Deep-water agglutinated foraminifera from the Lower Cretaceous (Neocomian) 'Complex à Aptychus' Formation (Corridor de Boyar, Betic Cordillera, southern Spain)

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ABSTRACT - The oldest deep-water sediments of the flysch units in the western part of the Betic Cordillera (southern Spain) are red and green pelagic claystones with intercalated siliciclastic and carbonate turbidites, ranging from Berriasian to Barremian in age. Autochthonous and redeposited benthic foraminiferal assemblages were studied in outcrops of this 'Complex à Aptychus' Formation in the 'Corridor de Boyar' near Grazalema. The assemblage of the autochthonous red and green claystones is wholly comprised of agglutinated forms, reflecting deposition beneath the calcium carbonate compensation depth (CCD). Compared to coeval abyssal and deep bathyal assemblages from the NW Australian Margin (Eastern Tethys), the Polish Outer Carpathians and the North Atlantic, the assemblage from the Betic Flysch Zone is more related to its Tethyan equivalents and may represent a truly abyssal Early Cretaceous sub-CCD environment. *J. Micropalaeontol.* **14**(1): 37–52, April 1995.

INTRODUCTION

Lower Cretaceous litho- and biofacies which are typical of a sub-calcium carbonate compensation depth (CCD) environment are poorly represented in the North Atlantic and western Mediterranean orogenic belt due to a relatively deep CCD in the Western Tethys at the time (deeper than 4 km according to Tucholke & Vogt, 1979). Typical Lower Cretaceous sedimentary formations in this area are the Blake Bahama Formation (Jansa *et al.*, 1979) in the North Atlantic and the rather similar Majolica Formation in the Western Mediterranean area, both ranging from late Tithonian to Barremian in age. Pelagic limestone deposition prevailed throughout this time interval. Oxygenated seafloor-conditions persisted throughout the Berriasian, but beginning in the Valanginian there is evidence for increasingly common episodes of poorly oxygenated bottom water (Tucholke & Vogt, 1979). Owing to the dominance of pelagic limestones in deep-water sequences and the often poorly oxygenated conditions in intercalated shaly intervals occurrences of rich benthic deep-water forminiferal assemblages from this time interval are exceptional curiosities. Lower Cretaceous abyssal and deep bathyal foraminiferal assemblages have so far been described from the Argo Abyssal Plain off the NW Australian Margin in the Eastern Tethys (Kuznetsova, 1974; Bartenstein, 1974; Riegraf & Luterbacher, 1989; Kaminski *et al.*, 1992), the Cieszyn Limestone Formation in the Polish Outer Carpathians (Geroch & Olszewska, 1990), and the Blake–Bahama Fomation of the North Atlantic (Luterbacher, 1972; Maync, 1973; Kuznetsova & Seibold, 1977; Gradstein, 1978; Sigal, 1979; Sliter, 1980; Riegraf & Luterbacher, 1989).

During a re-examination of the oldest deep water sediments of the flysch units in the western termination of the Betic Chain and the Campo de Gibraltar, the so-called 'Complex à aptychus' Formation (Didon *et al.*, 1973), the so far oldest well-preserved and diverse abyssal agglutinated foraminiferal assemblage of the Western Mediterranean was found in the Corridor de Boyar Unit near Grazalema. Eleven large bulk samples of 1–2 kg weight were removed from various lithologies in the 'Complex à aptychus' formation in the Corridor de Boyar (western part of the Betic Cordillera, Andalousia). Six of these samples, which were removed from greyish marlstones and greenish claystones were completely barren or contained only non identifiable fine-grained carbonate detritus, indicating that these sediments represent fine-grained parts of turbidites. Four samples from coarse grained laminated and graded turbidity sequences are mainly made up by fragments of aptychii and contain rich redeposited assemblages of benthic foraminifera. This study mainly focuses on autochthonous abyssal agglutinated foraminifera from two large bulk samples of the multicolored claystone in the lower part of the 'Complex à aptychus' formation. The bulk samples have been split in several subsamples, completely desintegrated in diluted buffered hydrogen peroxide and anionic tensides and washed over a 63 μm sieve. Four replicate samples were completely picked for foraminifera. The assemblages of 400–800 specimens were mounted in Plummer-slides, determined and counted.

