

MICROFOSSILS AND DEPOSITIONAL ENVIRONMENT OF LATE DINANTIAN CARBONATES AT HEIBAART (NORTHERN BELGIUM)¹

by

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(5 figures, 1 table and 5 plates)

RESUME.— Le contenu en microfossiles et les lithofaciès ont été étudiés à partir des intervalles carrottés de cinq sondages dans les carbonates dinantiens de la région de Heibaart dans le Nord de la Belgique.

Les foraminifères suggèrent un âge Warnantien précoce. Aucun conodonte n'a été isolé. Vingt-huit espèces d'ostracodes sont décrites ; deux d'entre elles sont nouvelles : *Bairdia robinsoni* nov. sp. et *Rectobairdia conili* nov. sp.

Les carbonates consistent en "wackestones" bioclastiques, en "grainstones" à "pellets" bioclastiques et en "bindstones" algaires.

L'environnement de dépôt a varié d'un lagon ouvert aux influences marines dans le Warnantien le plus ancien (zone Cf 6 α) à des lagons très peu profonds à circulation d'eau réduite dans la zone Cf 6 α - β .

La très grande taille des espèces d'ostracodes isolés de la zone Cf 6 α - β n'est pas caractéristique d'un faciès lagunaire très peu profond. Des ostracodes de très grande taille ont été observés dans d'autres faciès carbonatés d'âge Dinantien également.

ABSTRACT.— The core intervals of five boreholes in the Dinantian carbonates of the Heibaart area in northern Belgium have been investigated on their microfossil contents and lithofacies.

The foraminifers suggest an early Warnantian age. No conodonts have been recovered. Twenty-eight species of ostracodes are described, two of them being new : *Bairdia robinsoni* nov. sp. and *Rectobairdia conili* nov. sp. .

The carbonates consist of bioclastic wackestones, bioclastic-peloid grainstones and algal bindstones. The depositional environment varied from an open marine shelf lagoon in the earliest Warnantian (Cf 6 α zone) to very shallow lagoons with a restricted water circulation in the Cf 6 α - β zone.

The extreme large size of the ostracode species recovered from the Cf 6 α - β zone is not characteristic of the very shallow lagoon environment. Extremely large ostracodes have also been recognized in other carbonate facies of Dinantian age.

I.- INTRODUCTION

The boreholes DZ H1 thru DZ H6 (Distrigaz-Heibaart) were drilled between 1977 and 1980 on behalf of Distrigaz in order to test the possible reservoir qualities of the uppermost karstic zone in the Dinantian carbonates for underground hydrocarbon storage and the possible permeability of the Namurian cap rock on the Heibaart dome. They are situated at Heibaart (Loenhout), 25 km NNE of Antwerp and 20 km WNW of Turnhout in northern Belgium (fig. 1-2). Samples are kept at the Belgian Geological Survey under the

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reference numbers 7 E 196 (135) for borehole DZ H1
 7 E 198 (141) for borehole DZ H2
 7 E 199 (142) for borehole DZ H3
 7 E 200 (143) for borehole DZ H4
 7 E 201 (144) for borehole DZ H5
 7 E 202 (145) for borehole DZ H6

The ostracodes are stored with the paleontological collections of the Geologisch Bureau in Heerlen in the Netherlands.

At Heibaart a dome structure of Dinantian carbonates exists on the southwestern margin of the Campine-Brabant basin. This dome was recognized in 1953-1956 by a seismic survey on behalf of the Belgian Geological Survey. This survey was followed in 1962-1963 by a gravity survey and by an additional seismic survey on behalf of the S.C.R.E.M. The outline of this dome has been defined by a later seismic survey on behalf of Distrigaz in 1978. The Heibaart (He1 + 1bis)

borehole has been drilled in this dome in 1962 by Petrobelge.

No hydrocarbons were encountered, but some important karstic zones were recognized in the Dinantian carbonates. Descriptions and samples of this borehole are kept at Labofina and are not available for publication. A summary lithostratigraphic subdivision by Legrand (1969) indicates that the unconformity between the Cretaceous and the underlying Namurian was reached at 1052 m and the top of the Dinantian carbonates at 1138 m. Famennian sandstones were reached at 1487 m. The borehole penetrated the Silurian subcrop at 1627 m. The algal limestone of the cored interval between 1149 m and 1164 m is attributed to the V3; the cored interval between 1268 m and 1330 m to the V2b; the interval between 1330 m and 1425 m to the V2a (Legrand 1977).

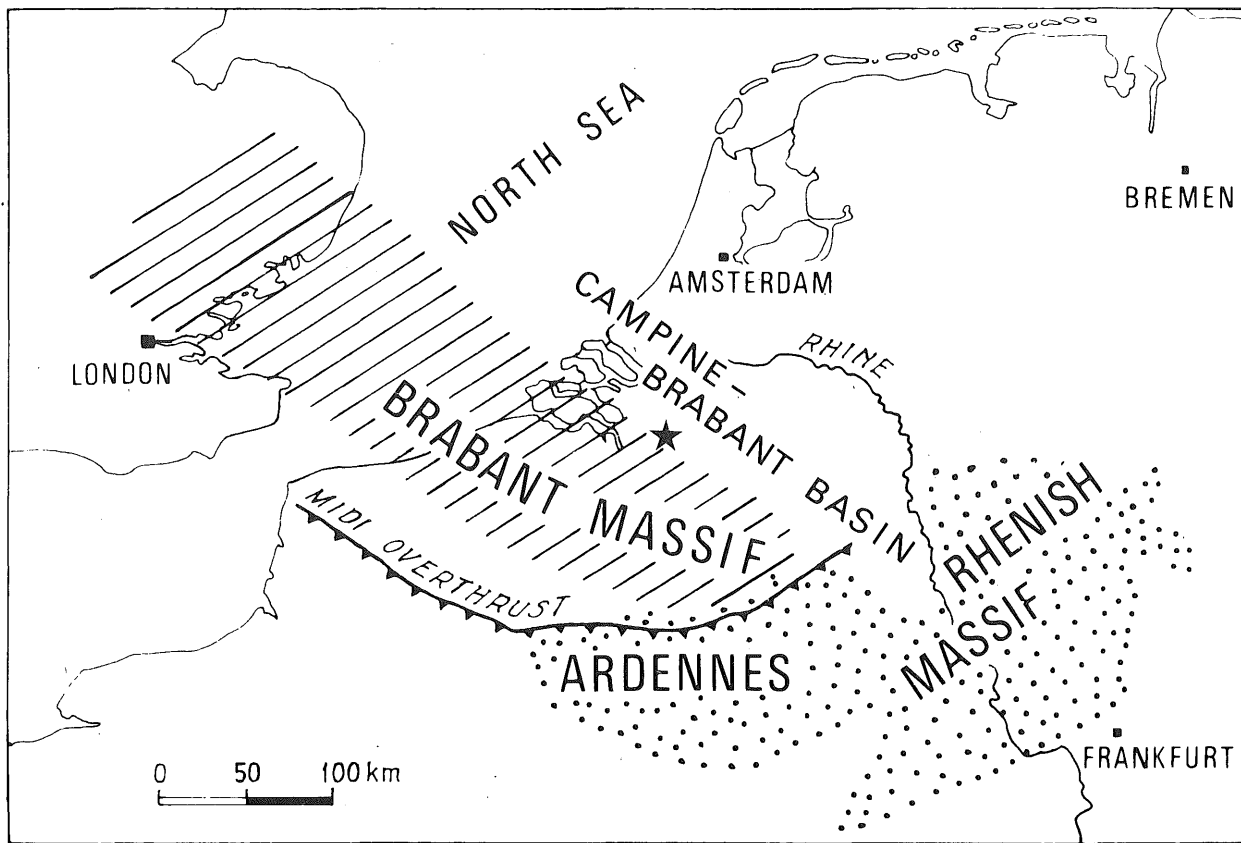


Figure 1.- Location of the Heibaart boreholes (marked by the black asterisk) on the southern margin of the Campine-Brabant Basin

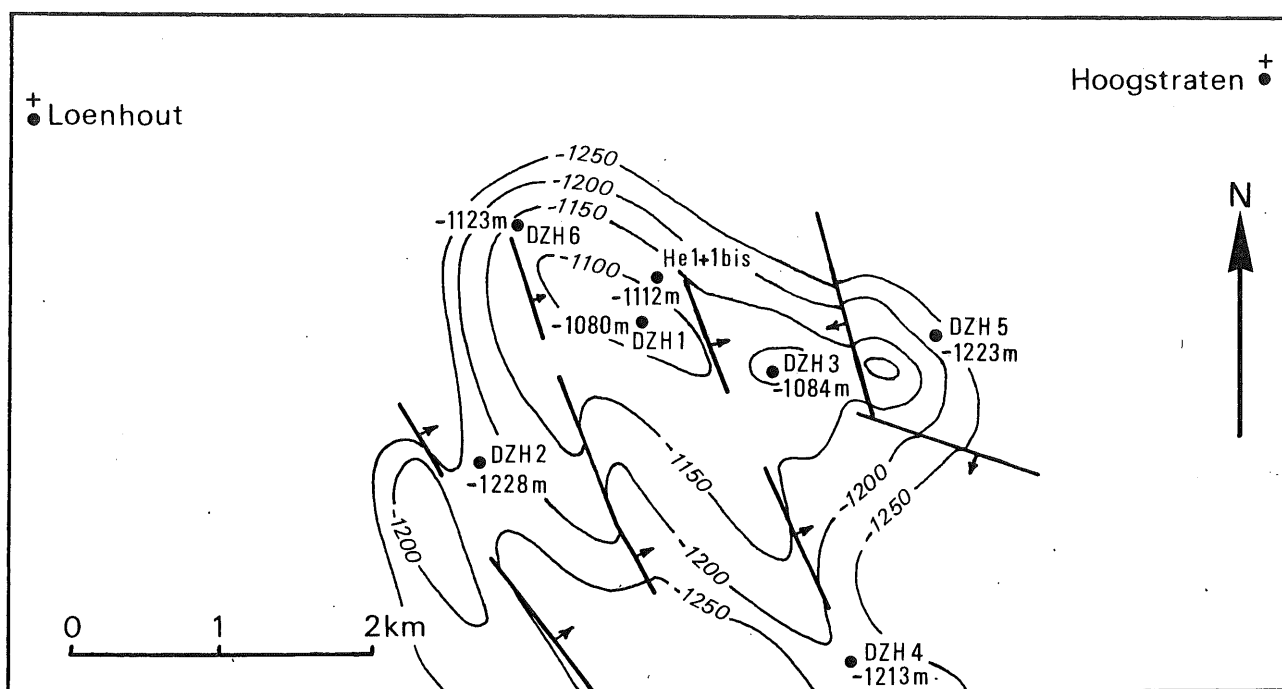


Figure 2.- Location of the Heibaart boreholes between Loenhout and Hoogstraten in northern Belgium (some 25 km NNE of Antwerp). The depth of the top of the Dinantian carbonates below sea level is indicated.

The present study is limited to the cored intervals in boreholes DZ H2 thru DZ H6 and comprises a lithological description of the Dinantian cores based on standard microfacies, their stratigraphic interpretation based on the foraminiferal biozonation, the ostracode distribution and systematics and an evaluation of the depositional environment. The data are compared with those of nearby boreholes (of which the Turnhout borehole is the best one documented; Delmer 1962; Bless *et al.*, 1976).

2.- THE PALEOZOIC

2.1.- THE NAMURIAN

In the Heibaart area the Namurian is separated from the overlying Upper Cretaceous by an unconformity. This unconformity gently dips in a NNE direction at an angle of $1^{\circ}20'$, lowering from -973 m in borehole DZ H2, to -1028 m in borehole DZ H5 (fig. 3).

The Namurian is not identified by biostratigraphic means. Cored samples have been taken in boreholes DZ H2 and DZ H3. Core 1 of borehole DZ H2 (1084,60 -1093,22 m) consists of dark-grey silty mudstones with

silty laminae, few small ironstone nodules, comminuted plant debris, horizontal bioturbation and rare vertical burrows. The strata are dipping 4° to 5° .

Core 1 of borehole DZ H3 (1084-1092 m) consists of dark-grey mudstones with disseminated pyrite and small pyrite nodules, burrows filled with pyrite and sand, and rare comminuted plant debris. The strata are dipping 7° to 8° .

Similar lithologies are found in the Turnhout borehole at respectively 1950 m and 2100 m. These have been dated as Kinderscoutian. The base of the siliciclastic sequence in the Heibaart boreholes is here accepted as the base of the Namurian. The thickness of the Namurian strata between the lithostratigraphic base and core 1 of presumed Kinderscoutian age in DZ H3 is only 15 m. This suggests an important sedimentary gap or an extremely condensed sequence in the Lower Namurian.

Similar sedimentary gaps have also been observed in other boreholes on the southern flank of the Campine-Brabant basin (Bless *et al.*, 1976).

