

Santonian macrofauna and nannofossils from northeast Belgium

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Abstract

From a limited number of mine shafts in the Belgian province of Limburg (Houthalen and Zolder/Voort areas), a small fauna comprising ammonites, belemnites and inoceramid bivalves is described. A nannofossil analysis of samples taken from the ammonites is added. This assemblage is of (late) middle to late Santonian age, and thus roughly corresponds to the 'Craie de Loncée' (province of Namur, Belgium) and the Aachen Formation of the Aachen-Vaals area (SE Netherlands and Germany).

Key-words: Cephalopoda, Bivalvia, nannofossils, late Cretaceous, biostratigraphy.

Résumé

De quelques charbonnages du Limbourg belge (Houthalen et Zolder-Voort) une faunule d'ammonites, belemnites et inocérames a été étudiée. Les nannofossiles des échantillons d'ammonites ont été identifiés. L'assemblage est d'âge Santonien moyen (supérieur) à supérieur et peut ainsi être comparé à la "Craie de Loncée" (province de Namur, Belgique) et à la Formation d'Aix-la-Chapelle de la région d'Aix-la-Chapelle - Vaals (SE des Pays-Bas et Allemagne).

Mots-clefs: Céphalopodes, bivalves, nannofossiles, Crétacé supérieur, biostratigraphie.

Introduction

During a revision of the ammonite fauna of the type Maastrichtian (KENNEDY, 1987a), it was noted that the collections of the Institut royal des Sciences naturelles de Belgique at Brussels also comprised ammonite faunules of Santonian age not previously described. These limited faunas were collected during the construction of mine shafts of the former Houthalen and Zolder/Voort collieries (Limburg, NE Belgium) (Text-fig. 1). Labels with the specimens state locality and depth below surface; other than this there are no stratigraphic details. In order to refine the dating it was decided to add data taken from belemnites and inoceramid bivalves from the same shafts and depths and to remove quantities of matrix for nannofossil analysis.

These faunas are of importance mainly in a broader context, in being roughly coeval with the "Glaucanie de Loncée" (CHRISTENSEN, 1994; MALCHUS *et al.*, 1994) of

Namur province (Belgium) and (part of) the Aachen Formation as exposed in the Dutch-Belgian-German borderland southwest of Aachen-Vaals (BATTEN *et al.*, 1988).

Material

All specimens are housed in the collections of the Institut royal des Sciences naturelles de Belgique at Brussels and generally bear IG registration numbers. The figured specimens have been transferred and renumbered to form part of type collections.

Systematic descriptions

AMMONOIDEA

Superfamily Hoplitaceae DOUVILLÉ, 1890
Family PLACENTICERATIDAE HYATT, 1900
Genus *Placenticerus* MEEK, 1876

TYPE SPECIES: *Ammonites placenta* DEKAY, 1828, p. 278, by original designation of MEEK (1876, p. 426).

Placenticerus polyopsis (DUJARDIN, 1837)
Pl. 1, Figs. 3-6.

- * 1837 *Ammonites polyopsis* DUJARDIN, p. 232, pl. 17, fig. 12.
- 1983 *Placenticerus polyopsis* (Dujardin, 1837) - KENNEDY & WRIGHT, p. 856, pls 86-88; text-figs. 1-4 (with full synonymy).
- 1987b *Placenticerus polyopsis* (Dujardin, 1837) - KENNEDY, p. 768 (with additional synonymy).
- 1994 *Placenticerus polyopsis* (Dujardin) - WIEDMANN *in* GISCHLER *et al.*, p. 238, pl. 43, figs. 10-12.

TYPE: Lectotype, by subsequent designation of KENNEDY & WRIGHT (1983, p. 856), is the original of DUJARDIN