The two main objectives of this taxonomic and palaeoenvironmental analysis of the autochthonous agglutinated foraminifera of the 'Complex à aptychus' Formation in the Corridor de Boyar are:

(1) using benthic foraminiferal assemblages as a tool for the reconstruction of the Early Cretaceous palaeoenvironment and palaeobathymetric evolution of the Alboran Margin;

(2) achieving a better understanding of the palaeogeographic position of the Corridor de Boyar deep-water basin by comparison of its benthic foraminiferal assemblages with coeval abyssal and deep bathyal assemblages from Argo Abyssal Plain (NW Australian Margin, Eastern Tethys), the Cieszyn Limestone Formation in the Polish Outer

Carpathians, and the Blake–Bahama Fomation of the North Atlantic, and thereby evaluating the potential of Lower Cretaceous deep water agglutinated foraminiferal (DWAF) assemblages for studies of Tethyan palaeobiogeography and palaeoceanography.

SAMPLE LOCALITY

Objective of this study is to examine the age and palaeoenvironment of the stratigraphically oldest formation within the 'Corridor de Boyar' Unit near Grazalema. This unit is situated in the western part of the Betic Cordillera,

where autochthonous pelagic sediments of the 'Betic Seaway' (Subbetic Zone, Fig. 1.) interfinger with the flysch units of the Campo de Gibraltar (Fig. 1). Occurrences of this Berriasian-Barremian 'Complex à aptychus' formation are scarce in this area and generally covered by vegetation. However, outcrops in the surroundings of a small mountain pass, about 1 km NNW of the village of Grazalema (4071.800 N, 288.300 E, sheet 14–44 Ubrique of the Mapa Militar de España 1:50 000) allow not only sampling of the turbiditic beds but also the intercalated hemipelagic and pelagic multicolored claystones (position of the locality is indicated as 'Boyar' on Figs 1 and 2).
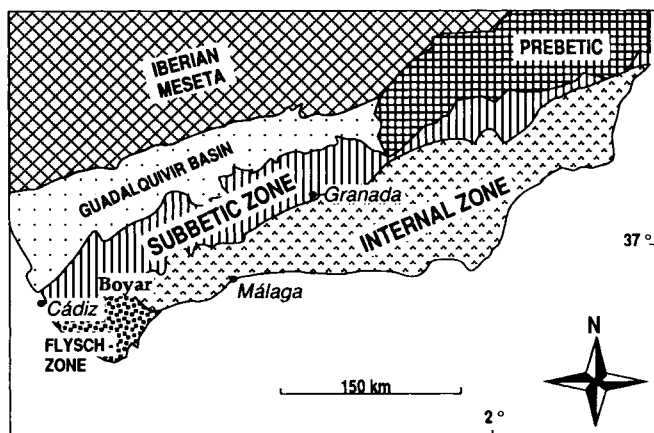
GEOLOGICAL SETTING

The structural and palaeogeographical setting of the 'Corridor de Boyar' near the village of Grazalema has been a point of vigorous discussion since the classic works of Blumenthal (1927, 1935a, 1935b, 1936) and Fallot (1930, 1948). At the Puerto de Boyar, west of Grazalema a Lower Cretaceous flysch type sedimentary sequence is tectonically sandwiched between a Penibetic carbonate platform sequence to the south and an Upper Jurassic carbonate platform sequence to the North (Sierra del Pinar). The origin and palaeogeographical position of this northern unit has been interpreted in very different ways. Hoeppener et al. (1964a, b) preferred a reconstruction where the present arrangement of units corresponds to their former palaeo-geographical position. Hoppe (1968) regarded the Sierra del Pinar as part of a large overthrusted mass, the root of which may have been south of the Penibetic, but regarded the flysch-type sediments of the Corridor de Boyar as

Fig. 1. Main structural units of the Betic Cordillera (southern Spain). Compiled using data of Azema et al. (1979) and IGME, Geological Map 1:400 000.
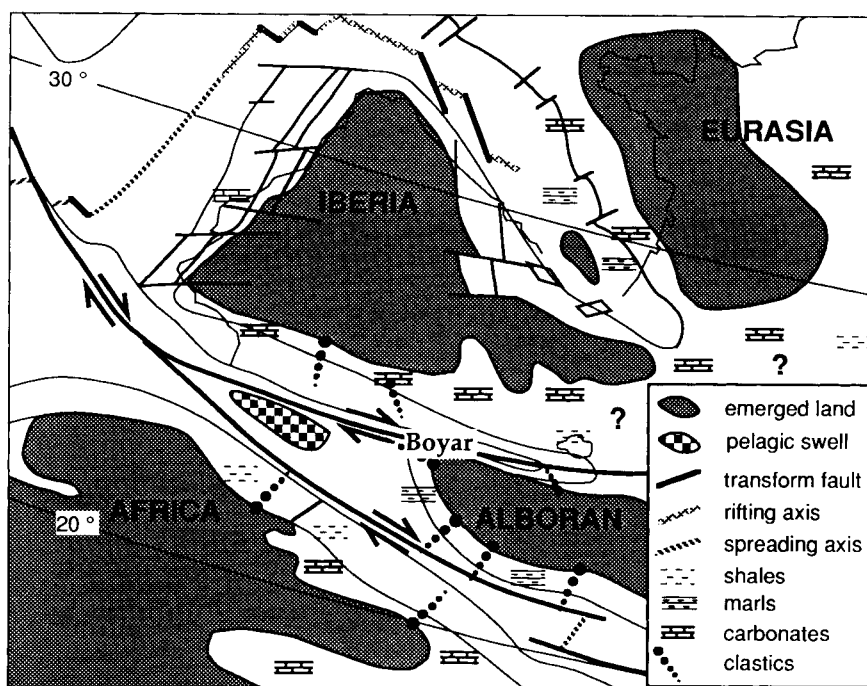

