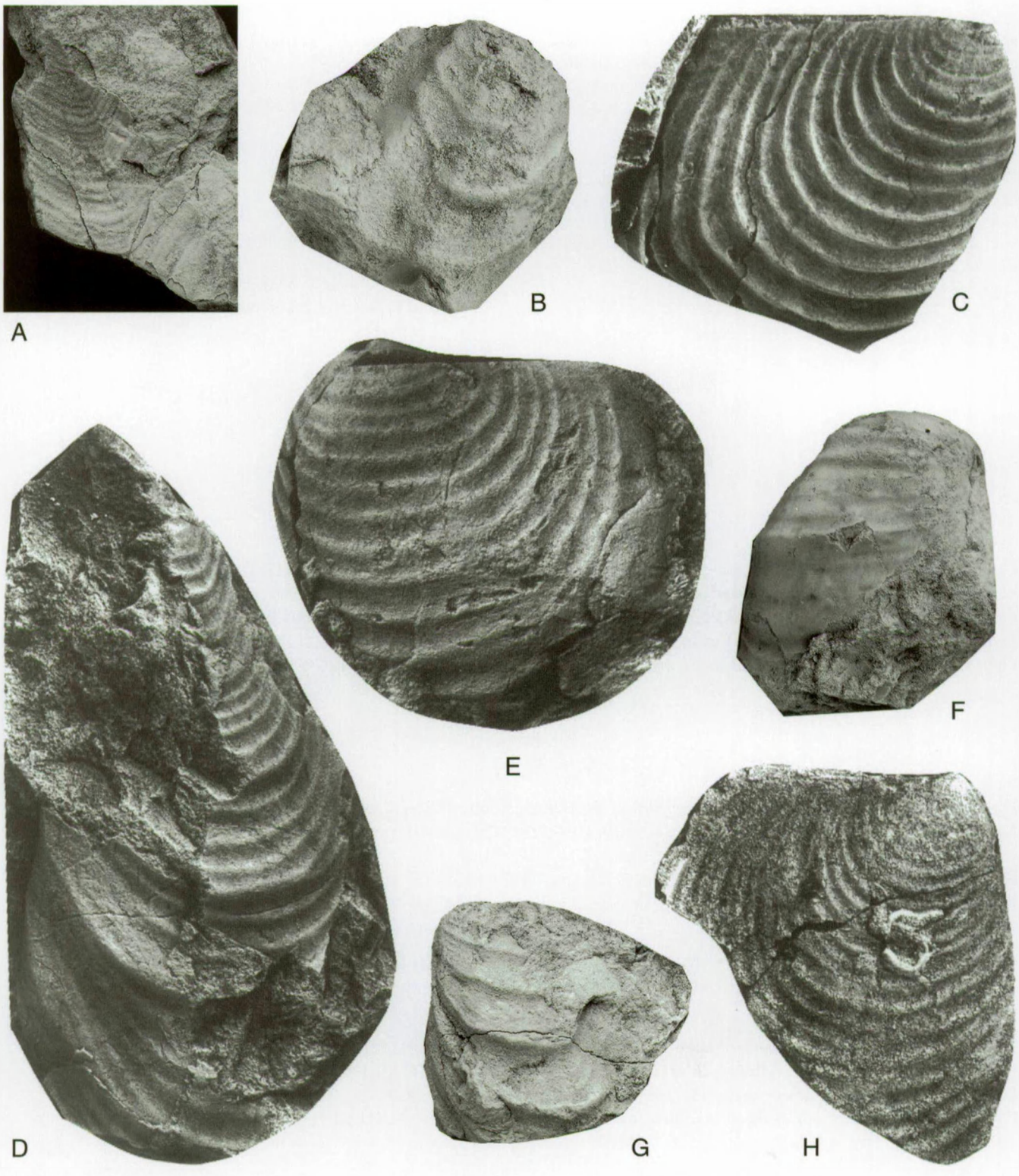
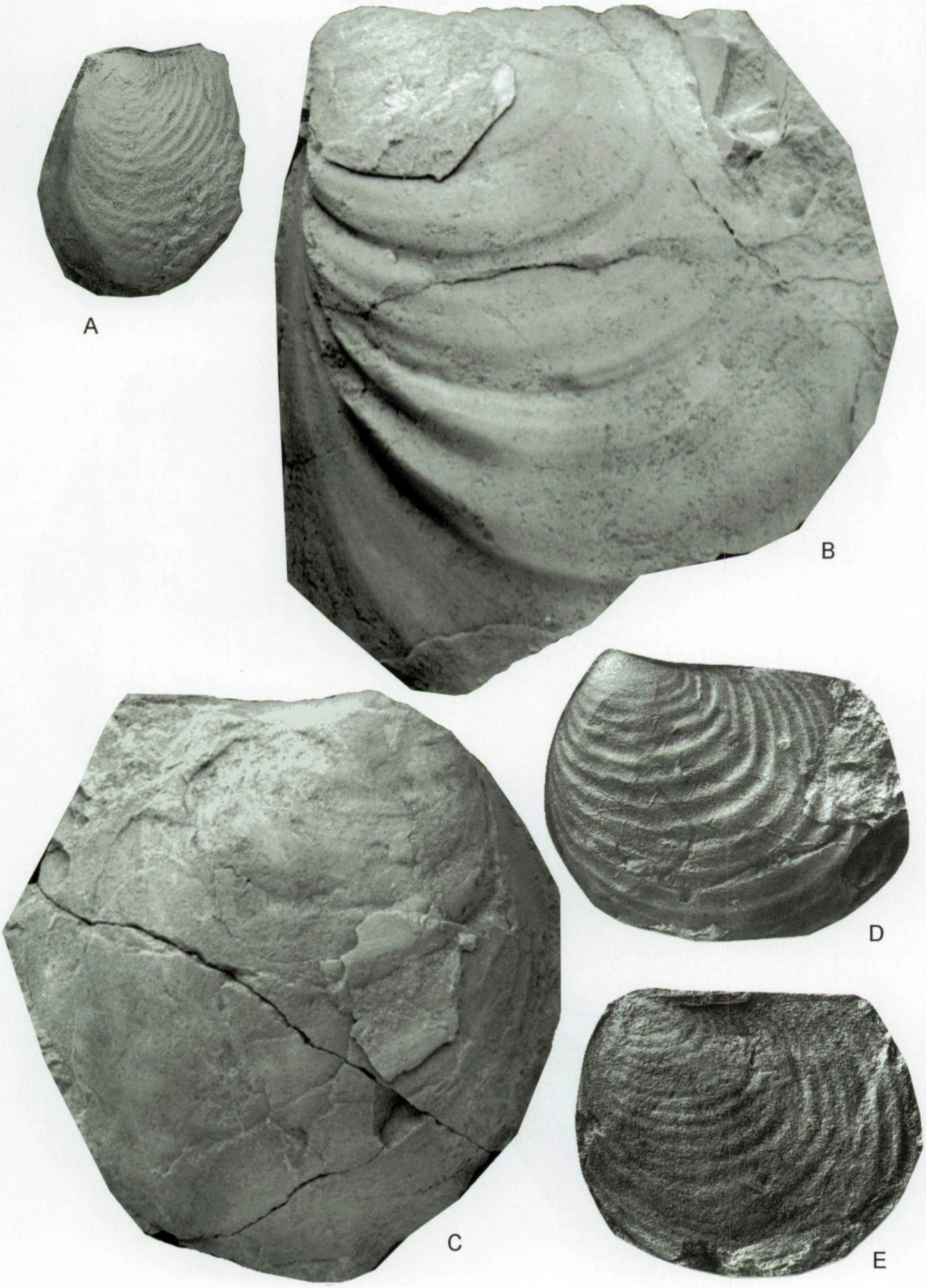