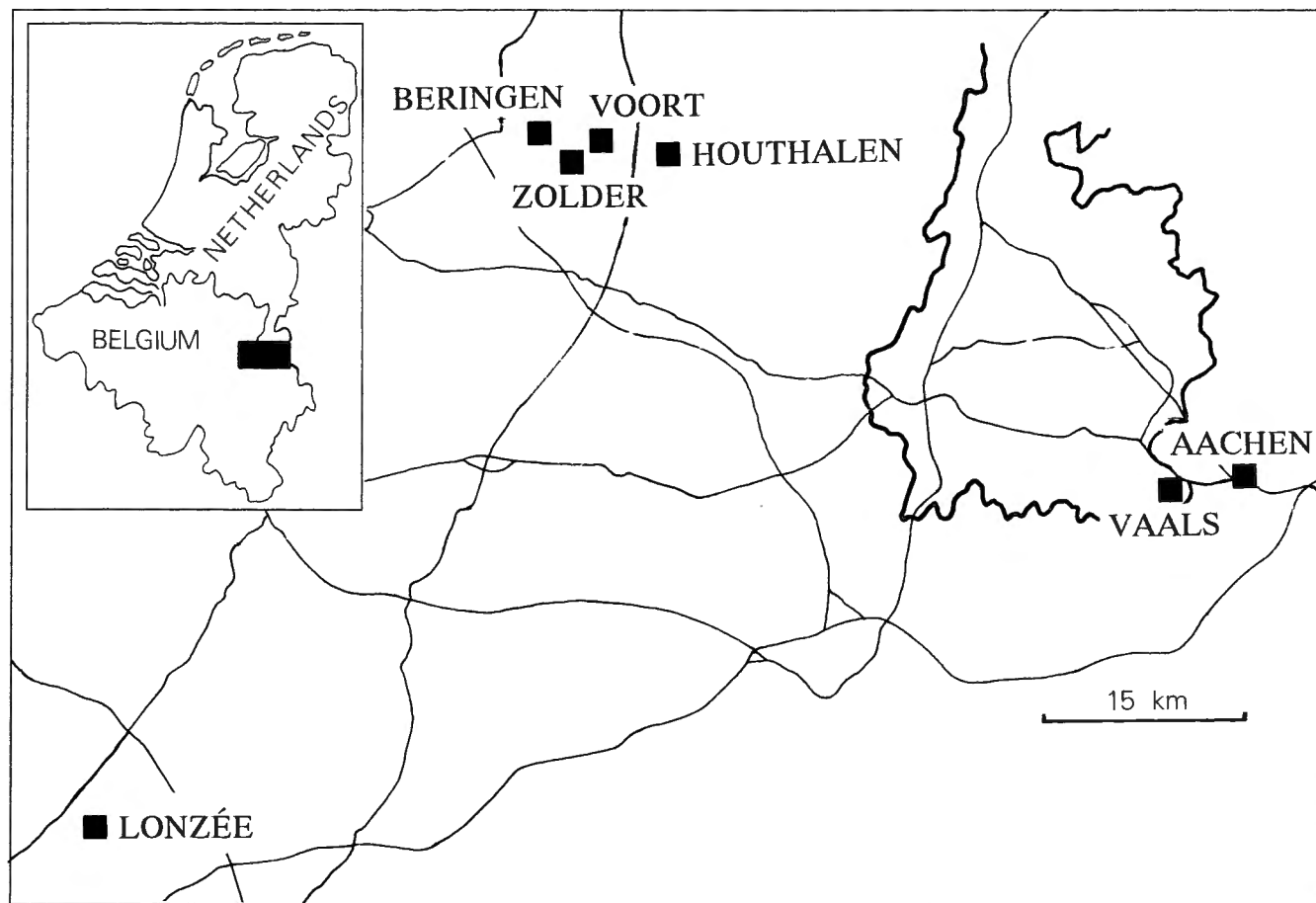


Fig. 1 — Locality map showing locations of mine shafts and exposures/outcrops mentioned in the text.

(1837, pl. 17, fig. 12) from the “Craie tuffau” of Touraine (France); its present whereabouts is unknown.

MATERIAL: IRSNB IG 9780 from the Hervian of the Charbonnage Houthalen, shaft 1, at a depth of 583-585 m; three fragments. IRSNB IG 8914, Charbonnage Zolder (Voort), shaft 2, seven fragments from a depth of 527 m. IRSNB 10378a, b, 10379 (IG 8831), from the same shaft at a depth of 581.45 m. IRSNB IG 8748, from shaft 1 at the same locality at a depth of 582-584.30 m.

DISCUSSION: These fragments are all rather poorly preserved composite moulds, either fragments of juveniles or of body chamber. All show the characteristic strong ornament of the middle growth stages of this species, which is discussed at length by KENNEDY & WRIGHT (1983).

OCCURRENCE: *Placenticeras polyopsis* ranges throughout the Santonian, and is widespread in France (Aquitaine Basin, Corbières, Beausset (Var), and Touraine), north-eastern Belgium, Germany and northern Spain.

Superfamily Acanthocerataceae de GROSSOUVRE, 1894
Family COLLIGNONICERATIDAE WRIGHT & WRIGHT, 1951
Subfamily Texanitinae COLLIGNON, 1948
Genus and subgenus *Texanites* (*Texanites*) SPATH, 1932

TYPE SPECIES: *Ammonites texanus* ROEMER, 1852, p. 31, pl. 3, fig. 1, by original designation of SPATH (1932, p. 379).

Texanites (*Texanites*) sp.
Pl. 1, Figs. 7, 8.

MATERIAL: A large composite internal mould, and an external mould (IG 8914) of the venter of a larger specimen (Wh c 100 mm), Charbonnage Zolder (Voort), shaft 1, at a depth of 583-590 m. IRSNB 10377 (IG 9780), labelled “Campanien (base)”, Houthalen (Charbonnages), shaft 1, at a depth of 596.97-598 m.

DESCRIPTION: IRSNB 10377 is a crushed composite mould with a maximum preserved whorl height of 60 mm. There are prominent umbilical bullae (1), clavate inner lateral (2), larger, clavate outer lateral (3), and larger, clavate inner (4) and outer ventrolateral clavi

(5), borne on strong, distant, straight, prorsiradiate ribs. A pronounced groove separates the outer ventrolateral clavi from a strong, slightly undulose siphonal keel.

DISCUSSION: Although only fragmentary, the present material is of interest as the only known representative of the Texanitinae from the area.

Superfamily Scaphitaceae GILL, 1871

Family SCAPHITIDAE GILL, 1871

Subfamily Scaphitinae GILL, 1871

Genus and subgenus *Scaphites* PARKINSON, 1811

TYPE SPECIES: *Scaphites equalis* J. SOWERBY, 1813, p. 53, pl. 18, figs. 1-3, by subsequent designation of MEEK (1876, p. 413).

Scaphites (Scaphites) kieslingswaldensis fischeri

RIEDEL, 1931

Pl. 1, Figs. 1, 2.

- 1931 *Scaphites bärtingi* RIEDEL, p. 701, pl. 79, figs. 3, 4.
 * 1931 *Scaphites fischeri* RIEDEL, p. 704, pl. 79, figs. 5, 6.
 1986 *Scaphites fischeri* Riedel, 1931 - KENNEDY, p. 124, fig. 40.
 1991 *Scaphites kieslingswaldensis fischeri* Riedel, 1931 - KENNEDY & CHRISTENSEN, p. 222, pl. 2, figs. 1, 2; pl. 5, fig. 2; pl. 6, figs. 2-4, 7; pl. 7, figs. 2, 4.
 1993 *Scaphites (Scaphites) kieslingswaldensis fischeri* Riedel, 1931 - KENNEDY & CHRISTENSEN, p. 155, figs. 4f, g, m, n.

TYPE: Lectotype, designated by KENNEDY (1986, p. 124), is the original of RIEDEL (1931, pl. 79, fig. 6).

MATERIAL: From the Charbonnage Houthalen, shaft 1, IRSNB 10383 (IG 9780), a single fragmentary specimen at a depth of 583-585 m.