2.2.- THE DINANTIAN

In practice the lithostratigraphic top of the Di-

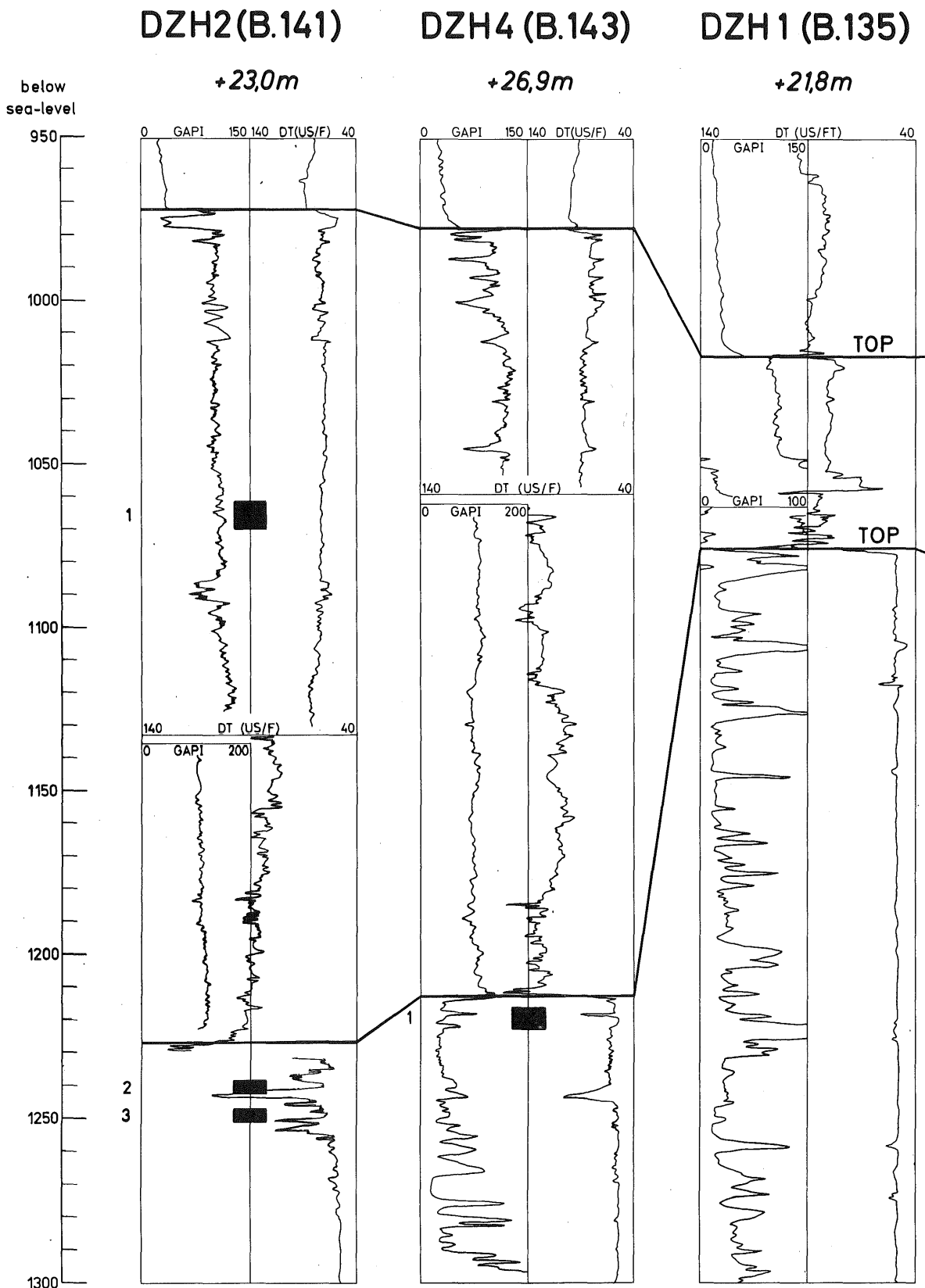


Figure 3.- Correlation of top Paleozoic (= top Namurian) and top Dinantian in the Heibaart boreholes DZ H1 thru DZ H6, and position of the cores discussed in this paper.

DZH3 (B.142)

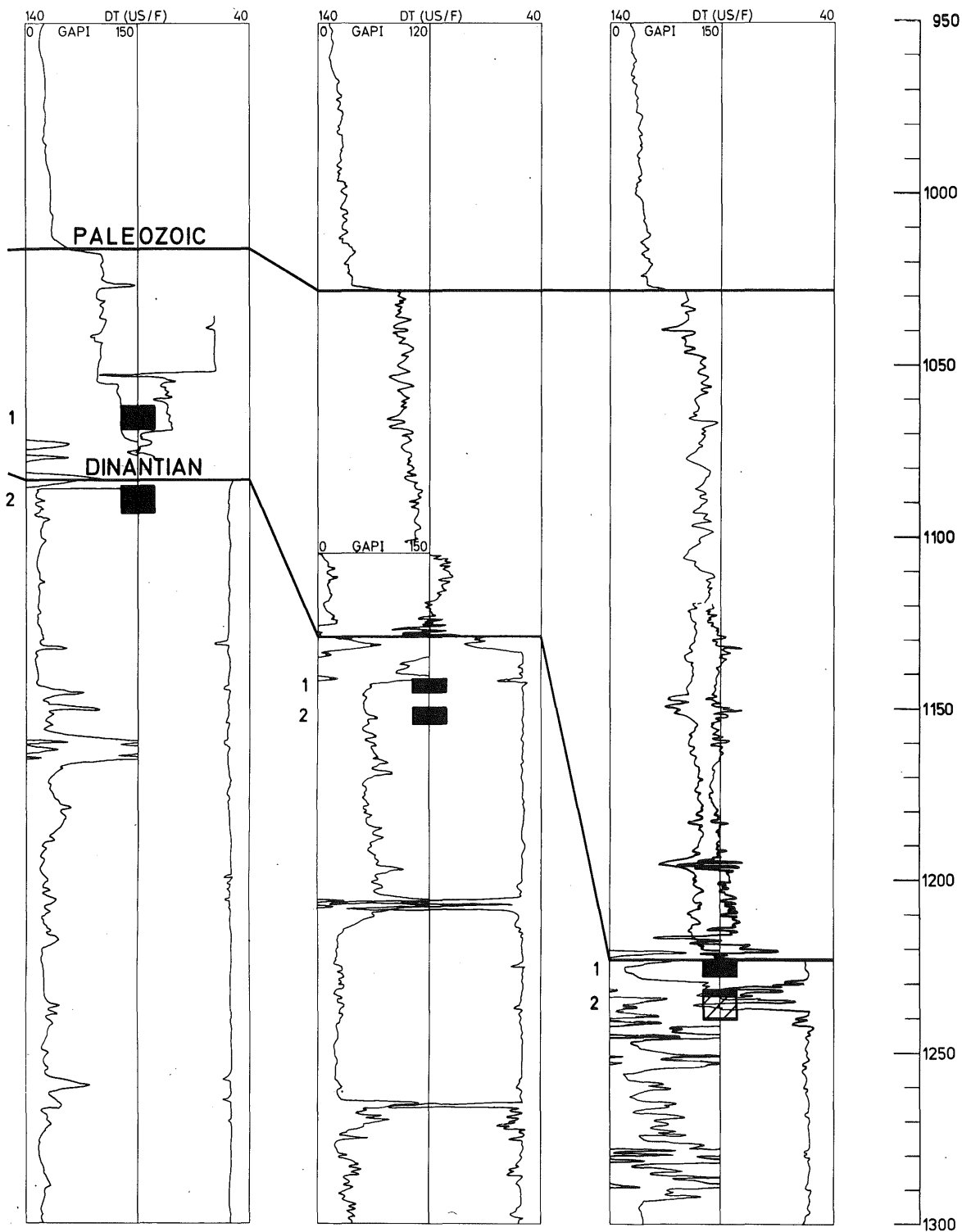
+22,6m

DZH6 (B.145)

+20,5m

DZH5 (B.144)

+25,3m



nantian is placed at the top of the carbonate sequence. The boundary between carbonates and siliciclastics is a well defined limit on the gamma-ray (GAPI) and sonic (DT) logs (fig. 3).

The Dinantian carbonates form a dome structure (fig. 2). The highest point of this dome was penetrated by the DZ H1 borehole.

Only a small part of the Dinantian carbonates has been cored in the boreholes DZ H2 thru DZ H6.

It is uncertain to what extent the lithology of these cores is representative for the total Dinantian sequence in the boreholes. Moreover, part of the cores is affected by dissolution, brecciation and recrystallisation. Since all the cores have been taken from the topmost part of the Dinantian carbonates, some conclusions may be drawn about the importance of the stratigraphic gap caused by the late Visean uplift.

The lithology of the Dinantian cores from boreholes DZ H2 thru DZ H6 is described here. Usually the lithology of the cores has been studied by means of acetate peels and thin slides. The Dunham (1962) classification of carbonate rocks according to depositional texture (emended by Embry & Klovan 1971) is followed, with reference to the carbonate textural spectrum by Folk (1959, 1962).

Carbonate rocks are further characterized according to the standard microfacies (SMF) in a sequence of standard facies belts (Wilson 1975 ; Flugel 1978).

2.3.- CORE DESCRIPTIONS

2.3.1.- Borehole DZ H2 (interval 1261,50-1265,50 m)

Dark-grey, fine-grained limestone, slightly carbonaceous, argillaceous, bioturbated ; core strongly broken and karstified, containing open (karst) fissures and stylolites.

Bioclastic wackestone ; bioclasts generally finely broken and often micritized to unrecognisable biolumps. Fossil contents : large brachiopod shells, complete ostracodes and thin-shelled gastropods. Micritic matrix, strongly recrystallized (textural inversion), development of clear spots of recrystallized micrite ; thin silicified beds, whereupon hard-grounds may be developed ; incomplete small authigenic quartz prisms.

SMF 9-10.

2.3.2.- Borehole DZ H2 (interval 1270,50-1274,15 m) 1270,50-1273,60 m :

Dark-grey, fine-grained limestone, carbonaceous, argillaceous, bioturbated ; core strongly broken and

karstified.

Bioclastic wackestone ; bioclasts consist of brachiopod shells and dorsal spines (Productids). Some black, calcareous shale intercalations and irregular black, cherty beds (overlain by a hardground) ; development of clear spots of recrystallized micrite.

SMF 9.

1273,50-1274,00 m :

Karst breccia containing material similar to over- and underlying limestone, insoluble residu accumulations with large clear calcite rhombs and finely disseminated pyrite.

1274,00-1274,15 m :

Light-grey, bioclastic limestone containing large crinoid ossicles.

2.3.3.- Borehole DZ H3 (interval 1108,70-1116,60 m)

Light-grey, fine-grained algal limestone, containing bioclastic intercalations ; open karst fissures and stylolites, and wide subvertical calcite veins.

Algal bindstone and thick stromatolitic laminites, occasionally large stromatolitic nodules (oncolites) with *stromatactis*-like core of up to 25 cm.

SMF 20.

Micritic sediments and oncoids occur on top of the algal crust in hollows and borings. Oncoids are sometimes grouped into grapestones. These oncoids may possess a core consisting of a crinoid ossicle or a bryozoan. They are overgrown by encrusting foraminifers and algal filaments. Micritic, structureless oncoids occur. Peloids are hardly discernible in the micrite. They can be distinguished as faecal pellets, lumps and micritic intraclasts whenever the micrites grade into biopelsparites. The bioclastic debris consists of crinoids, brachiopods (including one Productid of some 8 cm), gastropods, foraminifers, bryozoans, calcispheres, ostracodes and calcareous sponges. The bioclasts frequently possess a micritic envelope or may eventually be completely transformed into biolumps. Biolumps and non-micritized bioclasts are randomly distributed. Rare quiet-water ooids are dispersed among the other particles. Hollows and lenses within the algal mats are filled up with well sorted faecal pellets and accumulations of complete ostracode carapaces. The remaining voids are usually filled with radial-axial fibrous calcite. Traces of a primary veneer of fibrous calcite

along the walls of the voids have been observed.

SMF 16-17.

The micrite beds immediately underlying the algal laminites occasionally contain birdseye textures. Some V-shaped calcite veins, cut off by algal laminites and tapering out downwards in the micrite, possibly reflect desiccation cracks.

SMF 19.

Authigenic quartz prisms are very abundant (but rare in cementation zones), and extremely long (up to 20 mm).

2.3.4.- Borehole DZ H4 (interval 1243,50-1250,30 m) 1243,50-1244,62 m :

Light-grey, fine-grained limestone, containing coarser-grained bioclastic intercalations. At the base there is an intraformational conglomerate (12 cm thick). Some open karst fissures and subhorizontal stylolites occur.

Bioclastic grainstone with coated grains, poorly sorted ; bioclasts consist of crinoid ossicles, brachiopods, foraminifers, bryozoans, gastropods, calcispheres, echinoid spines, algal lumps and small oncoids. The crinoid ossicles are sometimes perforated, whereas the brachiopod shells show attached algal filaments and encrusting foraminifers. Micritisation of the bioclasts has produced micrite envelopes and eventually completely altered biolumps, which occasionally are grouped into grapestone lumps. The cement consists of recrystallized granular sparite. Syntaxial overgrowths occur around the crinoids. A primary fibrous cement lining is sometimes observed. The packing of the grains is rather dense as a result of pressure solution and stylolitisation. The grainstones are intercalated by fine-grained biopelmicrites, which occur also as reworked intraclasts in the grainstones. Large intraclasts of worn, white-coloured shells are concentrated near the base of this unit. Authigenic quartz prisms are rare.