Fig. 2. Palaeogeographical reconstruction of the western Mediterranean realm for the Lower Cretaceous (Anomaly M0, Lower Aptian). The reconstruction is based mainly on the 110 Ma (Aptian) Tethyan palaeogeographical map of Dercourt et al. (1985). It is supplemented by new observations in the surroundings of the Alboran microplate (Reicherter, Pletsch & Kuhnt, pers. comm.). Note the original position of the Corridor de Boyar basin lateral to the Penibetic pelagic swell.

autochthonous. More recent reconstructions (Dubois, 1971; Bourgois, 1978) suggested also for the Corridor de Boyar sequences a palaeogeographical origin south of the Penibetic and considered the Sierra de Pinar units as part of the stratigraphic basement of the Corridor de Boyar sequence. Thurow (1987) suggested a close palaeogeographical relationship between the Median Subbetic units and the Corridor de Boyar sequences from similarities in the composition of their clastic components. Consequently the palaeogeographical position of these units is regarded as north of the Penibetic zone. In all these reconstructions surprisingly little attention has been paid to the possible influence of lateral movements on the present-day configuration of structural units. Leblanc & Olivier (1984) estimated a 400 km dextral lateral displacement of the Alboran block along its northern margin (the North Betic Fault). Important lateral displacements may also have affected the more northerly palaeogeographical zones and it is quite possible, that the present day N–S transect across the Corridor de Boyar includes units that were originally situated several hundred kilometres to the east.

The theory of Bourgois (1978), that the sedimentation within the Corridor de Boyar is the stratigraphic continuation of the Sierra del Pinar sequence is now widely accepted (Durand Delga, 1980; Thurow, 1987). The Sierra del Pinar is formed by a thick Liassic carbonate platform, which was drowned during the late Dogger and early Malm (Bathonian?–Kimmeridgian), approximately coeval with the formation of the Mauretanian basin, the Betic seaway and the deep central North Atlantic. Durand Delga (1980) compared the palaeogeographical position of the Corridor de Boyar series with the Djebel Moussa in Northern Morocco, which can be regarded as a deep part of the Alboran Margin (Predorsalien Unit in the sense of Olivier, 1984). Its strange present day position north of the Penibetic Unit can be explained by a northward transport of the unit by large-scale overthrusting or within gigantic olisthostromes (Bourgois, 1978) or, more likely, by dextral strike-slip and/or rotational movements parallel to the major dextral strike-slip zone which separates the internal and external Betic Zones (Durand Delga, 1980). In both cases, the Sierra del Pinar–Corridor de Boyar sedimentary sequence can be regarded as part of the late Jurassic–Cretaceous continental margin of the Alboran microcontinent (Fig. 2).

THE 'COMPLEX À APTYCHUS' NORTH OF GRAZALEMA

The sedimentary succession within the Corridor de Boyar Unit was intially described by Bourgois (1978). A recent re-examination of the sequence (Thurow, 1987) added more detailed sedimentologic descriptions and a precision of the biostratigraphy using radiolarian assemblages but did not substantially change the initial stratigraphic subdivisions (Fig. 3). This study concentrates on the stratigraphically deepest units (subunits A1–A3 according to Bourgois, 1978), which can be observed NNW of Grazalema in a tectonically disturbed but generally continuous succession from W–E. The oldest subunit (A1) is the only sequence

where autochthonous deep-water foraminiferal assemblages have been obtained. A typical sedimentary sequence within this subunit comprises fine-grained carbonate turbidites with a maximum thickness of 20–30 cm, and hemipelagic and pelagic claystones with a thickness of a few tens of centimetres (Fig. 3). The whole sequence is intensely tectonically folded, and synsedimentary folding can also not be excluded. The overlying unit (A2) contains siliciclastic turbidites of up to 50 cm in thickness and intercalated calcareous–marly sediments ('preflysch' of the French authors). Micropalaeontologic samples from the marly hemipelagic layers in this unit were barren, but samples from the bases of turbidites yielded rich redeposited assemblages of typical Tethyan outer shelf and slope benthic foraminifers of Berriasian to Barremian age. The following age-diagnostic species have been identified:

Lenticulina eichenbergi Bartenstein & Brand, 1951
Dorothia praehauteriviana Dieni & Massari, 1966

Occasionally redeposited macro-invertebrates have been found, which allow a tentative dating of this subunit as Berriasian to Valanginian. Characteristic forms are (Bourgois, 1978 and sample E30/20):

Lamellaptychus gr. *beyrichi* (Oppel)
Lamellaptychus cf. *aplanatus* (Gill)
Lamellaptychus gr. *seranonis* (Coquand)
Lamellaptychus cf. *mortilleti* (Pictet & Loriol)
Lamellaptychus submortilleti Trauth
Punctaptychus ex gr. *punctatus* (Voltz).

FAUNAL CHARACTERISTICS AND PALAEOENVIRONMENT

Autochthonous benthic foraminiferal assemblages are exclusively made up of agglutinated foraminifera with organic, diagenetically silicified cement. Calcareous benthic foraminifera and agglutinated foraminifera with carbonate cement occur only in redeposited assemblages.

A striking characteristic of the Early Cretaceous abyssal agglutinated foraminiferal assemblage is a small test size. Tests with a maximum length of more than 200 μm make up less than 1% of the total assemblage and forms larger than about 400 μm are virtually absent. This unusual size distribution can be either explained by slow growth rates due to limited resources, or by high reproduction rates which may have been triggered by short seasonal spikes in phytodetritus supply, as it can be observed in Recent oligotrophic deep-sea areas.

Tubular morphotypes with epifaunal habitat (e.g. *Rhizammina indivisa*) are generally rare. However, the fossilization potential of these forms is low and is probably dependent on sedimentation rates. Since sedimentation rates in the early Cretaceous of the Corridor de Boyar were undoubtedly low, a lack of epifaunal soft-walled agglutinated foraminifera such as rhizamminids is not surprising.

Significant differences are observed between assemblages from red claystones (referred here as type A assemblages), indicating oxic bottom water conditions and from green claystones (type B assemblages, mildly dysaerobic bottom waters, see Fig. 3). Infaunal morphotypes such as
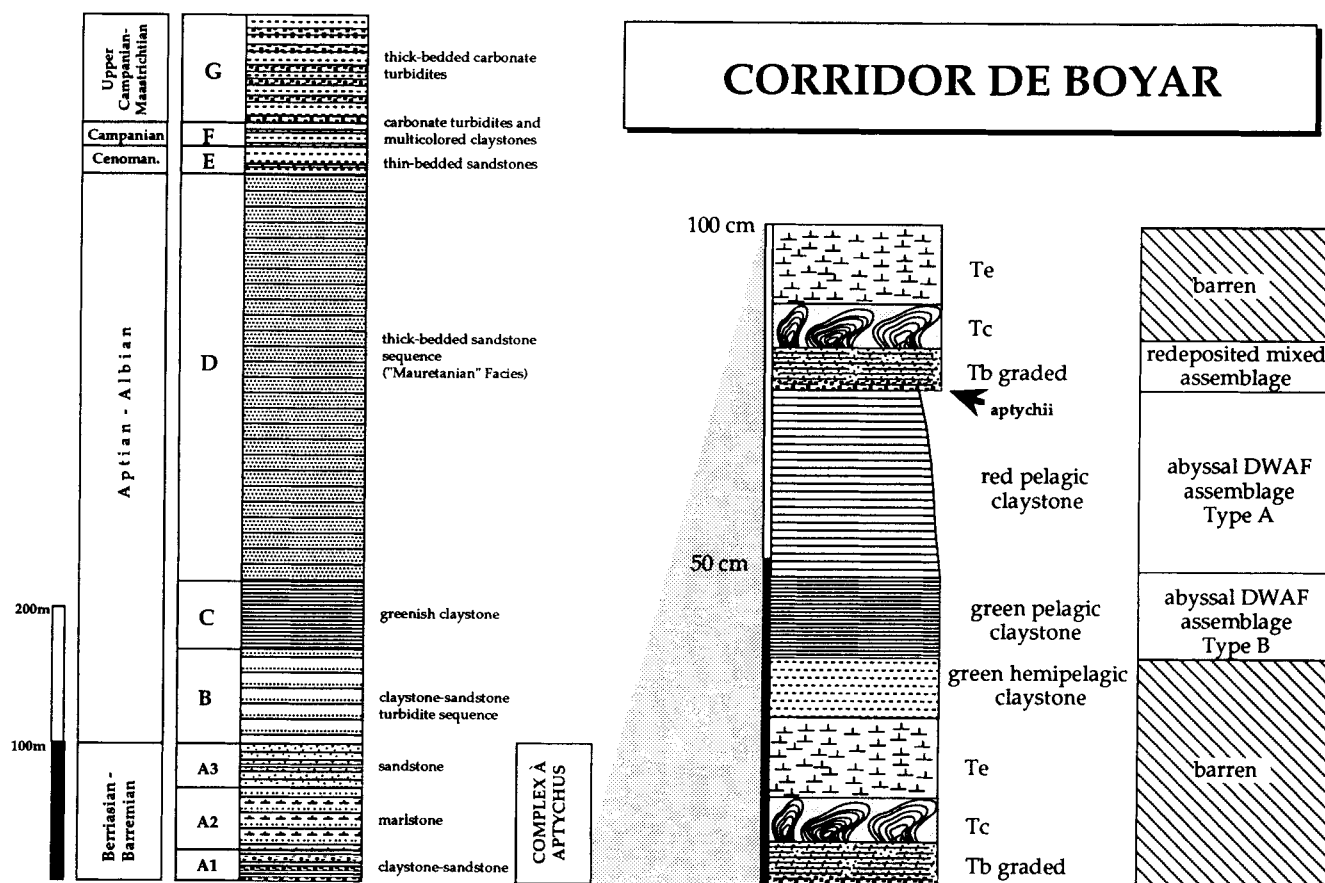
Fig. 3. Synthetic stratigraphic column of the Corridor de Boyar flysch (modified from Bourgois, 1978) and typical sequence within the Subunit A1 of the 'Complex à aptychus' Formation. In the studied outcrop these sequences are now generally overturned and intensely folded. No autochthonous benthic foraminiferal assemblages are so far known from the units D to F in the Corridor de Boyar area. These sequences may consist exclusively of redeposited material.