DISCUSSION: The single available specimen corresponds closely to material from the lowermost Campanian of Broitzem-Braunschweig (Germany) as figured by KENNEDY (1986, fig. 40); it is here recorded for the first time from the Upper Santonian/Lower Campanian of Belgium (see below).

OCCURRENCE: Lower Santonian to Lower Campanian of Germany, Santonian of Denmark and Sweden and Upper Santonian/Lower Campanian of Belgium.

BELEMNOIDEA

The present collection comprises 109 specimens, 15 of which are complete, 26 are fragments of the anterior end, and 68 are fragments of the middle and posterior part of the guard. All are referable to the genus *Goniot euthis* BAYLE, 1878.

The specimens come from Charbonnage Houthalen, shaft 1, at a depth of 575-598 m; Charbonnage Zolder (Voort), shaft 1, at a depth of 575.8-584.3 m; same colliery, shaft 2, at a depth of 581.45-588 m, and from Charbonnage Beringen, shaft 2, at a depth of 612 m.

The North European palaeobiogeographic province extends from Ireland in the west to the Ural Mountains in the east and includes the Central European and Central Russian Subprovinces. These subprovinces are well defined in the Coniacian-Lower Campanian. The Central European Subprovince is characterised by the genus *Goniot euthis* and the Central Russian Province by the genus *Belemnitella* d'ORBIGNY, 1840 (CHRISTENSEN, 1976, 1988, 1990). Belgian Limburg is part of the Central European Subprovince as defined on belemnites.

Family BELEMNITELLIDAE PAVLOW, 1914

Genus *Goniot euthis* BAYLE, 1878

TYPE SPECIES: *Belemnites quadratus* DE BLAINVILLE, 1827.

REMARKS: The evolutionary lineage of *Goniot euthis* includes seven species and subspecies occurring from the Middle Coniacian to the Lower/Upper Campanian boundary (Text-fig.2). This lineage was studied in great detail by the German authors E. STOLLEY, G. ERNST and M.-G. SCHULZ, in addition to I. JARVIS and W.K. CHRISTENSEN (references in CHRISTENSEN, 1991). Eleven zones have been established on the basis of this lineage (Text-fig. 2), based mainly on the Riedel-Quotient (= length of guard divided by depth of pseudoalveolus; see ERNST, 1964). ERNST & SCHULZ (1974) introduced the term Riedel-Index, which is the depth of the pseudoalveolus as a percentage of the length of the guard. The Schlankheits-Quotient (= Slenderness-Quotient) of ERNST (1964) is the length of the guard divided by the dorsoventral diameter at the alveolar end.

CHRISTENSEN (1991) analysed the growth relationship of guard length vs the depth of the pseudoalveolus, and guard length vs the dorsoventral diameter at the alveolar end of a large number of samples, representing all species of *Goniot euthis*, with the exception of *G. praewestfalica*. He showed that the relationship of guard length vs depth of pseudoalveolus is generally isometric. The *Goniot euthis* zonation of ERNST (1964) is therefore valid. On the other hand, the relationship of guard length vs dorsoventral diameter at the alveolar end is allometric to strongly allometric in most samples. Juvenile specimens are more slender than adults. It is therefore not valid to calculate the mean Slenderness-Quotient.

DISTRIBUTION: *Goniot euthis* is known from the upper Middle Coniacian to the Lower/Upper Campanian boundary. The genus had its evolutionary centre in NW Europe and is recorded almost exclusively from the Central European Subprovince.

Goniot euthis westfalica granulata (STOLLEY, 1897)
(See CHRISTENSEN, 1975a, b for synonymy).

TYPE: The original of STOLLEY (1897, pl. 2, fig. 16; pl. 3, fig. 6) was designated lectotype and reillustrated by CHRISTENSEN (1975b, pl. 10, fig. 1; text-fig. 2A).

BIOMETRY: Fifteen complete specimens were analysed using univariate statistical methods: these are FI 94-1/1 & 2 (2 specimens), IG 9780, Charbonnage Houthalen, shaft 1, 575-583 m; FI 94-1/13 (2 specimens), IG 8748, Charbonnage Zolder (Voort), shaft 1, 575.8-579.5 m; FI 94-1/9 (2 specimens), IG 8748, Charbonnage Zolder (Voort), shaft 1, 579.5-582 m; FI 94-1/8 (3 specimens), IG 8748, Charbonnage Zolder (Voort), shaft 1, 582-584.3 m; FI 94-1/7 (4 specimens), IG 8831, Charbonnage Zolder (Voort), shaft 2, 581.45 m; and FI 94-1/10 (2 specimens), IG 8831, Charbonnage Zolder (Voort), shaft 2, 588 m.

Univariate analysis

Character	N	\bar{X}	SD	CV	OR
L	15	60.1	3.8	6.4	52.0-64.9
RQ	15	9.2	2.4	25.8	6.4-15.0
RI	15	11.4	2.8	24.3	6.7-15.7
SQ	15	6.1	0.8	13.8	5.1- 7.5
L/MLD	13	6.2	1.0	15.6	4.9- 8.5
MLD/LDAE	13	1.1	0.1	5.5	1.0- 1.3

N = number of specimens; \bar{X} = mean value; SD = standard deviation; CV = coefficient of variation; OR = observed range; L = length of guard; RQ = Riedel-Quotient; RI = Riedel-Index; SQ = Slenderness-Quotient; MLD = maximum lateral diameter; LDAE = lateral diameter at alveolar end.