SMF 17 transitional to SMF 12-13.

1244,62-1244,98 m :

At the top a chert lense is found.

This interval consists of black, pyritic mudstone, very fossiliferous, containing delicate but flattened macrofossils (*Fenestella*, *Posidonomya*, *Leiorhynchus*, Productids with thin dorsal spines of over 1 cm, juvenile brachiopods, fish scales) ; faecal pellets are frequent.

Whole fossils wackestone.

SMF 8.

The wackestone is passing downwards into a pyritic, nodular argillaceous limestone, bioturbated and fossiliferous (Spiriferids, Productids, crinoids, foraminifers, ostracodes, calcispheres, algal filaments). Bioclastic wackestones, usually laminated, show development of clear spots consisting of recrystallized micrite.

SMF 9.

1244,98-1246,10 m :

Grey to dark-grey, fine-grained limestone, bioturbated, containing burrows. Grey enterolitic nodules in a dark-grey, very argillaceous laminated limestone. Core strongly broken near 1246 m, open karst fissures and stylolites.

Bioclastic wackestone. The bioclasts consist of rather large brachiopod shells, dorsal spines of Productids, crinoids with worn margins, ostracodes, local concentrations of gastropods, rare algal lumps with encrusting foraminifers. Vaguely delineated peloids are admixed to the bioclasts. The nodular texture of these carbonates is enhanced by the differential compaction of the pure micritic wackestone and the more argillaceous wackestone. This resulted in a concentration of fine, dark laminae which envelop the pure micrite. Tiny quartz prisms are concentrated in the stylolites.

SMF 9.

1246,10-1248,50 m :

Grey, fine-grained encrinitic limestone, containing some coarser-grained intercalations ; bioturbated, with horizontal stylolites.

Well sorted, peloid, bioclastic grainstone, diagenetically altered. The bioclasts consist of crinoids, large brachiopod shells, foraminifers and calcispheres. All bioclasts are strongly micritized into coated grains and biolumps. Peloids are abundant and occasionally occur agglutinated. The matrix is composed of recrystallized sparite. Syntaxial overgrowth occurs around crinoids. Tiny quartz prisms are concentrated in stylolites.

SMF 17 transitional to SMF 11-12.

1248,50-1250,30 m :

Dark-grey, fine-grained argillaceous and carbonaceous limestone, laminated or bioturbated ; generally

nodular ; alternating with chert beds and encrinitic lenses. Stylolites.

Peloid-bioclastic wackestone. The fine bioclast debris contains brachiopods, crinoids, ostracodes, foraminifers and calcispheres. Argillaceous and siliceous laminae pass from the argillaceous wackestone into the diagenetically altered nodules. These are bent and slightly displaced in the contact zone, however. Some chert beds are overlain by hardgrounds. They grade downwards into the underlying wackestone. The transitional zones are usually strongly bioturbated. Some slightly silicified beds display a microfacies similar to the fossiliferous, calcareous mudstone beds. Tiny authigenic quartz prisms are locally abundant.

SMF 9.

The core interval 1243,50-1250,30 m shows a cyclic alternation of SMF 8 (whole fossil wackestones deposited in quiet water below the normal wave base and containing a well preserved fauna) to SMF 9 (bioclastic wackestone formed in shallow water with open circulation at or just below the wave base, containing bioclasts jumbled together, and strongly bioturbated), and SMF 17 to SMF 11-12-13 (grapestone/peloid-coated bioclast grainstone containing crinoid ossicle concentrations and oncoids formed in areas of constant wave action with mud removed by winnowing, deposited in very warm, shallow water with only a moderate circulation).

2.3.5.- Borehole DZ H5 (interval 1250,50-1254,90 m)

Light-grey, fine-grained algal limestone containing bioclastic grainstone lenses. The sediment is strongly recrystallized. This is suggested also by the development of large calcite bands. Intense karstification has resulted in carbonate dissolution and brecciation. The insoluble residu with pyrite and galena is concentrated in large open stylolites. Calcite is observed in veins and voids. Frequent small geodes are lined up with quartz and calcite crystals. The breccia contains shale fragments. Authigenic quartz prisms are abundant and very large (20 x 2 mm).

2.3.6.- Borehole DZ H5 (interval 1258,50-1267,50 m)

No cores have been recovered between 1260,50 and 1266,90 m. The limestones resemble those from the interval 1250,50-1254,90 m (see 2.3.5.). They are intensely karstified.

2.3.7.- Borehole DZ H6 (interval 1162,90-1167,26 m)

Light-grey, fine-grained algal limestone alternating

with often coarser-grained bioclast intercalations. Many stylolites occur at the contacts. The karstification has resulted in open fissures, stylolites with enrichments of pyrite and insolubles, calcite bands, and pyrite-calcite geodes in the upper part of the interval. Several facies types have been recognized, which alternate in this core.

Algal bindstone containing *stromatactis*-like fabric in wavy beds. Large oncoids have been formed around a core containing *Renalcis*, encrusting foraminifers and burrows.

SMF 20.

Trapped sediment consisting of pelmicritic lenses containing dispersed micritized bioclasts, ostracodes, calcispheres and quiet-water ooids. The large and numerous hollows and voids are filled with ostracode-pelospirite and - generally multilayered - radial-axial fibrous cement or drusy mosaic cement.

SMF 16.

Micritic wackestone, containing vague peloids, faecal pellets, agglutinated peloid lumps and a few dispersed bioclasts or fine bioclastic debris. The bioclasts consist of ostracodes, gastropods, brachiopods, bryozoans, calcareous sponges, micritized crinoid ossicles, crinoid ossicles with an etched margin, algal lumps, and oncoids containing algal filaments growing around a calcareous sponge, possibly on a hardground.

At some distance above the algal mats the micrite is often winnowed out in between the peloids and bioclasts. Poorly developed birdseye fabrics occur. Some larger cavities are possibly filled with vadose cement.

SMF 17, reworked into SMF 19.

Peloid bioclastic grainstone with occasionally birdseye fabric ; hardgrounds covered by algal mats, overgrown by bryozoans. Cavities filled with multilayered coarse, fibrous cement. The bioclasts are strongly micritized. They consists of crinoids, brachiopods, bryozoans, foraminifers, gastropods, calcareous sponges, large ostracodes, calcispheres, algal filaments, biolumps. The peloids are agglutinated. Reworked pelmicrite intraclasts occur. The cement consists of recrystallized sparite, but traces of a primary fibrous cement are preserved.

SMF 17 influenced by SMF 19.

The rather small authigenic quartz prisms are usually concentrated in the stylolites.

2.3.8.- Borehole DZ H6 (interval 1171,60-1176,15 m)

Light-grey, fine-grained algal limestones containing bioclastic intercalations. Stylolites, open karstic fissures, calcite veins and small geodes occur throughout the core.

The algal beds consist of algal stromatolite mudstone. The cavities are filled with multilayered coarse fibrous and drusy cement; possibly also with vadose silt. Some voids are filled with *stromatactis*-like fabric. The algal laminites alternate with pelmicritic lenses, rich in well-sorted faecal pellets, lumps, agglutinated lumps and pellets, biolumps, coated grains and oncoids containing algal filaments, which envelop brachiopods, crinoids or calcispheres.

SMF 20, alternating with SMF 16-17.

The bioclastic intercalations consist of peloid-bioclastic grainstone. The bioclasts consist of micritized crinoid ossicles, brachiopods, ostracodes, bryozoans, foraminifers, gastropods, calcispheres. An undisturbed lamellibranch faunule of *Parallelodon corrugatus* De Koninck occurs at 1171,75 m. The grains also comprise peloids, agglutinated peloids, lumps, biolumps and small oncoids. The cement consists of diagenetically altered sparite with syntaxial overgrowths on crinoid ossicles. Traces of a primary fibrous cement are usually preserved around the bioclasts.

SMF 13, transitional to SMF 17.

3.- BIOSTRATIGRAPHY

3.1.- FORAMINIFERS AND ALGAE

Fifteen thin slides from five core intervals of the boreholes DZ H2, 1261,50-1265,50 m, DZ H3, 1108,70-1116,60 m, DZ H4, 1243,50-1250,30 m, and DZ H6, 1162,90-1167,25 m and 1171,60-1176,15 m, have yielded a foraminifer assemblage consisting of rather few genera and species, but sometimes with numerous Archaeodiscids.

The foraminifers are partly recrystallized. This seriously hampers their identification. Moreover, the majority of the specimens are extremely small. This suggests that the environment was not an optimal one for benthic foraminifers except Archaeodiscids.

Table 1 shows the distribution of foraminifers and algae within the core intervals studied. Some of the foraminifer species are shown on Figure 4.

The foraminifer assemblages of the core from borehole DZ H4 are dominated by Archaeodiscids.

Also some *Tetrataxis*, *Palaeotextularia*, *Eostaffella* and *Endostaffella* occur. Most of the Archaeodiscids belong to the stadia *concaus* and *angulatus*. There is a tendency towards *Nodosarchaediscus* and *Asperodiscus*. This assemblage suggests the Cf 6 α (*Asperodiscus*) Zone (Conil, Groessens & Pirlet 1976). The assemblage from borehole DZ H2 is rather impoverished, but may resemble that of DZ H4.

The cores from borehole DZ H6 are characterized by the presence of Archaeodiscids of the *Nodosarchaediscus* group, by the occurrence of *Vissariotaxis* and some *Howchinia* together with *Tetrataxis* and *Palaeotextularia*, and by one specimen of *Globoendothyra*.

The core from the borehole DZ H3 has a foraminifer assemblage which resembles that of borehole DZ H6. *Plectogyranopsis convexa* and *Endostaffella* occur.

The assemblages from boreholes DZ H3 and DZ H6 suggest the Cf 6 α - β (*Asperodiscus*) Zone because of the occurrence of *Vissariotaxis* and *Nodosarchaediscus*.

Earlandia is relatively rare. Calcispheres (notably *Archaeosphaera* gr. *inaequalis* and *Pachysphaerina pachysphaerica*) occur in almost all slides. The same is true for algae such as *Palaeobereselleae*. Also some *Stacheiinae* occur. However, these have no stratigraphic value. Only *Pachysphaerina pachysphaerica* is characteristic of the Visean (Conil & Lys 1964).

3.2.- OSTRACODES

The core interval DZ H4, 1243.50-1250.30 m did not yield any ostracodes. The core intervals DZ H3, 1108.70-1116.60 m, DZ H6, 1162.90-1167.25 m, and DZ H6, 1171.60-1176.15 m have yielded a small, but rather diversified ostracode assemblage. Usually, a one kilogram sample per metre was studied.

These ostracode assemblages can be compared with similar assemblages of Dinantian age in the U.S.A., Great Britain, Belgium, southern Netherlands, Germany and the U.S.S.R. However, at least part of the species are relatively long-ranging forms which do not permit a more precise determination of the biostratigraphic position of the cores. Some species seem to occur in an earlier period in the U.S.S.R. than in NW Europe.

The best correlations can be made with ostracode assemblages of the Dinantian in Great Britain. Of special interest are *Pustulobairdia* ex. gr. *confragosa* and *Rectobairdia* cf. *dorsennata* which suggest an Asbian age in Great Britain, and *Rectobairdia?* *berniciana* that ranges from Holkerian into Brigantian strata (Robinson 1978).