Verneuilinoides, Pseudobolivina, Pseudoreophax and *Bulbobaculites* dominate in the red claystones (Table 1, Fig. 4). These four genera make up about 60% of the assemblage. Ammodiscids are mainly represented by the species *Glomospira gordialis* and *Glomospira charoides*, which occur as infauna in Recent deep sea sediments (Gooday, 1990; Kuhnt, Collins & Scott, unpublished observations). Planispiral ammodiscids also occur, but there is an unusual dominance of the genus *Glomospirella*, whereas true *Ammodiscus* have only been observed in single specimens. All these aspects of the 'red' assemblages point to a deep-water environment, which is largely sheltered from terrigeneous detritic flux, oxic (cool?) bottom water masses, generally low surface productivity, and possibly a pronounced seasonality in phytodetritus supply from primary production.

Assemblages from green claystones differ from the 'red' assemblages mainly in the distribution pattern of the genera *Pseudoreophax, Bulbobaculites, Haplophragmoides, Glomospirella* and *Glomospira* (Fig. 4). *Pseudoreophax* and *Bulbobaculites* are almost absent in the 'green' assemblage. Both these forms can be regarded as infaunal morphotypes

which may be sensitive to a Redox-line close to the sediment surface. A similar occurrence restricted to red, oxic claystones has been observed for the Cenomanian–Turonian species *Bulbobaculites problematicus* in the Carpathians and the North Atlantic (Kuhnt & Kaminski, 1990). The genera *Haplophragmoides, Glomospira* and *Glomospirella* are significantly more abundant in 'green' assemblages (Fig. 4). These forms are characteristic representatives of Biofacies B assemblages (Kuhnt *et al.*, 1989), which characterize environments under mildly oxygen-deficient conditions at the sea-floor and probably increased surface water productivity. Their life habitat has been interpreted as epifaunal detritus-feeders which can take advantage of enhanced food supply from phytodetritus and are less sensitive to oxygen deficiency.

PALAEOBIOGEOGRAPHICAL ASPECTS

The new observations on earliest Cretaceous deep-water agglutinated foraminifera in the Corridor de Boyar of the Betic Cordillera confirm the cosmopolitan distribution of these forms. Most of the 18 genera and 26 species observed in the Berriasian–Valanginian of the 'Complex à aptychus'

Table 1. Species distribution of autochthonous deep-water agglutinated foraminifers in the 'Complex à aptychus' unit.