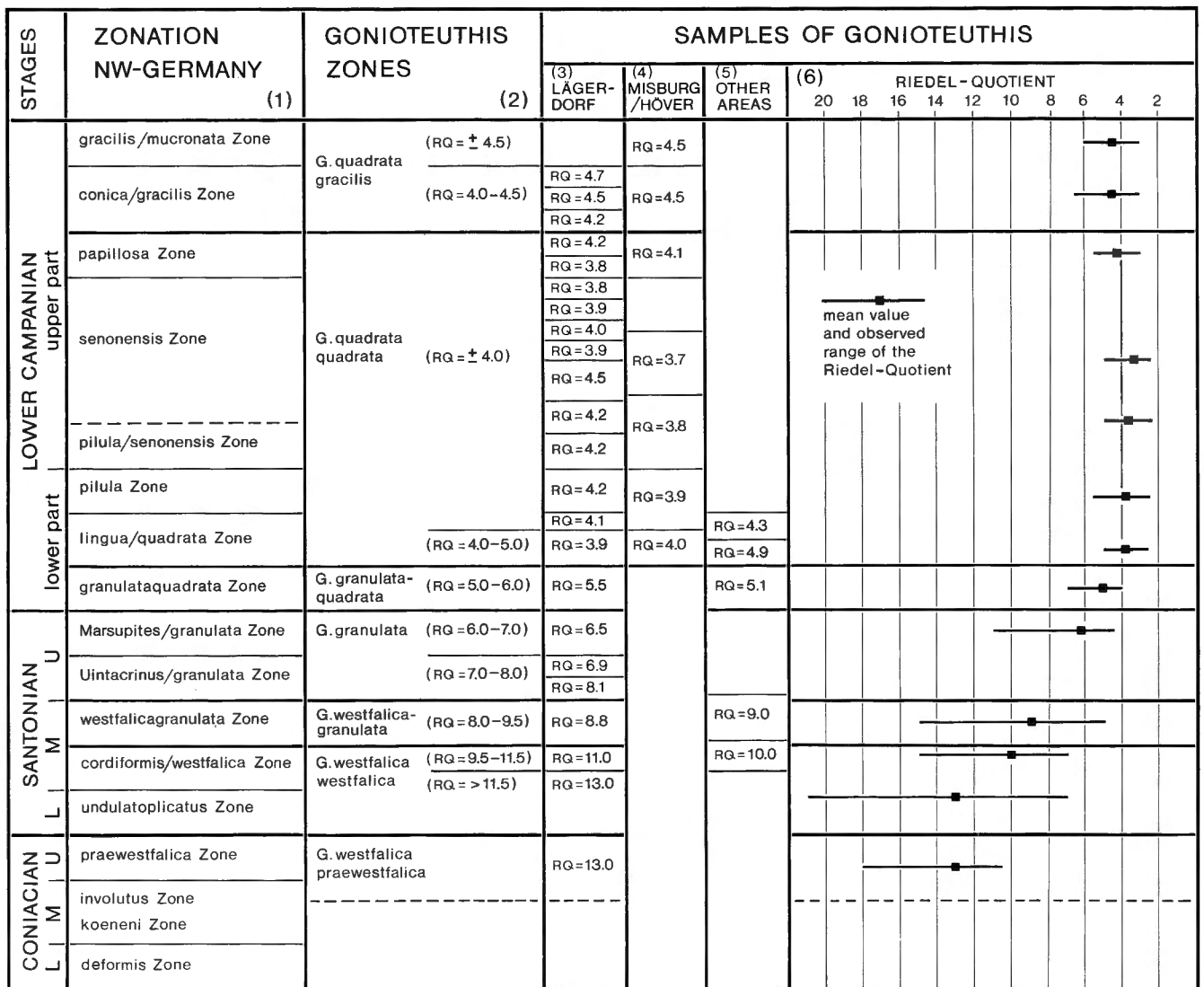


Fig. 2 — Zonation of the Coniacian-Lower Campanian of NW Germany (Braunschweig-Hannover area), *Goniot euthis* zones, and the mean value and observed range of the Riedel-Quotient of samples of *Goniot euthis* from Lagerdorf, Misburg/Höver (Hannover) and other areas (Braunschweig and Essen). Modified from CHRISTENSEN (1988).

DISCUSSION: According to ERNST (1964, 1968) samples of *G. westfalicagranulata* have a mean Riedel-Quotient of 8.0-9.5 (Text-fig. 2). The mean value of this index of the present sample is 9.2, and it can thus be referred to this species.

ERNST (1968) analysed two samples of *G. westfalicagranulata* from NW Germany; these samples have a mean Riedel-Quotient of 9.0, and the observed range is c. 5.5-15.0. The observed range of the Riedel-Quotient of the Belgian sample is 6.4-15.0, which is closely similar to the samples from NW Germany.

ERNST (1964, fig. 12) did not indicate the mean Slenderness-Quotient of samples of *G. westfalicagranulata* from NW Germany. He showed, however, that the mean Slenderness-Quotient of *G. westfalica* varied from 6.4-6.9, and the mean Slenderness-Quotient of *G. granulata* is about 5.7. The present sample has a mean Slenderness-Quotient of 6.1, implying that the specimens are stouter than *G. westfalica* and more slender than *G. granulata*. In this respect, the Belgian sample may be referred to *G. westfalicagranulata* as well.

As noted above, calculating the mean Slenderness-Quotient should be discarded, because the relationship of the length of the guard vs dorsoventral diameter is generally allometric to strongly allometric. Nevertheless, the mean Slenderness-Quotient has been calculated for the present sample in order to compare it with samples from NW Germany (ERNST, 1964). All specimens from NE Belgium are adult. If juvenile and adolescent specimens had been available, the mean Slenderness-Quotient would have been slightly larger. However, this would not have affected the above conclusion.

To summarise, the present sample is assigned to *G. westfalicagranulata* on the basis of the means of Riedel-Quotient and Slenderness-Quotient, in addition to the observed range of Riedel-Quotient. The sample exhibits a variation with respect to Riedel-Quotient, which does not differ in any significant respect with coeval samples from NW Germany.

DISTRIBUTION: *Goniot euthis westfalicagranulata* occurs in the upper Middle Santonian *westfalicagranulata* Zone (ERNST, 1964, 1968) (= *rogalae*/*westfalicagranulata* Zone of Lägerdorf; ERNST & SCHULZ, 1974; SCHULZ *et al.*, 1984).