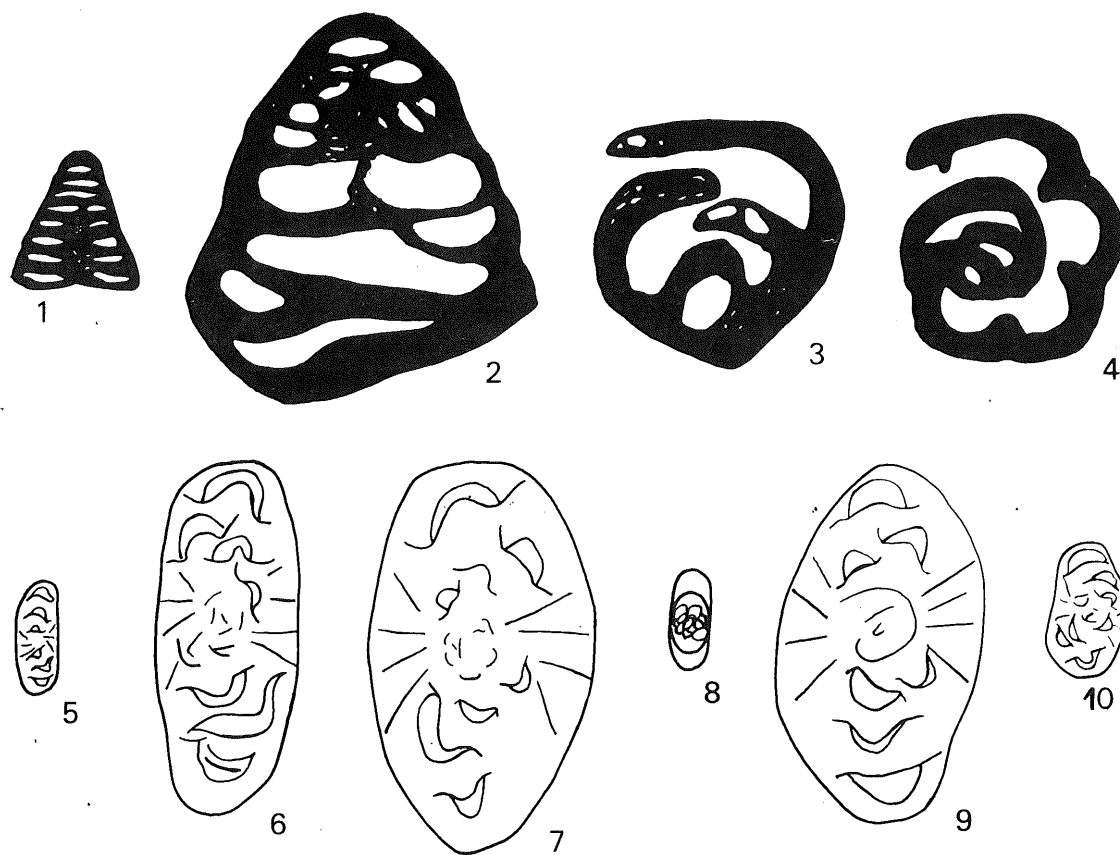
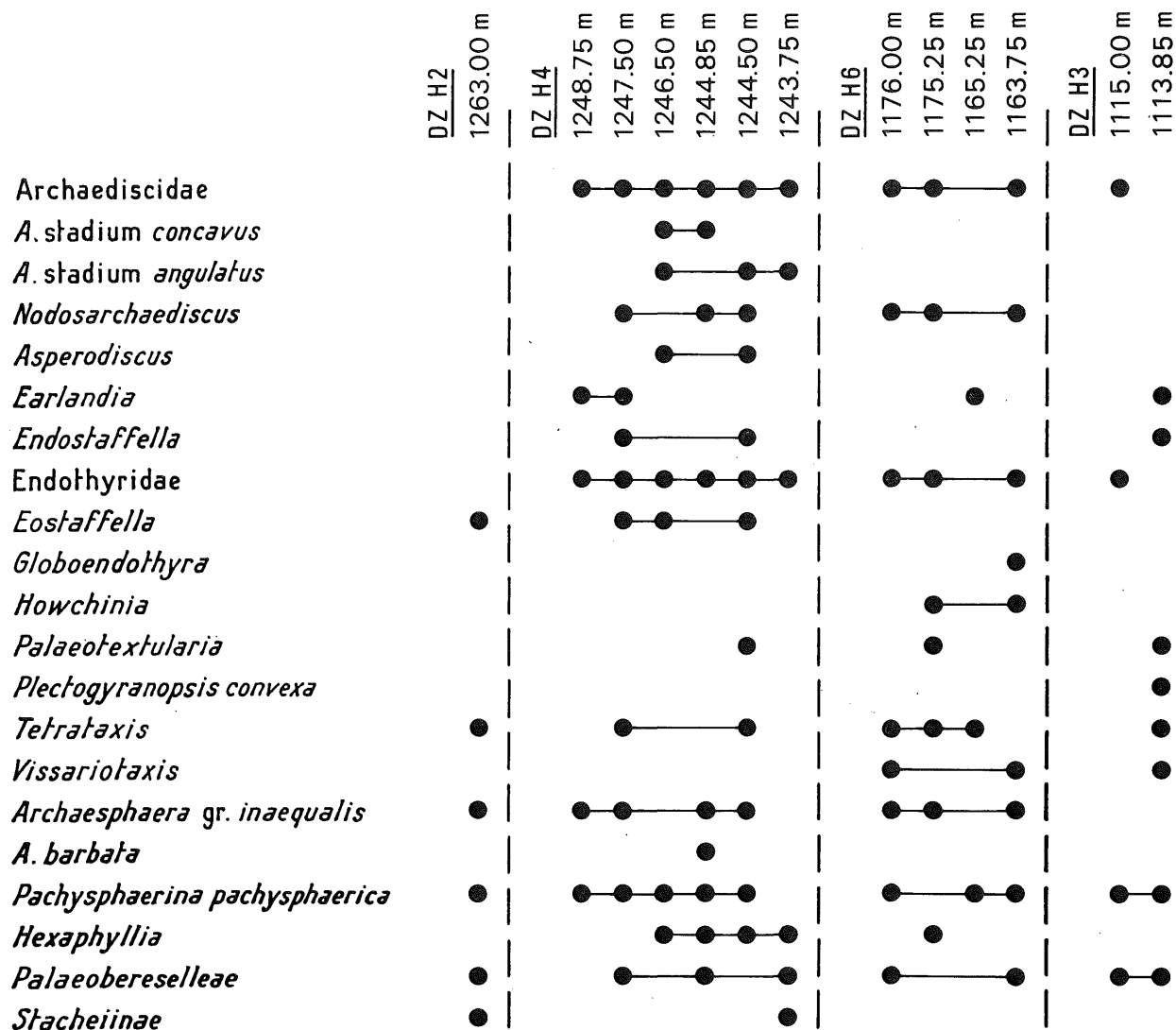


Figure 4

1. *Vissariotaxis* sp. DZ H6, 1163.75 m, x 75.
2. *Tetrataxis* sp. DZ H6, 1165.25 m, x 75.
3. *Palaeotextularia* sp. DZ H3, 1113.85 m, x 75.
4. *Plectogyranopsis convexa* (Rauser 1948) DZ H3, 1113.85 m, x 75.
- 5-7, 9-10. *Nodosarchaediscus* spp. (the specimens of fig. 6, 7 and 9 are extremely large within these *Archaediscid* assemblages).
5. DZ H4, 1244.85 m, x 140.
6. DZ H6, 1176.00 m, x 140.
7. DZ H6, 1175.25 m, x 140.
9. DZ H4, 1244.50 m, x 140.
10. DZ H4, 1244.85 m, x 140.
8. *Endostaffella* sp. DZ H4, 1244.85 m, x 75.

Table 1- Distribution of foraminifera and algae in the thin slides.



3.3.- CONODONTS

The core intervals DZ H3, 1108.70-1116.60 m, DZ H4, 1243.50-1250.30 m, DZ H6, 1162.90-1167.25 m, and DZ H6, 1171.60-1176.15 m, have been analyzed on their conodont contents. A one kilogram sample per metre was each time dissolved in monochloric acid. No conodonts have been observed.

4.- OSTRACODES

4.1.- SYSTEMATICS

Shishaella aff. *porrecta* (Zanina 1956) sensu Becker & Bless 1974
pl. 1 : 1-4

Material

Three complete carapaces and one damaged right valve.

Diagnosis

Lateral outline subelliptical to subcircular with almost straight dorsum. Single spine in posterodorsal quarter of right valve, more removed from posterior than from dorsal margin. Overlap of left valve over right valve along free margins narrow, greatest along venter and posterior.

Dimensions

Length of largest specimen slightly over 2.5 mm, height 1.8 mm.

Remarks

This species is conspecific with *Shivaella* aff. *porrecta* (Zanina 1956) sensu Becker & Bless 1974 from the Lower to Middle Tournaisian strata of Belgium. It also resembles *S. porrecta* (Zanina 1956) from the Dinantian of the Kuznetzk and Moscow Basins in the U.S.S.R. (Zanina 1956, Bushmina 1968), as well as *S. geisi* Sohn 1972 from the Meramecian Salem Limestone of Indiana and Missouri (U.S.A.).

Shivaella cf. *armstrongiana* (Jones & Kirkby 1886)

pl. 1 : 5-8

Material

One carapace and six single valves, all with spines broken off.

Diagnosis

Characterized by a large, posterodorsal spine on each valve. Spine at about equal distance from posterior and dorsal margin. Length of spines was more than half the length of the valves. However, spines were broken off during preparation.

Dimensions

Length of largest specimen slightly exceeding 1.5 mm, height 1.08 mm.

Remarks

Species distinguished by position of spine at some distance from dorsum. This form may be conspecific with *Shivaella armstrongiana* (Jones & Kirkby 1886) from the Courceyan to Arnsbergian of Great Britain (Jones & Kirkby 1886, Latham 1932), as well as with *Shivaella quasiporrecta* (Bushmina 1968) from the Tournaisian of the Kuznetzk Basin and Lena area in the U.S.S.R. (Bushmina 1968, 1970), and finally with *S. buccera* (Kummerow 1953) from the Dinantian of Poland.

Shivaella sp. 1

pl. 1 : 9

Material

One right valve.

Diagnosis

Posterodorsal spine close to dorsal border and at about one-third from posterior margin.

Dimensions

Length 1.10 mm, height 0.75 mm.

Remarks

This specimen is distinguished by the position of the spine close to the dorsal margin. It resembles *Shivaella macallisteri* Sohn 1972 from the Kinderhookian to Lower Osagian (= Middle to Upper Tournaisian) of California (U.S.A.).

Aparchites sp. 1

pl. 1 : 10-13

Material

Some twenty complete carapaces and single valves, part of them with remnants of velar ridge.

Diagnosis

Posterior and anterior margins almost equally rounded. Dorsum straight, venter convex. Cardinal angles distinct, obtuse. Surface smooth. Remnants of smooth velar ridge preserved. Velar ridge apparently extending along entire free border. Small spine present at position of posterior (?) cardinal angle of left valve in specimen GB10513.

Dimensions

Length including frill of largest specimen slightly over 1.0 mm, height including frill 0.8 mm.

Remarks

The same species is rather common in V1 limestones at Richelle near Visé (NE Belgium). This species is distinguished from *Aparchites* sp. 41 Becker & Bless 1974 from Upper Famennian of Ourthe Valley (Belgium) and *Aparchites* sp. 126 Becker *et al.* 1974 from Lower Tournaisian of Ourthe Valley (Belgium) by its smooth surface.

Kummerowia sp.

pl. 1 : 14-16

Material

Five single valves, part of them broken.

Diagnosis

Straight-hinged carapace with dorsal outline sometimes broadly arched and evenly convex domicilium. With or without well-developed sulcal pit. Surface coarsely to weakly reticulate. Striate frill of varying width.

Dimensions

Length of *Kummerowia* sp. 1 about 1.15 mm, height 0.58 mm. Length of *Kummerowia* sp. 2 0.90 mm, height 0.50 mm. Length of *Kummerowia* sp. 3 1.91 mm, height 0.78 mm.

Remarks

The genus *Kummerowia* is distinguished from *Kirkbya*

by the absence of a well-developed posterior "shoulder" and by a more evenly convex domicilium. The specimens at hand seem to represent different species which can be distinguished by variations of the relative width of the frill and of the reticulate surface ornamentation.

The genus *Kummerowia* has been recorded from the Tournaisian of Belgium (Becker & Bless 1974, Becker *et al.* 1974) the Russian Moscow Basin (Samoilova & Smirnova 1960) and Germany (Kummerow 1939). Holkerian to Brigantian ostracodes of Great Britain, assigned to *Kirkbya* by Robinson (1978) are here considered to belong to *Kummerowia*. Also *Kirkbya? reflexa* Girty 1910 from the Hombergian Fayetteville Shale (U.S.A.) is here inserted in *Kummerowia*.

cf. *Acanthoscapa* sp. 1

pl. 1 : 17

Material

One left(?) valve.

Diagnosis

Long, smooth, asymmetrical ostracode with almost straight dorsum and acuminate ends well above mid-height. Posteroventral portion of valve extremely flattened like a "keel".

Dimensions

Length 1.52 mm, height 0.38 mm.

Remarks

This specimen shows some resemblance to *Acanthoscapa*. This genus has only been recorded from Silurian to Middle Devonian strata up to now.

Microcheilinella sp. 1

pl. 1 : 19

Material

Two complete carapaces.

Diagnosis

Carapace extremely swollen, width exceeding height. Surface smooth. Dorsum gently convex, venter flat. Anterior margin rounded in lateral view, acuminate in dorsal and ventral views. Posterior margin also rounded in lateral view, but with slightly angular posteroventral part that may reflect position of blunt spine base. Greatest width slightly behind mid-length, greatest height anterior.

Dimensions

Length 0.90 mm, height 0.54 mm, width 0.68 mm.

Remarks

This species resembles *Microcheilinella subcorbuloides* (Jones & Kirkby 1885) from the Asbian to Pendleian of Great Britain in lateral and dorsal outlines. But it lacks the well-developed posteroventral spines.

Acutiangulata sp. 1

pl. 1 : 20

Material

One, slightly damaged, carapace.

Diagnosis

Rather elongate carapace with acuminate posteroventral end. Surface smooth.

Dimensions

Length 0,87 mm, height 0,49 mm, width 0,38 mm.

Remarks

Specimen resembles *Acutiangulata acutiangulata* (Posner 1960) sensu Bushmina (1970) from the Tournaisian of the River Lena area (U.S.S.R.).

Acratia sp. 1

pl. 1 : 21

Material

One, slightly damaged, carapace.