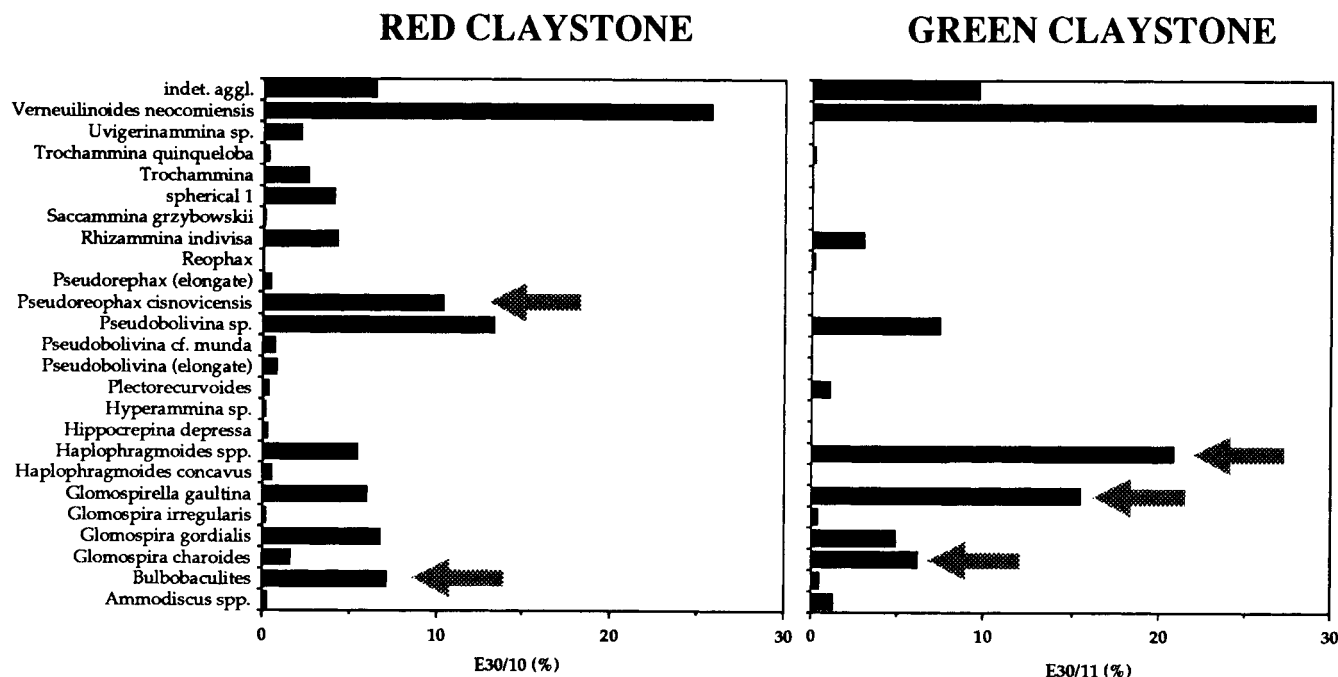| SAMPLE	E30/10-1	E30/10-1 %	E30/10-2	E30/10-2 %	E30/10-3	E30/10-3 %	E30/10 sum	E30/10 average %	E30/11	E30/11 %
Ammodiscus spp.	1	0,25	3	0,70	1	0,12	5	0,30	8	1,27
Bulbobaculites sp. A	2	0,49	48	11,19	69	8,31	119	7,15	3	0,47
Glomospira charoides	9	2,22	6	1,40	11	1,33	26	1,56	39	6,17
Glomospira gordialis	24	5,91	57	13,29	32	3,86	113	6,79	31	4,91
Glomospira irregularis	3	0,74		0,00		0,00	3	0,18	2	0,32
Glomospirella gaultina	35	8,62	27	6,29	38	4,58	100	6,01	98	15,51
Haplophragmoides cf. concavus	4	0,99		0,00	5	0,60	9	0,54		0,00
Haplophragmoides spp.	35	8,62	16	3,73	40	4,82	91	5,47	132	20,89
Hippocrepina depressa		0,00		0,00	4	0,48	4	0,24		0,00
Hyperammina spp.	1	0,25		0,00	2	0,24	3	0,18		0,00
Thalmannammina cf. neocomiensis		0,00	3	0,70	3	0,36	6	0,36	7	1,11
Pseudobolivina sp. A	6	1,48		0,00	7	0,84	13	0,78		0,00
Pseudobolivina cf. munda	3	0,74	8	1,86	1	0,12	12	0,72		0,00
Pseudobolivina spp.	49	12,07	72	16,78	100	12,05	221	13,27	47	7,44
Pseudoreophax cisnovicensis (juvenile)	18	4,43	18	4,20	32	3,86	68	4,08		0,00
Pseudoreophax cisnovicensis	66	16,26	34	7,93	73	8,80	173	10,39		0,00
Pseudorephax cisnovicensis (elongate)	3	0,74	4	0,93		0,00	7	0,42		0,00
Reophax sp.		0,00		0,00		0,00	0	0,00	1	0,16
Rhizammina indivisa and Rhabdammina cylindrica	14	3,45	7	1,63	50	6,02	71	4,26	19	3,01
Saccammina grzybowskii	1	0,25		0,00	1	0,12	2	0,12		0,00
Trochammina sp. A	5	1,23	7	1,63	31	3,73	43	2,58		0,00
Trochammina quinqueloba		0,00	1	0,23	4	0,48	5	0,30	1	0,16
Uvigerinammina sp. 1	12	2,96	9	2,10	14	1,69	35	2,10		0,00
Verneuilinoides neocomiensis and Gaudryina oblonga	103	25,37	94	21,91	232	27,95	429	25,77	183	28,96
indet. aggl.	12	2,96	15	3,50	80	9,64	107	6,43	61	9,65
total	406		429		830		1665		632	