Middle Santonian belemnite faunas

Four belemnite genera occur in the Middle Santonian: *Actinocamax* MILLER, 1823, *Goniot euthis*, *Belemnelloca-max* NAIDIN, 1964 and *Belemnitella* (see CHRISTENSEN, 1988, 1990). In NW Europe, *Actinocamax* is restricted to a single species, *A. verus* MILLER, 1823, *Goniot euthis* to two species, *G. westfalica* (SCHLÜTER, 1876) and *G. westfalicagranulata*, *Belemnelloca-max* to one group, *B. ex gr. grossouvrei* (JANET, 1891) and *Belemnitella* to a single species, *B. propinqua* (MOBERG, 1885).

The belemnite fauna of Belgian Limburg comprises but a single species, *G. westfalicagranulata*. The absence

of *A. verus* is enigmatic and may be due to collection failure, because this species occurs commonly in the Santonian near-shore "Glaucanie de Loncée" (CHRISTENSEN, 1994) and in the upper Middle Santonian marls at Eriksdal in Scania, Sweden (CHRISTENSEN, 1986). The absence of *B. ex gr. grossouvrei* may be explained by its overall rarity. *Belemnitella propinqua* occurs mainly on the Russian Platform and in southern Scandinavia. Outside this area, only three specimens have been recorded from southern England (CHRISTENSEN, 1991). Its absence in Limburg may be explained by its overall rarity in the Central European Subprovince.

INOCERAMID BIVALVES

Superfamily Pteriacea

Family INOCERAMIDAE ZITTEL, 1881 (ICZN 473)

The collections of the Institut royal des Sciences naturelles de Belgique include the following poorly preserved inoceramid material, from the mine shafts discussed herein:

- Charbonnage Houthalen, shaft 1 (IG 9780)
583-585 m *Cordiceramus brancoiformis* (SEITZ, 1961)
Platyceramus cf. cycloides (WEGNER, 1905)
- Charbonnage Zolder, shaft 1 (IG 8748)
579.5-582 m *Endocostea baltica* (J. BÖHM, 1907)
- Charbonnage Zolder, shaft 2 (IG 8831)
581.45 m *Endocostea aff. baltica*.

The stratigraphic range of *Cordiceramus brancoiformis* is Middle - Upper Santonian in Germany (SEITZ, 1967; TRÖGER, 1987); *Platyceramus cycloides* is known throughout the Santonian and also from the Lower Campanian (TRÖGER, 1987). The oldest *Endocostea baltica* specimens recorded by SEITZ (1967) and TRÖGER (1987) are from the Upper Santonian, but the species reaches throughout the Campanian and possibly into the Maastrichtian (DHONDT, 1993). These ranges agree well with the belemnite and ammonite/nannofossil ages.

NANNOFOSSILS

Nine calcareous sandstone samples were analysed for nannofossils. Due to the high sand content of the material (sample descriptions appear below), nannofossil slides were prepared in the following way: each sample was rinsed, placed into a beaker with distilled water, and subjected to ultrasonic vibration for a few minutes, until break-down of the sample was effected. The suspension was stirred, the coarse (sandy) fraction allowed to settle for a few seconds, and the uppermost (nannofossil-bearing) part of the suspension pipetted onto a glass coverslip on a hotplate. The suspension was allowed to dry. The sediment on the coverslip was then remobilised with a drop of distilled water, and the sediment smeared evenly and more thinly across the coverslip with a flat-sided toothpick. The smear was then dried and mounted on a glass slide, using Norland Optical Adhesive, for examination.