Diagnosis

Extremely elongate carapace with pointed posteroventral end. Anteroventral end probably acuminate. Venter almost straight, except for slightly upswept anterior part.

Dimensions

Length about 1.4 mm, height 0,42 mm, width 0,38 mm.

Cavellina? sp. 1

pl. 1 : 22

Material

One complete carapace.

Diagnosis

Subelliptical, smooth carapace. Posterior end more rounded than anterior. Maximum height posterior. Greatest width about at mid-length. Right valve overlaps left valve along venter.

Dimensions

Length 0.95 mm, height 0.45 mm.

Remarks

Specimen shows cavellinid outline, but lacks overall overlap of right over left valve. However, this may be due to imperfect preservation.

Baschkirina sp. 1

pl. 1 : 23-25

Material

One complete carapace and two right valves.

Diagnosis

Inequivalved, asymmetrical carapace with unequal ends. Right valve extends beyond left valve dorsally, but left valve overlaps right valve ventrally. Right valve with low, bulbous swelling in mid-dorsal position that merges with the rest of the domicilium. Dorsal margin gently curved. Hingement and muscle scar unknown. Anterior margin broadly rounded. Posterior margin more tapering in lateral view. Greatest height just in front of mid-length. Greatest width about at mid-length. Surface smooth.

Dimensions

Length of complete carapace 1.05 mm, height 0.58 mm, width 0.45 mm.

Remarks

The overlap and dorsal swelling are characteristic of *Baschkirina* Rozhdestvenskaja 1959 and *Rishona* Sohn 1960. It is suggested here, that *Rishona* is a junior synonym of *Baschkirina*. *Baschkirina* is well known from the Silurian and Devonian. Sohn (1960) suggested that *Cypridina laevigata* Eichwald 1857 from the Carboniferous of the U.S.S.R. should be included in this genus.

Baschkirina sp. 1 shows a close affinity to *Baschkirina tuberculata* Polenova 1974 from the Early Devonian of Novaya Zemlya (U.S.S.R.).

Bairdia robinsoni nov. sp.

pl. 2 : 26-33

Bairdia curta McCoy 1844 sensu Jones & Kirkby 1879, pl. 28 : 3-4 (not fig. 1-2, 5-7).

Bairdia mccoyi Croneis & Gutke 1939 sensu Cooper 1941, pl. 2 : 17-18

Bairdia sp. B. Sohn 1960, p. 33

Bairdia sp. cf. 92 Becker & Bless 1974, pl. 47 : 2.

Holotype : GB 10568 (pl. 2 : 27).

Type-level : Early Warnantian.

Type-location : DZ H6 borehole near Heibaart, N Belgium, 1174.60-1175.60 m.

Derivation of name : In honour of Dr. Eric Robinson, University College London, Great Britain, who published an outstanding paper on ostracodes from the Carboniferous of Great Britain.

Material

Some 15 complete carapaces, part of them damaged.

Diagnosis

Large, elongate carapace (length more than twice the height). Anterior margin round, anterior point well above

mid-height. Venter curved, slightly concave in central portion. Ventroposterior margin curved upward, posterior point at or slightly above mid-height. Dorsal margin about one-third of length of carapace, subparallel to venter. Posterodorsal margin approximately one-third of greatest length.

Dimensions of holotype

Length 2.57 mm, height 0.97 mm, width 0.69 mm.

Remarks

Distinguished from *Bairdia curta* McCoy 1844 and *Bairdia girtyi* Sohn 1960 by more rounded anterior margin, anterior point well above mid-height and almost straight dorsal margin subparallel to venter.

Bairdia robinsoni has been described from the Upper Viséan (V3bγ) of NE-Belgium (Becker & Bless 1974), Lower Carboniferous Limestone (= Brigantian) of Scotland (Jones & Kirkby 1879), and Chesterian Glen Dean Formation of Illinois, U.S.A. (Cooper, 1941).

Bairdia plebeia Reuss sensu Jones & Kirkby 1879

pl. 3 : 48, 52

Material

Two complete carapaces.

Diagnosis

Relatively elongate carapace with gently convex dorsum and straight to somewhat concave posterodorsal and anterodorsal margins. Dorsum subparallel to venter. Posterior point acuminate, slightly below mid-height. Anterior point above mid-height.

Dimensions of largest specimen

Length 1.68 mm, height 0.76 mm, width 0.52 mm.

Remarks

Bairdia plebeia Reuss 1854 is a Permian species, that is different in outline from the specimens described by Jones & Kirkby (1879) from the Dinantian strata of Great Britain. The material here at hand doesn't allow the creation of a separate species. Presumably, also *Bairdia plebeia* sensu Jones & Kirkby 1879 (their pl. 28 : 9-16) includes several species.

Bairdia sp. 1

pl. 1 : 18

Material

One broken carapace.

Remarks

This elongate specimen (length more than twice the height) has an outline that resembles *Bairdia robinsoni* nov. sp. This may be a juvenile instar.

Rectobairdia? berniciana (Robinson 1978)

pl. 3 : 53-54

Material

Two complete carapaces.

Diagnosis

Carapace tumid. Dorsum short, almost straight, gently sloping to posterior. Anterodorsal and posterodorsal margins straight to slightly concave. Anterior point above mid-height. Anterior merging with anteroventral margin. Venter straight. Posteroventral margin upcurved. Posterior point slightly upturned, below mid-height. Carapace strongly inflated in dorsal view.

Dimensions of largest specimen

Length slightly over 1.5 mm, height 0.94 mm, width 0.82 mm.

Remarks

Rectobairdia? berniciana (Robinson 1978) was a new name for *Bairdia brevis* Jones & Kirkby 1867 (nomen nudum). *Bairdia brevis* was figured and described by Jones & Kirkby 1879. The species is characterized by its tumid, short carapace. The generic position is doubtful. Sohn (1960) assigned it to *Bairdia*, Robinson (1978) to *Cryptobairdia*. Because of the almost straight dorsum and distinct anterodorsal margin, it is here tentatively placed in *Rectobairdia*. Robinson (1978) recorded *R.? berniciana* from Holkerian to Brigantian strata of Great Britain. Bushmina (1968) recognized *Bairdia brevis* (= *R.? berniciana*) and the closely related (if not conspecific) *Bairdia compacta* Geis sensu Bushmina 1968 from, respectively the Upper Tournaisian and Lower Visean of the Kuznetzk Basin (U.S.S.R.). Bushmina (1975) described *Bairdia brevis* from the Upper Tournaisian of the Kolymian Massif (U.S.S.R.).

Rectobairdia conili nov. sp.

pl. 3 : 40, 44-47

Bairdia amputata (Kirkby) sensu Jones & Kirkby 1879, pl. 31 : 15-18

Rectobairdia sp. A Sohn 1960, p. 56.

Holotype : GB 10504 (pl. 3 : 40).

Type-level : Early Warnantian.

Type-location : DZ H6 borehole near Heibaart, N Belgium, 1163.50 m.

Derivation of name : In honour of Prof. Raph. Conil, Université Catholique de Louvain-la-Neuve, one of the leading specialists on Dinantian stratigraphy.

Material

Five complete carapaces.

Diagnosis

Dorsum straight, distinctly sloping to the posterior,

about one-third of greatest length. Posterodorsal margin concave, strongly sloping to posterior acuminate point. Anterodorsal margin short, almost subparallel to venter. Anterior margin merging with anteroventral margin. Anteroventral margin forms distinct "hook" with straight ventral margin. Posteroventral margin gently upcurved. Surface smooth.

Dimensions of holotype

Length 2.08 mm, height 1.02 mm, width 0.75 mm.

Remarks

Species closely related to *Rectobairdia natiformis* (Bushmina 1970) from Lower Visean of Lena area (U.S.S.R.) and *Rectobairdia posneri* Sohn 1960 from Lower Carboniferous of Moscow Basin (U.S.S.R.).

This species is separated from *Pustulobairdia confragosa* (Samoilova & Smirnova 1960). The latter has a similar lateral outline, but is ornamented with pores and pustules. Robinson (1978) believed that the smooth forms are abraded or polished forms. But the excellent state of preservation of the material at hand justifies the erection of a species on its own right.

Cryptobairdia praecisa (Jones & Kirkby 1879) from the upper part of the Calciferous Sandstone Measures (= Asbian-Lower Brigantian) of Scotland somewhat resembles *Rectobairdia conili*. It is distinguished, however, by a more downward curving anterodorsal margin.

Rectobairdia deformis (Jones & Kirkby 1879)

pl. 3 : 43

Material

One complete carapace.

Diagnosis

Straight dorsum, sloping to posterior. Anterodorsal and posterodorsal margins concave, ending in pointed extremities. Anterior margin merging with anteroventral margin, ending in slightly upturned anterior point. Posterior point low, acuminate and almost in line with the ventral margin.

Dimensions

Length 1.38 mm, height 0.67 mm, width 0.52 mm.

Remarks

The posterior point is lower than in *Rectobairdia cuspidata* Robinson 1978 from the Arnsbergian of Great Britain. *R. deformis* has been recorded from the Carboniferous Limestone of Steeraway (England).

Rectobairdia cf. dorsennata Robinson 1978

pl. 2 : 34-39

Bairdia Hisingeri Münster) sensu Jones & Kirkby 1879, pl. 29 : 4-10.

Rectobairdia sp. D Sohn 1969, p. 56.
cf. *Rectobairdia dorsennata* Robinson 1978, pl. 12 : 1.

Material

Some ten complete carapaces, some of them broken.

Diagnosis

Dorsal margin almost straight, between one-third and one-half the greatest length, subparallel to venter. Venter distinctly concave in central portion and clearly convex in anterior and posterior parts. Anterior margin almost round, merging gradually with dorsal and ventral margins. Posterodorsal margin concave, located in posterior quarter of greatest length. Posterior point well below mid-height. Dorsal and ventral overlap of left valve over right valve narrow.

Dimensions

Length of largest specimen 1.61 mm, height 0.68 mm.

Remarks

This rather elongate species is distinguished from *Bairdia tabaensis* Bushmina 1970 from the Tournaisian of the River Lena area (U.S.S.R.) by its more broadly rounded anterior margin. *Rectobairdia dorsennata* Robinson 1978 is considerably larger and possesses a more raised and inflated posterodorsal portion than the specimens recovered here. *R. dorsennata* is a guide for the Asbian (= V3b) of Central England and Scotland. *Bairdia Hisingeri* sensu Jones & Kirkby 1879 has been recognized a.o. from Brigantian strata (= V3c) of Scotland.

Pustulobairdia ex. gr. *confragosa* (Samoilova & Smirnova 1960)

pl. 3 : 41-42

Material

Two complete carapaces.

Diagnosis

Dorsal margin straight, distinctly sloping to the posterior, between one-quarter and one-third of greatest length. Posterodorsal margin concave, strongly sloping to posterior, acuminate point. Anterodorsal margin slightly concave, almost subparallel to venter. Anterior point at about the same height as junction between dorsal and posterodorsal margins. Anterior end merging with anteroventral margin. Anteroventral margin forms distinct "hook" with short, straight venter. Posteroventral margin gently upcurved. Surface ornamented with punctae and wart-like low, subdued pustules.

Dimensions

Length 1.70 mm, height 0.87 mm, width 0.73 mm.

Remarks

The present specimens are here attributed to the species group *confragosa* (Samoilova & Smirnova 1960), that includes closely related forms such as *P. subampla* (Posner 1951) sensu Tschigova 1959, p. 215, pl. 13 : 1 from the Upper Visean of the European part of the U.S.S.R., *P. sculpta* (Tschigova 1958) sensu Tschigova 1960, p. 230, pl. 13 : 2 from the Tournaisian and Lower Visean of the European part of the U.S.S.R., *P.*

confragosa (Samoilova & Smirnova 1960) from the Middle Tournaisian of the Moscow Basin (U.S.S.R.) and *P. confragosa* (Samoilova & Smirnova 1960) sensu Robinson 1978, pl. 12 : 4 from the Asbian of Great Britain.

Orthobairdia spp.

pl. 3 : 49-51

Material

Three complete carapaces.

Diagnosis

Bairdiid ostracodes with more or less parallel sides in dorsal view.

Remarks

The material at hand possibly includes several species.

Bairdiocypris aff. *robusta* Kummerow 1939

pl. 3 : 55-57

Material

Three complete carapaces and one left valve.

Diagnosis

Carapace elongate (length more than twice the height). Dorsum straight to gently convex, merging with convex anterodorsal and posterodorsal margins. Anterior and posterior margins well rounded. Venter distinctly concave, merging with anterior and posterior margins.

Dimensions of largest specimen

Length 2.50 mm, height 1.07 mm.

Remarks

The present species shows a close affinity to *Bairdiocypris robusta* Kummerow 1939 from the Lower Tournaisian of Belgium. It is conspecific with *Bairdiocypris* aff. *robusta* Kummerow sensu Becker & Bless 1974 from the Lower Tournaisian of Belgium. Also *Bairdiocypris quasielongata* Bushmina 1968 from the Middle to Upper Tournaisian of the Kuznetzk Basin and River Lena area in the U.S.S.R. is comparable to our specimens.