PLATE 1



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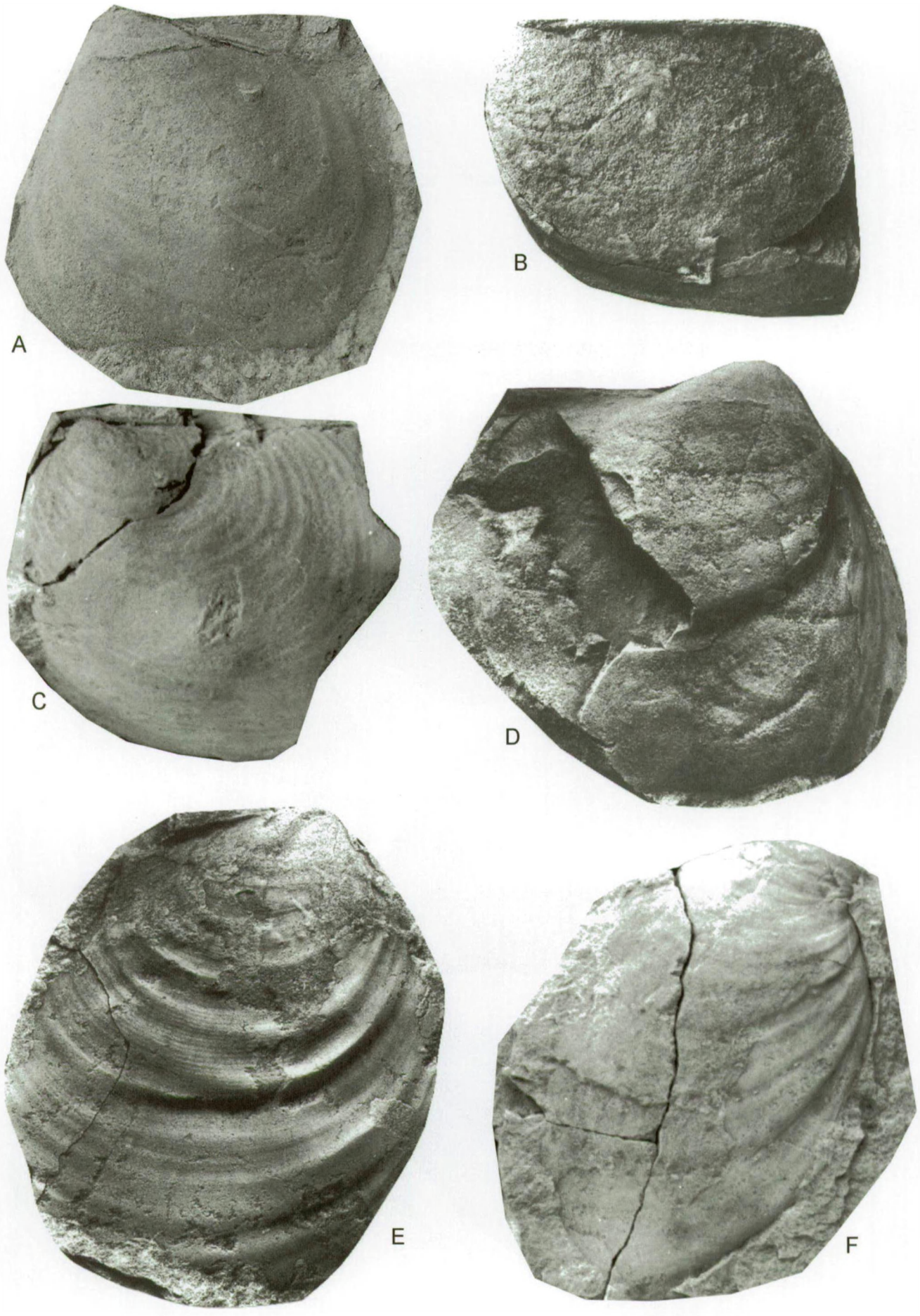

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