NF ABUNDANCE	NF ZONE	SAMPLES	HOUTHALEN 1		ZOLDER 1		ZOLDER 2		Dr. 3 (1)	
			583-585 m (2)	583-585 m (4)	582-584.3 m (7)	585-590 m (5)	572 m (1)	572 m (3)	581.45 m (6)	581.45 m (9)
Common - 1-10/field of view	CC16/177									
Few - 1-2/10 fields of view	CC16									
Rare - 1/11-100 fields of view	CC16									
- = absent	CC15/167									
?	CC16									
TAXA (IN ALPHABETICAL ORDER)										
<i>Ac. scotus</i>										
<i>Ab. octoradiata</i>										
<i>Ab. regularis</i>										
<i>Am. brooksii</i> (large form)										
<i>Ar. cymbiformis</i>										
<i>Bi. ellipticum</i>										
<i>Bi. sp.</i>										
<i>Bra. bigelowii</i>										
<i>Bro. enormis</i>										
<i>Bro. parva expansa</i>										
<i>Bro. signata</i>										
<i>Ca. cf. Ca. obscurus</i>										
<i>Ca. obscurus</i>										
<i>Ca. ovalis</i>										
<i>Ch. amphipous</i>										
<i>Ch. bifarius</i>										
<i>Ch. litterarius</i>										
<i>Ch. synquadriferatus</i>										
<i>Ch. tetragonothyrus?</i>										
<i>Co. oxigum</i>										
<i>Co. signum</i>										
<i>Cre. conicus</i>										
<i>Cre. striatus</i>										
<i>Cril. ehrenbergii</i>										
<i>Cyc. margerelii</i>										
<i>Cyc. rotaclypeata</i>										
<i>Cyl. biarcus</i>										
<i>Di. ignotus</i>										
<i>Ei. eximius</i>										
<i>Ei. gorkae</i>										
<i>Ei. parallelus</i>										
<i>Ei. currisseiffelii</i>										
<i>Ga. obliquum</i>										
<i>Ge. coronadventis</i>										
<i>Ha. circumradiatus</i>										
<i>He. anceps</i>										
<i>He. trabeculatus</i>										
<i>Ka. magnificus</i>										
<i>Litha. grillii</i> s.s.										
<i>Lithr. carniolensis</i>										
<i>Lo. armilla</i>										
<i>Lu. arcuatus</i>										
<i>Lu. cayuxii</i>										
<i>Lu. maleformis</i> (long form)										
<i>Lu. maleformis</i> (short form)										
<i>Man. pennatoides</i>										
<i>Mar. furcatus</i> s.s.										
<i>Micr. belgicus</i>										
<i>Micr. decoratus</i>										
<i>Micr. helicoides</i>										
<i>Micr. undosus</i>										
<i>Micu. concava</i>										
<i>Micu. cubiformis</i>										
<i>Micu. staurophora</i>										
<i>Micu. swastica</i>										
<i>Nannoconus regularis</i>										
<i>Nannoconus</i> sp. (x-section)										
<i>Oc. cf. Oc. multiplus</i>										
<i>Pl. fibuliformis</i>										
<i>Pl.?</i> cf. <i>Zy. sigmoides</i>										
<i>Pr. bukryi</i>										
<i>Pr. cf. Pr. grandis</i>										
<i>Pr. cretacea</i>										
<i>Pr. ponticula</i>										
<i>Pr. spinosa</i> (medium form)										
<i>Pr. spinosa</i> (large form)										
<i>Pr. stoveri</i>										
<i>Qu. gothicum</i>										
<i>Rec. compactus</i>										
<i>Rel. anthophorus</i>										
<i>Rep. parvidentatum</i>										
<i>Ret. angustiforata</i>										
<i>Ret. crenulata</i>										
<i>Rh. angustus</i>										
<i>Rh. infinitus?</i>										
<i>Rh. plebeius</i>										
<i>Rh. reniformis</i>										
<i>Rh. splendens</i>										
<i>Ro. crenulatus</i>										
<i>Sc. fossilis</i>										
<i>So. horticus</i>										
<i>St. compacta integra</i>										
<i>St. crux</i>										
<i>St. laffittei</i>										
<i>St. mielnicensis</i>										
<i>Te. coptensis?</i>										
<i>Th. ecclesiastica</i>										
<i>Tr. gabalus</i>										
<i>Tr. minimus</i>										
<i>Tr. orlonatus</i>										
<i>Va. matalosa</i> (medium form)										
<i>Va. matalosa</i> (small form)										
<i>Wa. barnesae</i>										
<i>Wa. fossacincta</i>										
<i>Wa. manivita</i>										
<i>Wa. quadriradiata</i>										
<i>Ze. biperforatus</i>										
<i>Ze. diplogrammus</i>										
<i>Ze. erectus</i>										
<i>Ze. noelliae</i>										

The nannofossil assemblages in all of the samples are diverse (a total of 100 taxa were identified), but preservation is generally poor to moderate, although this did not affect the identification of any taxa. Etching of calcite is typically predominant in sediments of this nature, where the sand has aided percolation of acidic pore-waters.

The numerical zonation scheme of SISSINGH (1977), modified and summarised by PERCH-NIELSEN (1985), was applied to the assemblages in order to assign biostratigraphical zones. These are summarised below. The stage age-assignments, shown in brackets, are those derived from SISSINGH and PERCH-NIELSEN. Table 1 shows the taxa recorded from each sample and the nannofossil zone assigned on the basis of the assemblage. A complete taxonomic list appears below.

- Charbonnage Houthalen, shaft 1
583-585 m (sample 2): CC16 (late Santonian)
583-585 m (sample 4): CC16 (late Santonian), possibly CC17 (Santonian/Campanian)
596.97-598 m (sample 8): CC16 (late Santonian)
- Charbonnage Zolder (Voort), shaft 1
582-584.3 m (sample 7): CC15 (late early Santonian), possibly CC16 (late Santonian)
585-590 m (sample 5): CC16 (late Santonian)
- Charbonnage Zolder (Voort), shaft 2
572 m (sample 1): CC16 (late Santonian)
572 m (sample 3): CC16 (late Santonian, possibly CC17 (Santonian/Campanian)
581.45 m (sample 6): CC16 (late Santonian)
581.45 m (sample 9): CC16 (late Santonian)

Sample descriptions

- Charbonnage Houthalen
Shaft 1, 583-585 m (sample 2): indurated, medium-dark grey, calcareous sandstone.
Shaft 1, 583-585 m (sample 4): relatively soft, cohesive, dark grey, clayey calcareous sandstone.
Shaft 1, 596.97-598 m (sample 8): relatively soft, cohesive, dark green (Cu ?)/black, calcareous sandstone.
- Charbonnage Zolder (Voort)
Shaft 1, 582-584.3 m (sample 7): as sample 4.
Shaft 1, 585-590 m (sample 5): as sample 8.
Shaft 2, 572 m (sample 1): soft, non-cohesive, dark grey, clayey sandstone.
Shaft 2, 572 m (sample 3): as above.
Shaft 2, 581.45 m (sample 6): as above.
Shaft 2, 581.45 m (sample 9): as above.



Table 1. Nannofossil stratigraphical distribution.