Bairdiocypris cf. *rudolphi* (Kummerow 1939)

pl. 4 : 58-61

Bythocypris rudolphi Kummerow 1939, p. 48, pl. 5 : 9.

Silenites bilobatus (Münster 1830) sensu Kummerow 1939, p. 49-50, pl. 5 : 11.

Material

Six complete carapaces.

Diagnosis

Dorsum almost evenly curved. Venter gently concave. Ends well rounded in lateral view, pointed in dorsal view.

Dimensions of largest specimen

Length 1.66 mm, height 1.00 mm.

Remarks

The present specimens seem comparable to *Bairdiocypris rudolphi* (Kummerow 1939) from the Lower Visean of Germany and to the probably conspecific *B. bilobatus* sensu Kummerow 1939 from the Lower Visean of Germany and Belgium. This species is also closely related to *Bairdiocypris fomikhaensis* Bushmina 1968 from the Upper Tournaisian of the Kuznetzk Basin, River Lena area and Kolyman Massif of the U.S.S.R. (Bushmina 1968, 1970, 1975). Becker & Bless (1974) recorded *Bairdiocypris* cf. *rudolphi* from uppermost Famennian to Upper Visean strata of Belgium.

Bairdiocypris cf. *truncatiformis* Zanina & Bushmina 1968
pl. 4 : 62-65

Bairdiocypris truncatiformis Zanina & Bushmina in Bushmina
1968, p. 95-96, pl. 19 : 1-2.

Material

Five complete carapaces.

Diagnosis

Overlap of LV over RV narrow, most important along dorsum. Venter straight to gently concave. Anterior and anteroventral margins distinctly depressed and flattened.

Dimensions of largest specimen

Length 1.48 mm, height 0.99 mm, width 0.68 mm.

Remarks

This species resembles *Bairdiocypris truncatiformis* Zanina & Bushmina 1968 from the Middle to Upper Tournaisian of the Kuznetzk Basin (U.S.S.R.). The generic assignment may be disputable because of the depressed anterior margin. However, typical species of the closely related genus *Bekena* Gibson 1955 have both end margins flattened (see also Sohn 1960).

CYPRIDINACEA BAIRD 1850

pl. 4 : 66-70

Remarks

This superfamily includes numerous Paleozoic, and notably Carboniferous genera and species (cf., e.g. Jones, Kirkby & Brady 1874, Bless & Sanchez de Posada 1973). The definition of genera and species is still unsatisfactory. Frequently, the low number of available specimens makes a revision problematic. Therefore, the descriptions here below are bound to be provisional.

"*Cypridina*" sp. 1
pl. 4 : 66

Material

One partly crushed carapace.

Diagnosis

Rostrum relatively large. Anterior margin below rostrum directly merging with venter. Dorsal margin broadly curved. Slightly incised, short hingeline. No caudal siphon observed.

Dimensions

Length about 1.85 mm, height about 1.25 mm.

Remarks

Exact position of this species within Cypridinacea is unknown. *Cypridina* is a recent genus with carapace poorly or not calcified. "*Cypridina*" sp. 1 closely resembles *Cypridina brevementum* Jones, Kirkby & Brady 1874 from the Carboniferous Limestone of Ireland, Great Britain and Belgium. Both species show the rapidly backward sloping anteroventral margin.

Cypridinella sp. 1
pl. 4 : 68

Material

One right valve.

Diagnosis

Prow distinct, more prominent than rostrum. Caudal process blunt.

Dimensions

Length 1.01 mm, height 1.04 mm.

Remarks

This may be a juvenile specimen of *Cypridinella*.

Cypridinella vel *Cyprisurcella* sp.
pl. 4 : 69

Material

One right valve.

Diagnosis

Anteroventral prow poorly marked. Anterior margin straight and vertical. Caudal process blunt. Rostrum small. Lateral outline sub-triangular.

Dimensions

Length 1.38 mm, height 1.07 mm.

Remarks

This form is close to *Cypridinella* vel *Cyprisurcella* sp. sensu Bless & Sanchez de Posada 1973 from the basal Stephanian of Spain.

Cyprisurcella sp. 1
pl. 4 : 67

Material

One left valve.

Diagnosis

Anteroventral prow poorly marked. Anterior margin almost straight and vertical. Caudal process blunt. Nuchal furrow well developed. Rostrum small. Lateral outline sub-triangular. Surface pitted.

Dimensions

Length 1.78 mm, height 1.18 mm.

Remarks

The species shows the characteristic nuchal furrow of *Cyprisurcella*. The caudal process is less well developed than in *C. papillosa* Sanchez de Posada & Bless 1971 from the Upper Westphalian of Spain. The surface ornamentation is also different.

"*Cypridina*" sp. 2
pl. 4 : 70

Material

One left valve.

Remarks

The more distinct junction between the anterior and ventral margins distinguish this species from "*Cypridina*" sp. 1.

4.2.- PALEOECOLOGY

The ostracode assemblages from the core intervals DZ H3, 1110.60-1116.60, and DZ H6, 1163.50-1176.60 m, are distinguished by the relative size of the species.

Fifty percent of the 28 species recovered shows a maximum length of more than 1.50 mm, whereas 85 % of the species has a maximum length of more than 1.00 mm. Remarkable is the fact that even smaller species, such as *Microcheilinella* sp. 1 are relatively large as compared to other representatives of the same genus.

This feature is not confined to the Visean ostracodes of the Heibaart borehole. It has also been observed for other Tournaisian and Visean ostracode assemblages of Belgium (fig. 5). Of special interest is the fact that these assemblages have only few species in common. For example, the Visean assemblage of Heibaart (28 species) and the Visean assemblage of other boreholes and outcrops in northeastern Belgium and the southern Netherlands (35 species) have only seven species in common, whereas only five species occur in both the Visean assemblage of Heibaart (28 species) and the Tournaisian of the Ourthe Valley (44 species). This suggests that the relatively large size of the ostracodes in these assemblages is not related to a certain group of species. These assemblages have in common, that they have been extracted from massive limestones.

A review of the literature readily learns that ostracodes from shale-dominated rock sequences - even if these include interbedded limestone horizons - are always predominated by species smaller than 1.00 mm (usually more than 59 % of the species).

An intermediate length is found in the Lower Dinantian *Gattendorfia* beds of Germany, which consist of limestone nodules in a shale matrix.

Although the relation size-sediment seems obvious, this doesn't necessarily imply that the size of species was dependent on the substratum. One should

keep in mind that presumably at least part of the ostracode species (notably the Cypridinacea) were nektonic forms. Maybe, the relative transparency of the water, practically devoid of floating clay particles, was a much more important factor. This is also suggested by the observation that the ostracode assemblages of the Dinantian in Belgium and the southern Netherlands have been recovered from bioclastic limestones, pseudo-oolitic and oolitic limestones and even from the so-called Waulsortian carbonate mud-mounds.

5.- DEPOSITIONAL ENVIRONMENT

The cores of boreholes DZ H2 and DZ H4 (both located on the southern flank of the Heibaart dome) are distinguished from those of the boreholes to the north by their lithology and age.

The cores of borehole DZ H2 are dominated by bioclastic wackestone (SMF 9).

The DZ H4 cores show a cyclic alternation of bioclastic wackestone (SMF 9) and bioclastic grainstone to grapestone pelsparite (SMF 11, transitional to SMF 17). This latter facies also occurs in the boreholes to the north.

Deposition of these sediments occurred in an open marine shelf lagoon under shallow water conditions (facies belt 7). Admixed clay is responsible for the nodular bedding. The grainstones have possibly been formed in areas where periods of constant wave action alternated with periods of moderate water circulation (during which micritisation took place). Sharp contacts between these facies may suggest stratigraphic gaps.

The DZ H3 and DZ H6 cores (and possibly also the DZ H1 and DZ H5 cores) consist of algal bindstones and peloidal wackestones often with birdseye fabric (SMF 20 and SMF 16-19), grading into or alternating with bioclastic grainstone to grapestone pelsparites (SMF 11 and 13, transitional to SMF 16-17).

These facies include sediments deposited in very shallow lagoons with a restricted water circulation and hypersaline water (facies belt 8). Sediments with birdseye fabric and algal stromatolites suggest a tidal flat environment. The fairly rich and diversified fauna and flora suggest an exchange of organisms between the open marine shelf and the shallow lagoon with restricted water circulation.

The microfossil contents of the Heibaart cores

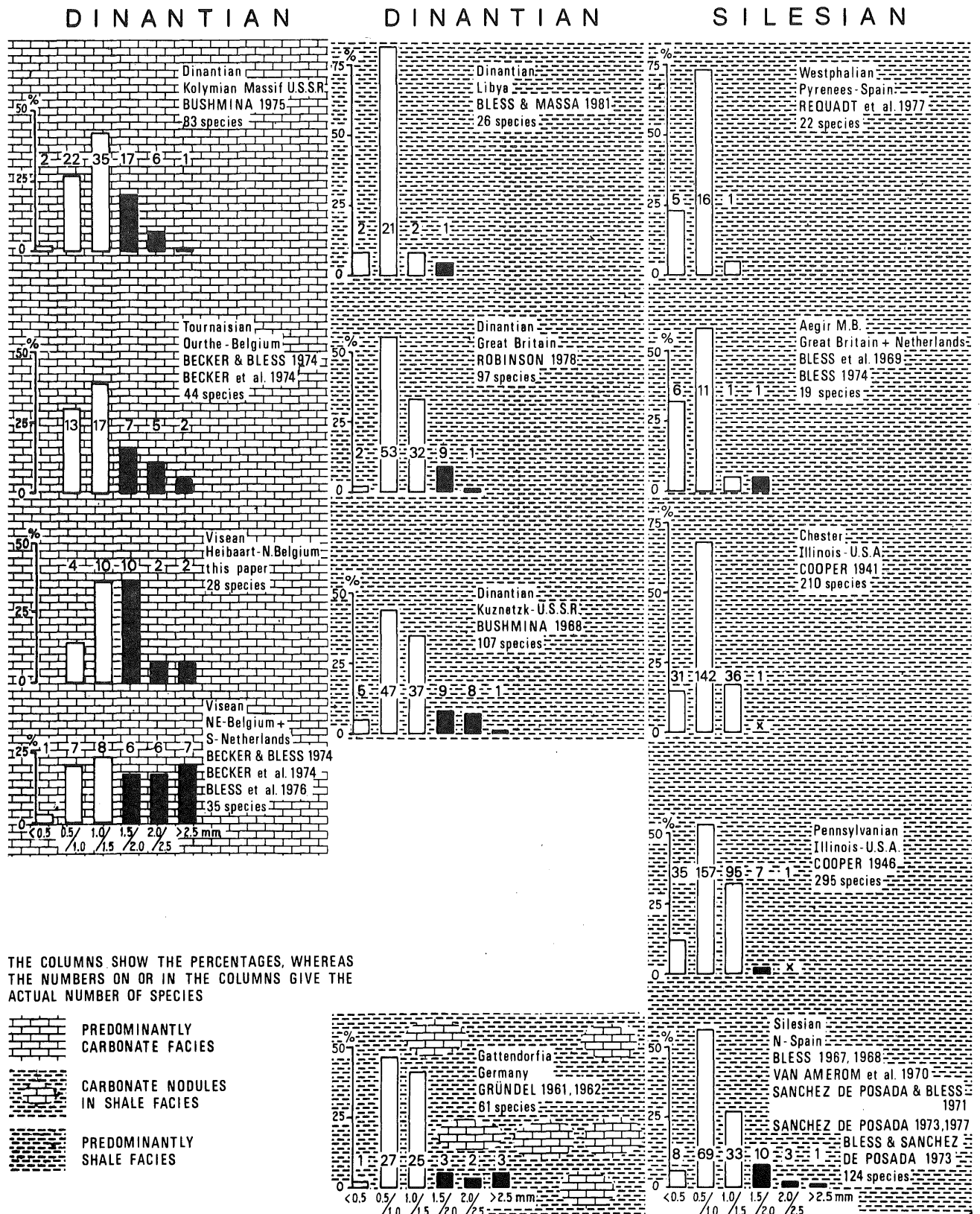


Figure 5.- Histograms showing distribution of greatest recorded length of ostracode species in Carboniferous assemblages.

largely matches that of other late Dinantian carbonates in Belgium and the southern Netherlands.

The virtual absence of conodonts in Livian and lower Warnantian beds is confirmed by the present study.

Practically all the ostracode specimens recovered from the DZ H3 and DZ H6 cores are complete carapaces. This may suggest that the ostracodes represent (par-) autochthonous species which once lived in this environment. The assemblage includes presumably nektonic (e.g. Cypridinacea), crawling (e.g. bairdiids) and some burrowing (e.g. *Microcheilinella*) forms.

The foraminifer assemblage is small. Maybe, this habitat was not an optimal niche for foraminifers, except for some Archaediscids.