RED CLAYSTONE   GREEN CLAYSTONE

Fig. 4. Quantitative composition of autochthonous deep-water agglutinated foraminiferal assemblages from green and red claystones in the 'Complex à aptychus' unit. The plot is based on 1665 specimens counted from red claystones and 632 specimens counted from green claystones. Arrows indicate forms with significant differences in distribution between red and green claystones.

unit seem to occur within the entire Tethys ocean. Occurrences of similar assemblages are known from the West Australian Margin (Indian Ocean = Eastern Tethys), the Polish Carpathians and the Central North Atlantic (= western termination of the Tethys ocean). However, this type of 'Tethyan' abyssal and deep-bathyal assemblages is not known from high latitude areas. It may be speculated that most of the forms observed in these assemblages have their ecological niche in deep-sea environments with restricted resources, and are unable to compete with other forms in more favourable environments.

CONCLUSIONS

The Cretaceous turbiditic sequences of the Corridor de Boyar unit were deposited in a deep continental margin setting close to the western termination of the Alboran Block. Sediments and autochthonous benthic foraminiferal assemblages within the Corridor de Boyar basin represent a truly abyssal sub-CCD environment as early as in Berriasian–Valanginian times. The foraminiferal assemblage is composed of cosmopolitan forms, fairly diverse (26 species) and not dominated by single species. Red sediment colour and the presence of numerous infaunal benthic

foraminiferal morphotypes indicate well-oxygenated bottom-water conditions within the basin. From these observations can be concluded that during Berriasian–Valanginian times the Corridor de Boyar flysch basin was connected to the belt of Lower Cretaceous flysch basins within the western Tethys (Durand Delga, 1980) and had deep-water connections to the Tethys ocean and the central North Atlantic abyssal basin. The main subsidence phase of this part of the western Alboran margin was already terminated in the Berriasian–Valanginian and probably took place within a short time interval in the latest Jurassic. This Late Jurassic subsidence phase coincides with the first formation of oceanic crust on the Tagus Abyssal Plain (Mauffret *et al.*, 1989). Transform directions associated with this old spreading ridge are WSW–ENE (Malod, 1989) and thus in agreement with the general trend of the northern margin of the Alboran block at this time (compare Fig. 2). Kinematic reconstructions of the Iberian plate (Malod, 1989) predict a significant extension between Africa and Iberia during the Late Jurassic rifting. It may be speculated that the abyssal Corridor de Boyar basin was formed along a transform-margin of the Alboran block during a Late Jurassic extensional phase, which affected not only the