Nannofossil taxonomic list

- Acuturris scotus* (RISATTI, 1973) WIND & WISE in WISE & WIND, 1977
- Ahmuellerella octoradiata* (GORKA, 1957) REINHARDT, 1966
- A. regularis* (GORKA, 1957) VERBEEK, 1977
- Amphizygus brooksii* BUKRY, 1969
- Arkhangelskiella cymbiformis* VEKSHINA, 1959
- Biscutum ellipticum* (GORKA, 1957) GRÜN in GRÜN & ALLEMANN, 1975
- Biscutum* sp. [similar to *B. ellipticum* but much larger]
- Braarudosphaera bigelowii* (GRAN & BRAARUD, 1935) DEFLANDRE, 1947
- Broinsonia enormis* (SHUMENKO, 1968) MANIVIT, 1971
- B. parca expansa* WISE & WATKINS in WISE, 1983
- B. signata* (NOEL, 1969) NOEL, 1970
- Calculites obscurus* (DEFLANDRE, 1959) PRINS & SISINGH in SISINGH, 1977
- C. cf. obscurus* [similar to *C. obscurus* but smaller and with much lower birefringence]
- C. ovalis* (STRADNER, 1963) PRINS & SISINGH in SISINGH, 1977
- Chiastozygus amphipons* (BRAMLETTE & MARTINI, 1964) GARTNER, 1968
- C. bifarius* BUKRY, 1969
- C. litterarius* (GORKA, 1957) MANIVIT, 1971
- C. synquadriperforatus* BUKRY, 1969
- C. tetragonothyris?* HILL, 1976
- Corolithion exiguum* STRADNER, 1961
- C. signum* STRADNER, 1963
- Cretarhabdus conicus* BRAMLETTE & MARTINI, 1964
- C. striatus* (STRADNER, 1963) BLACK, 1973
- Cribrosphaerella ehrenbergii* (ARKHANGELSKY, 1912) DEFLANDRE in PIVETEAU, 1952
- Cyclagelosphaera margerelii* NOEL, 1965
- C. rotaclypeata* BUKRY, 1969
- Cylindralithus biarcus* BUKRY, 1969
- Discorhabdus ignotus* (GORKA, 1957) PERCH-NIELSEN, 1968
- Eiffellithus eximius* (STOVER, 1966) PERCH-NIELSEN, 1968
- E. gorkae* REINHARDT, 1965
- E. parallelus* PERCH-NIELSEN, 1973
- E. turriseiffelii* (DEFLANDRE, 1954) REINHARDT, 1965, BUKRY, 1969
- Gartnerago obliquum* (STRADNER, 1963) REINHARDT, 1970
- Gephyrorhabdus coronadventis* (REINHARDT, 1966) HILL, 1976
- Haqius circumradiatus* (STOVER, 1966) ROTH, 1978
- Helicolithus anceps* (GORKA, 1957) NOEL, 1970
- H. trabeculatus* (GORKA, 1957) VERBEEK, 1977
- Kamptnerius magnificus* DEFLANDRE, 1959
- Lithastrinus grillii* STRADNER, 1962
- Lithraphidites carniolensis* DEFLANDRE, 1959
- Loxolithus armilla* (BLACK in BLACK & BARNES, 1959) NOEL, 1965
- Lucianorhabdus arcuatus* FORCHHEIMER, 1972
- L. cayeuxii* DEFLANDRE, 1959
- L. maleformis* REINHARDT, 1966
- Manivitella pemmatoidea* (DEFLANDRE in MANIVIT, 1965) THIERSTEIN, 1971
- Marthasterites furcatus* (DEFLANDRE, 1954) DEFLANDRE, 1959, BUKRY, 1969
- Microrhabdulus belgicus* HAYE & TOWE, 1963
- M. decoratus* DEFLANDRE, 1959
- M. helicoideus* DEFLANDRE, 1959
- M. undosus* PERCH-NIELSEN, 1973
- Micula concava* (STRADNER in MARTINI & STRADNER, 1960) BUKRY, 1969, VERBEEK, 1976
- M. cubiformis* FORCHHEIMER, 1972
- M. staurophora* (GARDET, 1955) STRADNER, 1963 (= *M. decussata* VEKSHINA, 1959)
- M. swastica* (sensu PRINS, 1977) STRADNER & STEINMETZ, 1984
- Nannoconus regularis* DÉRÈS & ACHERITÉGUY, 1980
- Octolithus* cf. *O. multiplus* (PERCH-NIELSEN, 1973) ROMMEIN, 1979 [similar to *O. multiplus* but smaller and with only six blocks visible]
- Placozygus fibuliformis* (REINHARDT, 1964) HOFFMANN, 1970
- P. cf. Zygodiscus sigmoides* BRAMLETTE & SULLIVAN, 1961 [possibly a predecessor of *Z. sigmoides*]
- Prediscosphaera bukryi* PERCH-NIELSEN, 1973
- P. cretacea* (ARKHANGELSKY, 1912) GARTNER, 1968
- P. grandis* PERCH-NIELSEN, 1979
- P. cf. P. grandis* [similar to *P. grandis* but smaller]
- P. ponticula* BUKRY, 1969, PERCH-NIELSEN, 1984
- P. spinosa* (BRAMLETTE & MARTINI, 1964) GARTNER, 1968
- P. stoveri* (PERCH-NIELSEN, 1968) SHAFIK & STRADNER, 1971
- Quadrum gothicum* (DEFLANDRE, 1959) PRINS & PERCH-NIELSEN in MANIVIT *et al.*, 1977
- Rectapontis compactus* (BUKRY, 1969) VAROL & JAKUBOWSKI, 1989
- Reinhardtites anthophorus* (DEFLANDRE, 1959) PERCH-NIELSEN, 1968
- Repagulum parvidentatum* (DEFLANDRE & FERT in DEFLANDRE, 1954) FORCHHEIMER, 1972
- Retecapsa angustiforata* BLACK, 1971
- R. crenulata* (BRAMLETTE & MARTINI, 1964) GRÜN in GRÜN & ALLEMANN, 1975
- Rhagodiscus angustus* (STRADNER, 1963) REINHARDT, 1971
- R. infinitus* (WORSLEY, 1971) APPLIGATE *et al.* in COVINGTON & WISE, 1987
- R. plebeius* PERCH-NIELSEN, 1968
- R. reniformis* PERCH-NIELSEN, 1973
- R. splendens* (DEFLANDRE, 1953) VERBEEK, 1977
- Rotelapillus crenulatus* (STOVER, 1966) PERCH-NIELSEN, 1984
- Scapholithus fossilis* DEFLANDRE, 1954
- Sollasites horticus* (STRADNER *et al.* in STRADNER & ADAMIKER, 1966) ČEPEK & HAY, 1969
- Staurolithites compacta integra* (BUKRY, 1969)
- S. crux* (DEFLANDRE & FERT in DEFLANDRE, 1954) CARATINI, 1963
- S. laffittei* CARATINI, 1963