Authigenic quartz prisms are an important minor rock constituent. Presumably, these were formed in a late diagenetic phase under hypersaline conditions (Nachsel 1966). Their habitus and length-width ratio are remarkably constant although their size and relative abundance vary. Very large (up to 20 mm, with a length-width ratio approaching 10) crystals abound in boreholes DZ H3 and DZ H5, where they occur most profusely in the peloid grainstone intercalations within the algal stromatolites. The quartz prisms in the boreholes DZ H4 and DZ H6 are small and usually concentrated in stylolites. Quartz prisms are rare and incompletely crystallized in borehole DZ H2. In this latter hole, quartz prisms of rather large size have been found in large numbers in the cuttings some 20 m below the base of the lowermost core at -1270 m. Possibly, they indicate a change towards a lagoonal facies with algal limestones.

In borehole DZ H3, the quartz prisms disappear at about -1245 m, possibly indicating a facies change to a more argillaceous, open lagoon limestone. At comparable depths, the quartz prisms disappear in boreholes DZ H2 and DZ H4. These observations suggest that the algal limestones might have a thickness of a least 140 m.

Noteworthy is the presence of sulphide minerals (mainly pyrite and some galena and sphalerite), which are dispersed in all limestone types. These are concentrated within the insoluble residu of karst dissolution joints. They are most abundant in DZ H5, interval 1252-1293 m.

The DZ H2 and DZ H4 cores have been attributed to the Cf6 α Zone. The DZ H3 and DZ H6 cores to the slightly younger Cf6 α - β Zone. Rock units of the same age and similar facies have not been described from the Turnhout borehole. In this borehole,

a limestone breccia is found at the stratigraphic position of the lower Warnantian at a depth of 2250-2276 m. Also in the Halen borehole, a limestone breccia between 964 and 984 m occurs at the stratigraphic position of the lower Warnantian Heibaart carbonates (Bless *et al.* 1976).

Upper Warnantian carbonates (recognized at Turnhout and Halen) have not been observed in the Heibaart and Woensdrecht areas, where an important gap between Livian to early Warnantian carbonates and Alportian to Kinderscoutian siliciclastics exists.

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PLATE 1

- 1-4 : *Shishaella* aff. *porrecta* (Zanina 1956) sensu
Becker & Bless 1974.
1. GB10505, DZ H6, 1163.50 m, LV
 2. GB10576, DZ H6, 1174.60-1175.60 m, LV and D
 3. GB10563, DZ H6, 1174.60-1175.60 m, LV and D
 4. GB10578, DZ H6, 1174.60-1175.60 m, LV and D
- 5-8 : *Shivaella* cf. *armstrongiana* (Jones & Kirkby
1886)
5. GB10509, DZ H6, 1163.50-1164.50 m, RV
 6. GB10549, DZ H6, 1172.60-1173.60 m, RV
 7. GB10577, DZ H6, 1174.60-1175.60 m, RV
 8. GB10508, DZ H6, 1163.50-1164.50 m, LV
- 9 : *Shivaella* sp. 1
GB10565, DZ H6, 1174.60-1175.60 m, RV
- 10-13 : *Aparchites* sp. 1
10. GB10518, DZ H6, 1164.60-1165.60 m, LV and D
 11. GB10513, DZ H6, 1163.50-1164.50 m, LV
 12. GB10514, DZ H6, 1164.60-1165.60 m, fragment
with flange
 13. GB10517, DZ H6, 1164.60-1165.60 m, RV and D
14. : *Kummerowia* sp. 1
GB10585, DZ H3, 1111.60-1112.60 m, RV
- 15 : *Kummerowia* sp. 2
GB10552, DZ H6, 1173.60-1174.60 m, RV
- 16 : *Kummerowia* sp. 3
GB10553, DZ H6, 1173.60-1174.60 m, LV
- 17 : cf. *Acanthoscapha* sp. 1
GB10556, DZ H6, 1173.60-1174.60 m, RV
- 18 : *Bairdia* sp. 1
GB10551, DZ H6, 1173.60-1174.60 m, RV,
LV and D
- 19 : *Microcheilinella* sp. 1
GB10561, DZ H6, 1173.60-1174.60 m, RV, D,
ventral and posterior.
- 20 : *Acutiangulata* sp. 1
GB10547, DZ H6, 1172.60-1173.60 m, RV
and D
- 21 : *Acratia* sp. 1
GB 10562, DZ H6, 1174.60-1175.60 m, RV
and D
- 22 : *Cavellina?* sp. 1
GB10575, DZ H6, 1174.60-1175.60 m, RV
and D
- 23-25 : *Baschkirina* sp. 1
23. GB10519, DZ H6, 1165.60-1166.60 m, RV,
LV and D
 24. GB10538, DZ H6, 1171.60-1172.60 m, RV
 25. GB10546, DZ H6, 1171.60-1172.60 m, RV

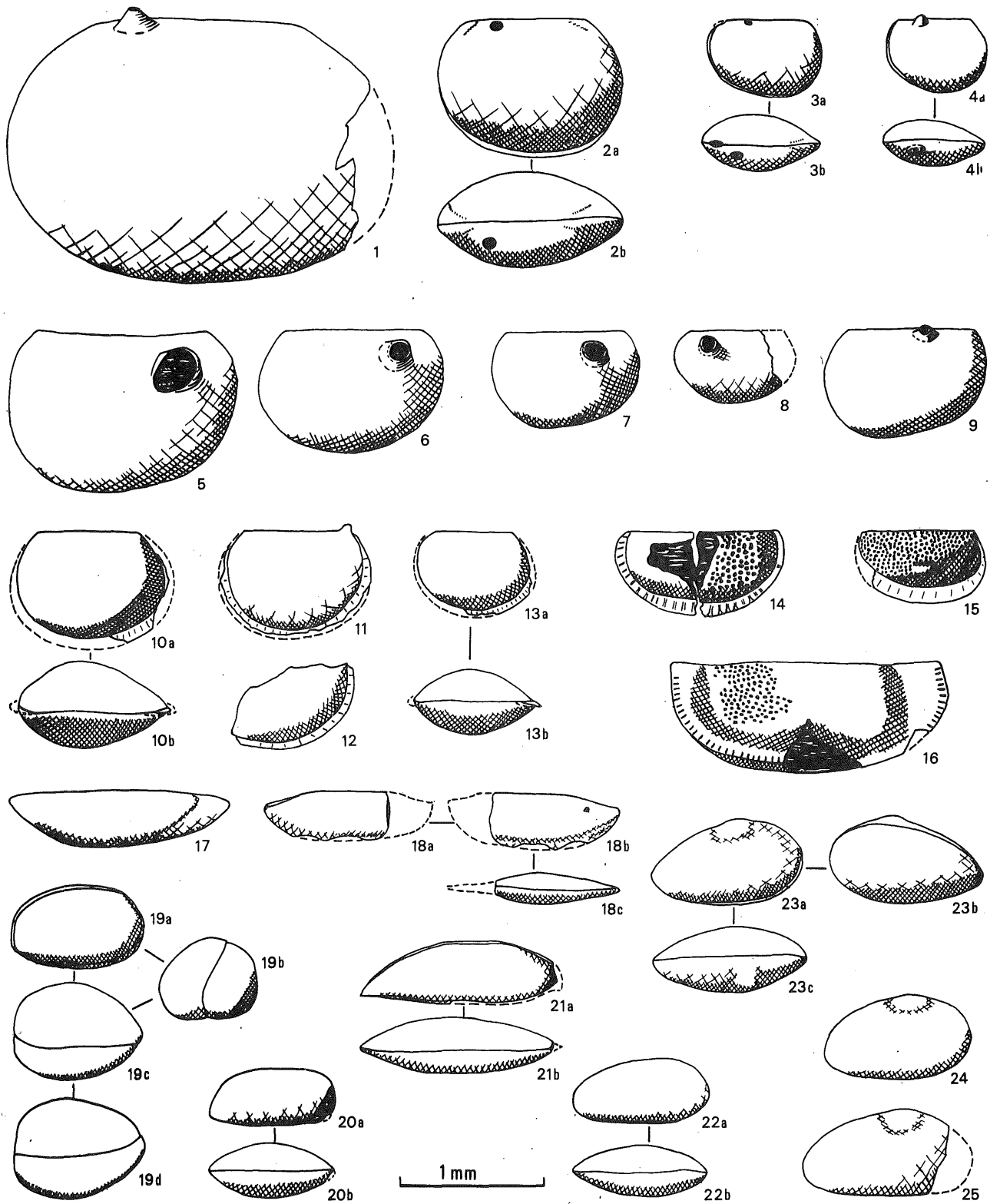


PLATE 2

26-33 : *Bairdia robinsoni* nov. sp.

- 26. GB10543, DZ H6, 1171.60-1172.60 m, RV and D
- 27. GB10568, DZ H6, 1174.60-1175.60 m, RV and D
holotype
- 28. GB10590, DZ H3, 1112.60-1113.60 m, RV and D
- 29. GB10599, DZ H3, 1115.60-1116.60 m, RV and D
- 30. GB10548, DZ H6, 1172.60-1173.60 m, RV and D
- 31. GB10511, DZ H6, 1163.50-1164.50 m, RV and D
- 32. GB10523, DZ H6, 1166.60-1167.25 m, RV and D
- 33. GB10536, DZ H6, 1171.60-1172.60 m, RV and D

34-39 : *Rectobairdia* cf. *dorsennata* Robinson 1978

- 34. GB10589, DZ H3, 1112.60-1113.60 m, RV and D
- 35. GB10593, DZ H3, 1114.60-1115.60 m, RV and D
- 36. GB10564, DZ H6, 1174.60-1175.60 m, RV and D
- 37. GB10583, DZ H6, 1175.60-1176.15 m, RV and D
- 38. GB10506, DZ H6, 1163.50 m, RV and D
- 39. GB10559, DZ H6, 1173.60-1174.60 m, RV and D

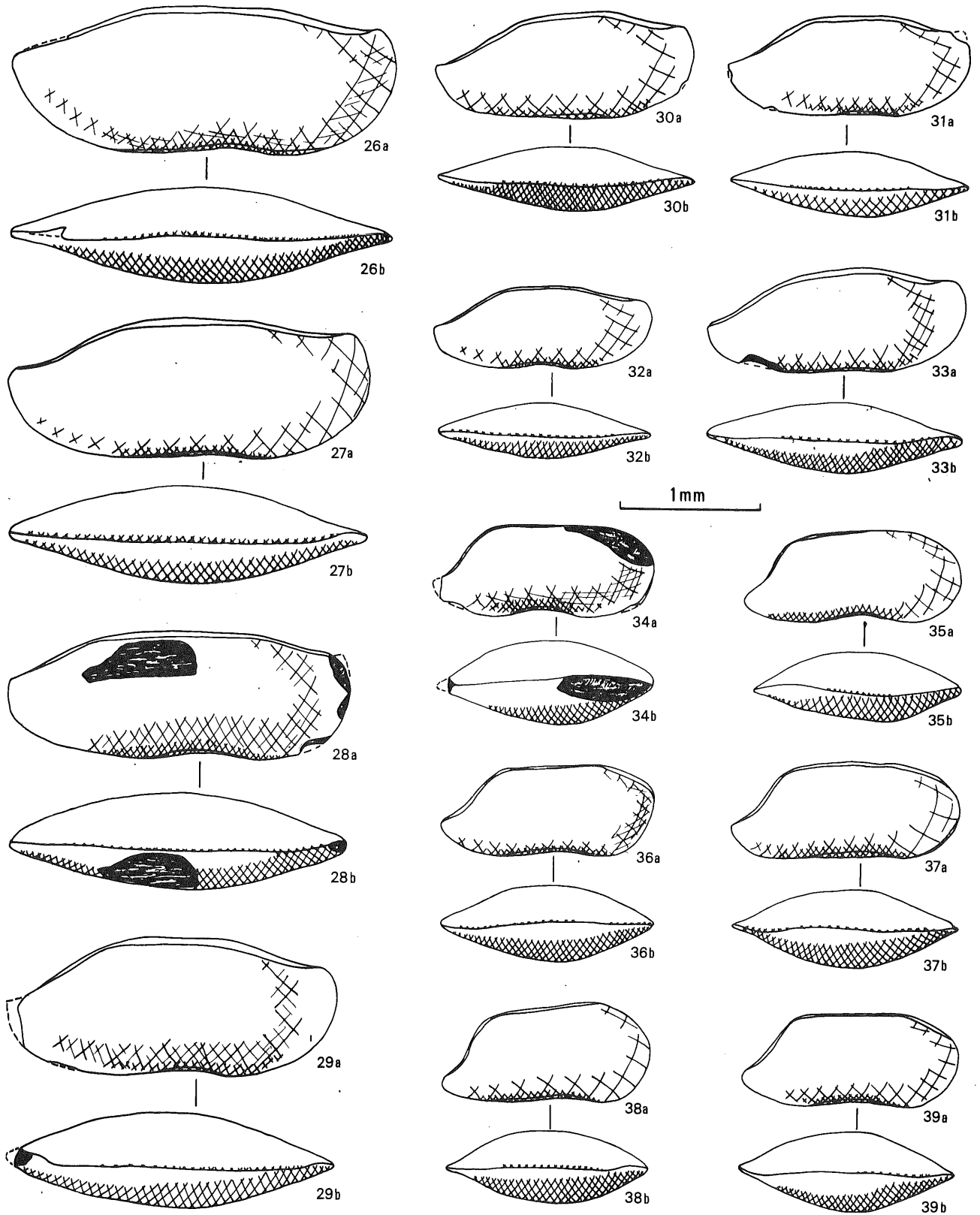


PLATE 3

40, 44-47 : *Rectobairdia conili* nov. sp.