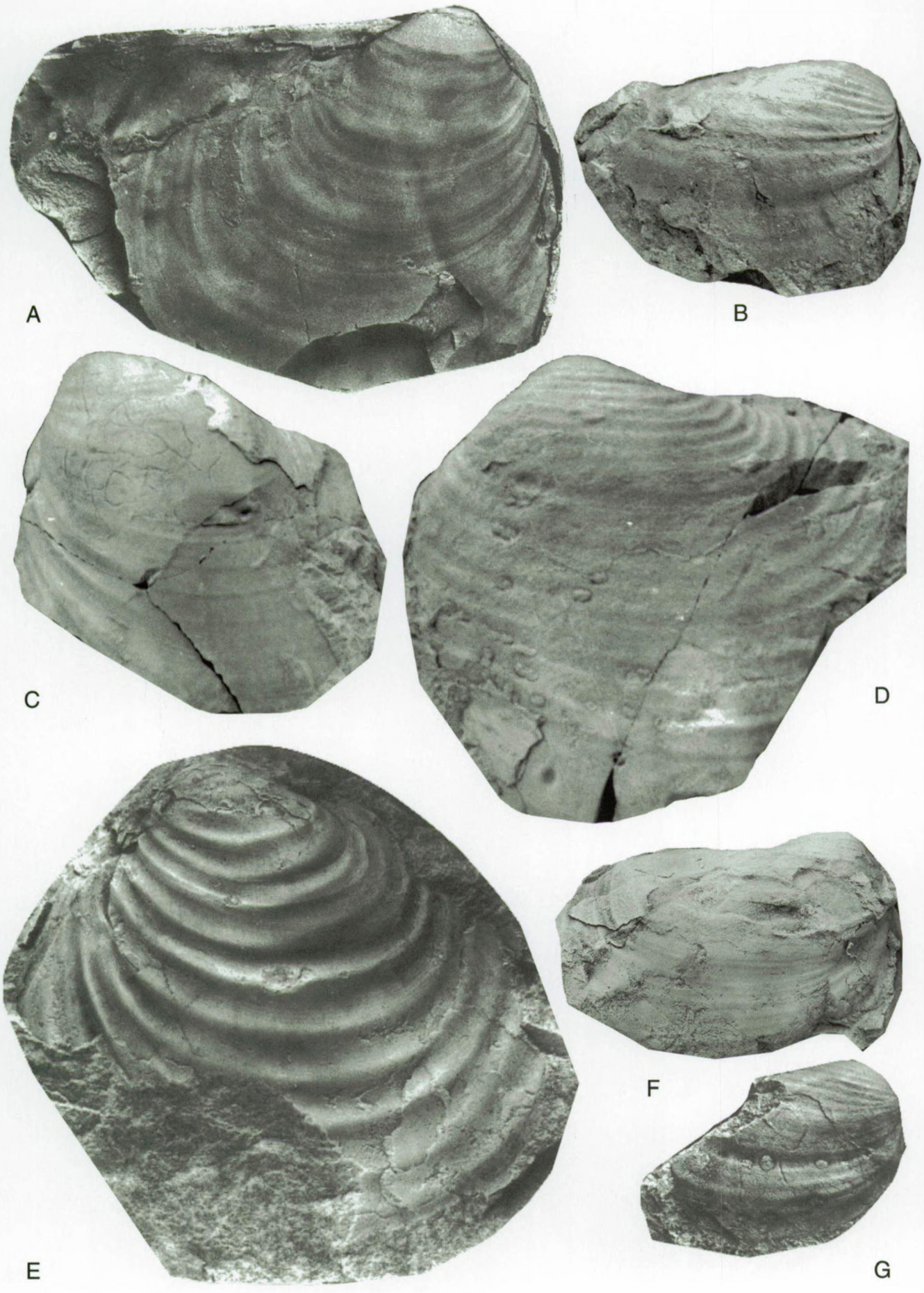

PLATE 4