- S. mielnicensis* (GORKA, 1957) PERCH-NIELSEN, 1968,
CRUX in LORD, 1982
- Tetrapodorhabdus coptensis?* BLACK, 1971
- Thiersteinia ecclesiastica* WISE & WATKINS in WISE,
1983
- Tranolithus gabalus* STOVER, 1966
- T. minimus* (BUKRY, 1969) PERCH-NIELSEN, 1984
- T. orionatus* (REINHARDT, 1966a) REINHARDT, 1966b (= *T. phacelosus* STOVER, 1966)
- Vagalapilla matalosa* (STOVER, 1966) THIERSTEIN, 1973
- Watznaueria barnesae* (BLACK in BLACK & BARNES,
1959) PERCH-NIELSEN, 1968
- W. fossacincta* (BLACK, 1971) BOWN in BOWN & COOPER,
1989
- W. manivittae* BUKRY, 1973
- W. quadriradiata* BUKRY, 1969
- Zeugrhabdotus biperforatus* (GARTNER, 1968)
- Z. diplogrammus* (DEFLANDRE in DEFLANDRE & FERT,
1954)
- Z. erectus* (DEFLANDRE, 1954) REINHARDT, 1965
- Z. noeliae* ROOD *et al.*, 1971

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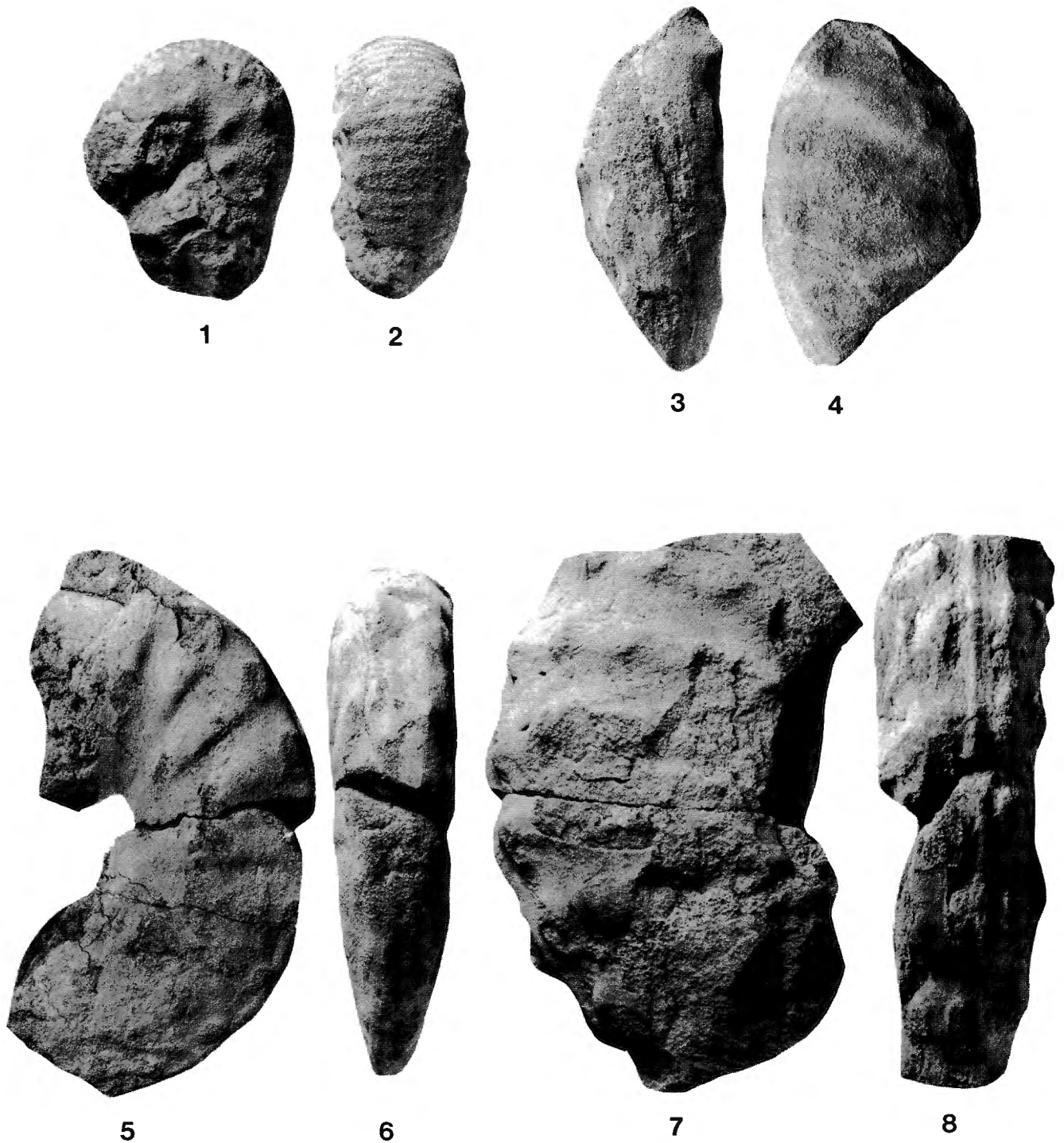


PLATE 1

- Figs. 1, 2 — *Scaphites (Scaphites) kieslingswaldensis fischeri* Riedel, 1931, IRSNB 10383, from the Charbonnage Houthalen, shaft 1, at a depth of 583-585 m, x 1.
- Figs. 3-6 — *Placenticerus polyopsis* (Dujardin, 1837). 3, 4 - IRSNB 10378a, from Charbonnage Zolder (Voort), shaft 2, at a depth of 581.45 m, x 1. 5, 6 - IRSNB 10378b, from Charbonnage Zolder (Voort), shaft 2, at a depth of 581.45 m, x 1.
- Figs. 7, 8 — *Texanites (Texanites)* sp. IRSNB 10377, from Charbonnage Zolder (Voort), shaft 1, at a depth of 583-590 m, x 1.