- 40. GB10504, DZ H6, 1163.50 m, RV and D, holotype
- 44. GB10525, DZ H6, 1166.60-1167.60 m, RV and D
- 45. GB10531, DZ H6, 1166.60-1167.60 m, RV and D
- 46. GB10587, DZ H3, 1111.60-1112.60 m, RV and D
- 47. GB10596, DZ H3, 1114.60-1115.60 m, RV and D

41-42 : *Pustulobairdia* ex gr. *confragosa* (Samoilova & Smirnova 1960)

- 41. GB10574, DZ H6, 1174.60-1175.60 m, RV and D
- 42. GB10573, DZ H6, 1174.60-1175.60 m, RV and D

43 : *Rectobairdia deformis* (Jones & Kirkby 1879)
GB10584, DZ H6, 1175.60-1175.15 m, RV and D

48, 52 : *Bairdia plebeia* Reuss sensu Jones & Kirkby 1879

- 48. GB10601, DZ H3, 1115.60-1116.60 m, RV and D
- 52. GB10588, DZ H3, 1112.60-1113.60 m, RV and D

49-51 : *Orthobairdia* spp.

- 49. GB10598, DZ H3, 1115.60-1116.60 m, RV and D
- 50. GB10582, DZ H6, 1175.60-1176.15 m, RV and D
- 51. GB10560, DZ H6, 1173.60-1174.60 m, RV and D

53-54 : *Rectobairdia* ? *berniciana* (Robinson 1978)

- 53. GB10591, DZ H3, 1114.60-1115.60 m, RV and D
- 54. GB10581, DZ H6, 1175.60-1176.15 m, RV and D

55-57 : *Bairdiacypris* aff. *robusta* Kummerow 1939

- 55. GB10522, DZ H6, 1165.60-1166.60 m, LV
- 56. GB10567, DZ H6, 1174.60-1175.60 m, RV and D
- 57. GB10592, DZ H3, 1114.60-1115.60 m, RV and D

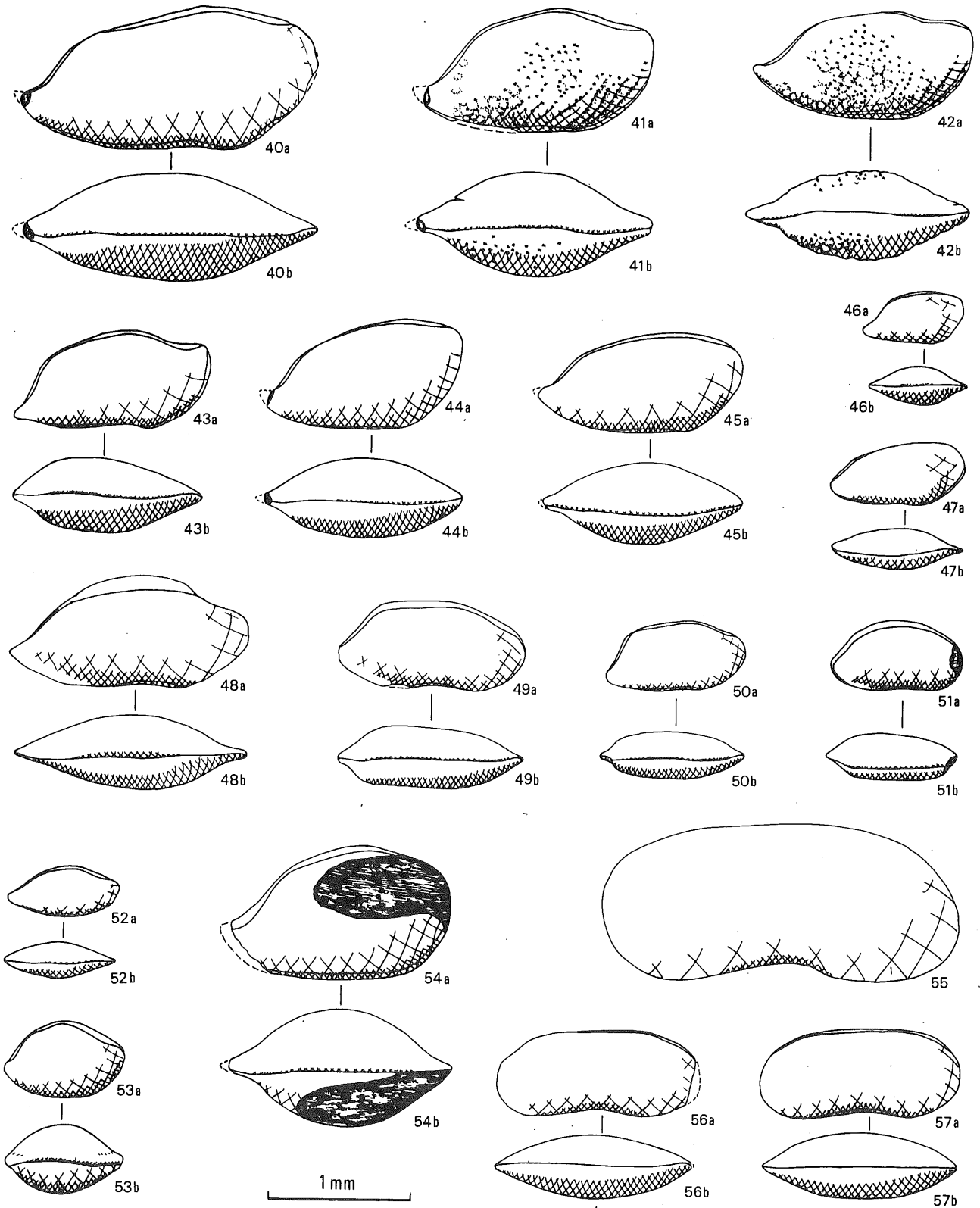


PLATE 4

- 58-61 : *Bairdiocypris* cf. *rudolphi* (Kummerow 1939)
58. GB10554, DZ H6, 1173.60-1174.60 m, RV and D
 59. GB10539, DZ H6, 1171.60-1172.60 m, RV and D
 60. GB10541, DZ H6, 1171.60-1172.60 m, RV and D
 61. GB10524, DZ H6, 1166.60-1167.25 m, RV and D
- 62-65 : *Bairdiocypris* cf. *truncatiformis* Zanina & Bushmina 1968
62. GB10537, DZ H6, 1171.60-1172.60 m, RV and D
 63. GB10512, DZ H6, 1163.50-1164.50 m, RV and D
 64. GB10515, DZ H6, 1164.60-1165.60 m, RV and D
 65. GB10516, DZ H6, 1164.60-1165.60 m, RV and D
- 66 : "*Cypridina*" sp. 1
 GB10580, DZ H6, 1175.60-1176.15 m, LV, RV,
 D and ventral
- 67 : *Cyprisurcella* sp. 1
 GB10510, DZ H6, 1163.50-1164.50 m, LV
- 68 : *Cypridinella* sp. 1
 GB10555, DZ H6, 1173.60-1174.60 m, RV
- 69 : *Cypridinella* vel *Cyprisurcella* sp.
 GB10520, DZ H6, 1165.60-1166.60 m, RV
- 70 : "*Cypridina*" sp. 2
 GB10586, DZ H3, 1111.60-1112.60 m, LV

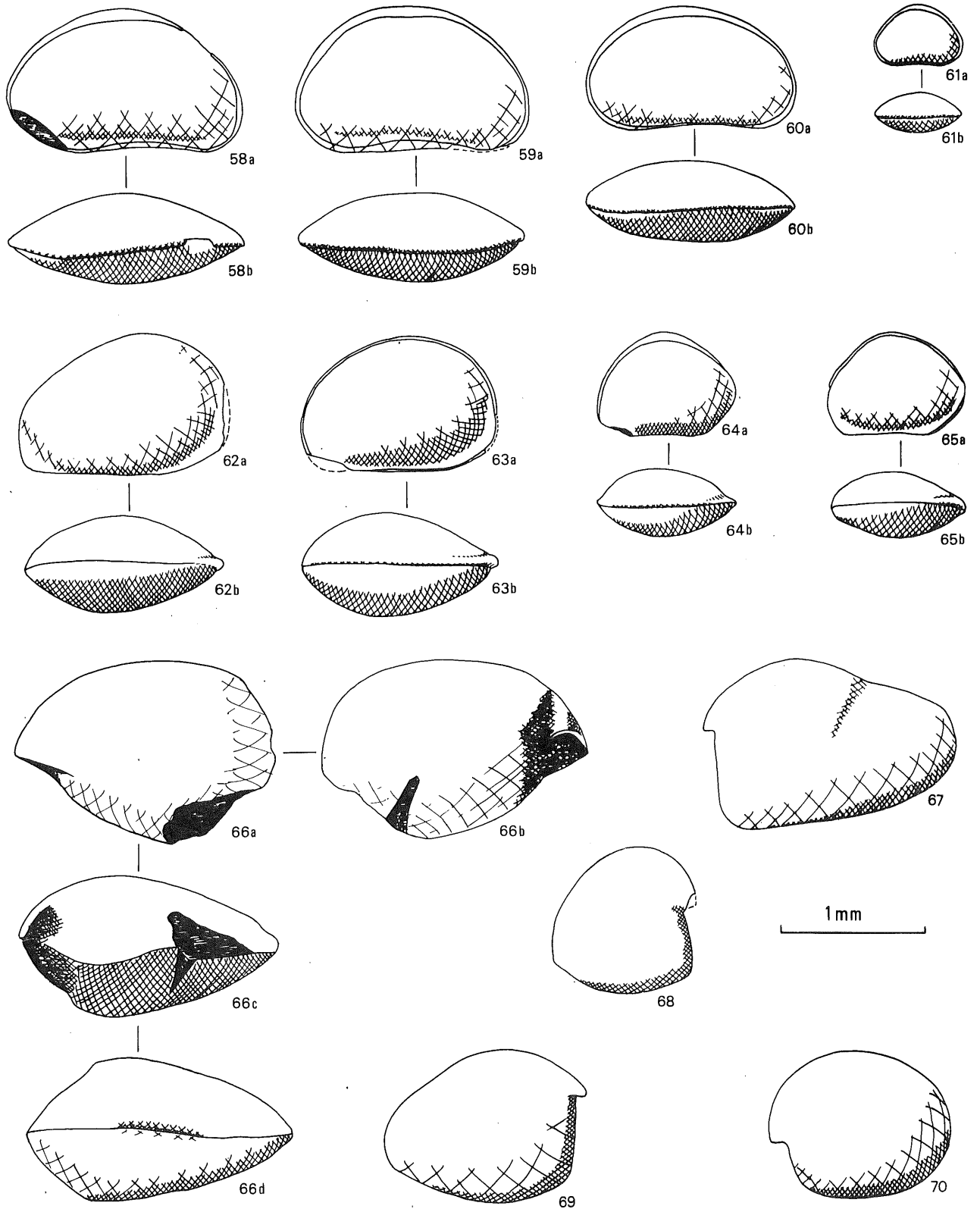


PLATE 5

All photographs are at natural size

1. DZ H6, 1171.60 m. Bioclastic peloid grainstone. Bioclasts consist of crinoid ossicles, ostracodes, bryozoans, large lamellibranch and brachiopod shells, gastropods, calcareous red algae and primitive foraminifers. Many bioclasts possess an algal coating and resemble incipient oncoids, or they may be transformed into biolumps. The peloids are occasionally agglutinated. Authigenic quartz prisms are concentrated in stylolites. SMF 13.
2. DZ H6, 1164 m. Bioclastic peloid wackestone with micritized bioclasts (bryozoans, calcareous sponges, ostracodes, foraminifers, crinoids), lumps and pellets. The micrite grades into biopelsparite. The hardground is covered by a thin algal crust, which is overgrown by bryozoans. The cavity in the hardground is filled with a peloid-ostracode assemblage cemented by sparry calcite. In the lower part of the sample a birdseye fabric can be observed. Authigenic quartz prisms are concentrated in stylolites. SMF 19, transitional to SMF 17.
3. DZ H4, 1249.50 m. Bioturbated, argillaceous wackestone containing argillaceous laminations and fine bioclastic debris and peloids, alternating with chert beds. The bioclasts consist of brachiopods, crinoid ossicles, ostracodes, foraminifers and calcispheres. Wavy nodular bedding is the result of micrite recrystallisation and differential compaction. Tiny authigenic quartz crystals are locally abundant. SMF 9.
4. DZ H6, 1166 m. Pelmicritic wackestone with vague peloids, lumps and dispersed micritized bioclasts (ostracodes, bryozoans, calcareous algae). Large voids possibly filled with vadose cement. Development of birdseye fabric. Some dispersed authigenic quartz prisms. SMF 19.
5. DZ H3, 1110.90 m. Algal bindstone, showing oncolites, micritic oncoids containing algal filaments and encrusting foraminifers and some trapped pelmicritic sediment bound by algal crusts. Large, conspicuous authigenic quartz prisms. SMF 20.