Explanation of Plate 1

Fig. 1. *Rhizammina indivisa* Brady (1884), sample E30/10, ×170. **Fig. 2.** *Rhabdammina cylindrica* Glaessner 1937, sample E30/10, ×170. **Fig. 3.** *Hyperammina gaultina* Ten Dam 1950, sample E30/10, ×170. **Fig. 4.** *Hyperammina* cf. *dilatata* Grzybowski 1896, sample E30/10, ×170. **Fig. 5.** *Hippocrepina depressa* Vasicek 1947, sample E30/10, ×170. **Figs 6–7.** *Ammodiscus tenuissimus* (Guembel 1862), sample E30/11, 6: ×170, 7: ×240. **Figs 8–9.** *Glomospira charoides* (Jones & Parker 1860), sample E30/10, ×240. **Fig. 10.** *Glomospira gordialis* (Jones & Parker 1860), sample E30/10, ×200. **Fig. 11.** *Glomospirella gaultina* (Berthelin 1880), sample E30/10, ×125. **Figs 12–13.** *Glomospira irregularis* (Grzybowski 1898), sample E30/10, ×170. **Fig. 14.** *Saccammina grzybowskii* (Schubert 1902), sample E30/10, ×170.
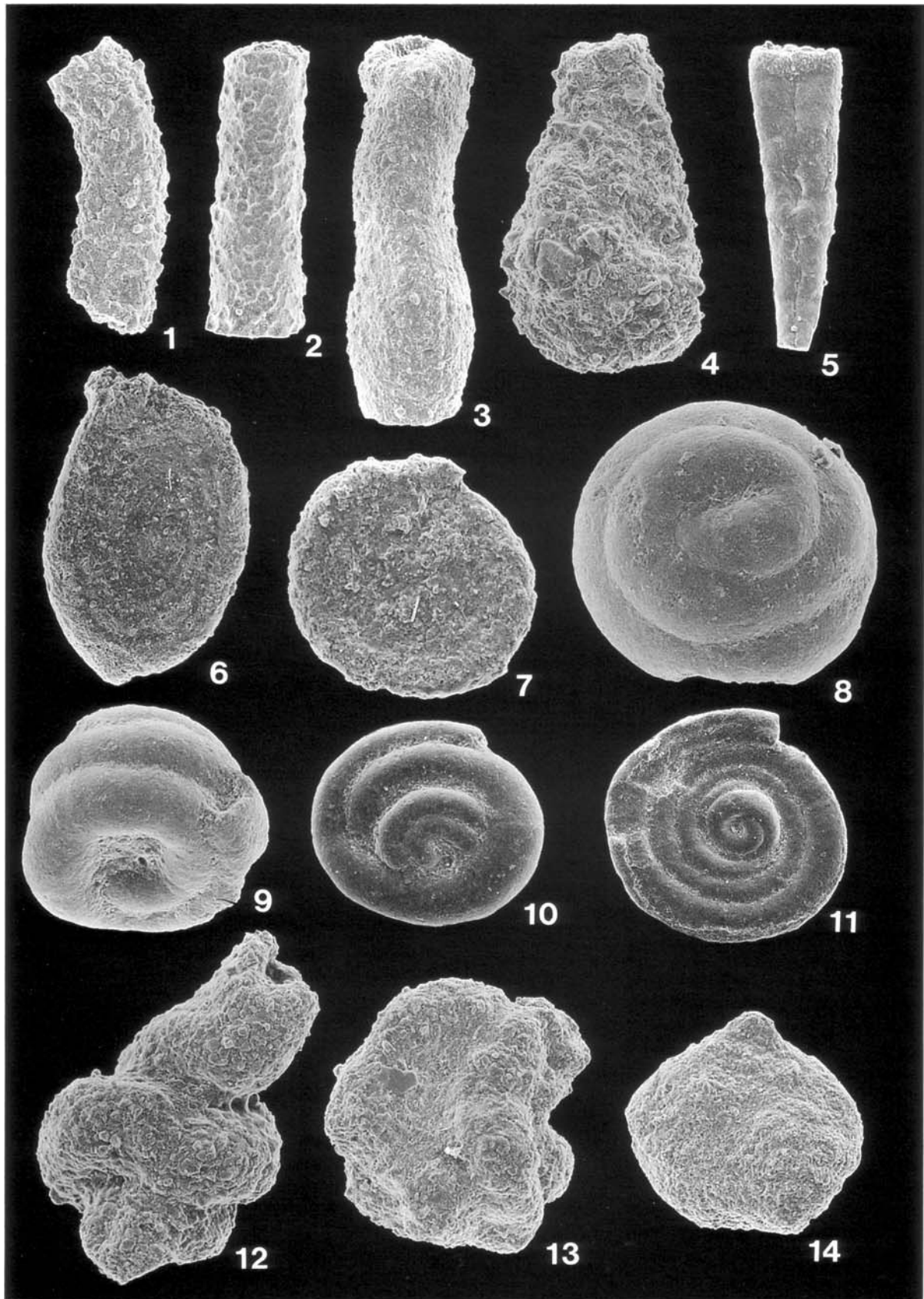
Plate 1

Tagus abyssal plain but also the southern Iberian margin and Alboran block.

TAXONOMIC NOTES (excluding redeposited species)
Specimens figured are deposited in the micropalaeontology collection of the Geologisch-Paläontologisches Institut und Museum der Christian-Albrechts Universität zu Kiel.

Ammodiscus cretaceus Reuss, 1845
1845 *Operculina cretacea* Reuss: 35, pl. 13, figs 64, 65 a–b.
1972 *Ammodiscus cretaceus* (Reuss); Hanzlikova: 34, pl. 3, fig. 9.
1974 *Ammodiscus incertus* (d'Orbigny); Bartenstein: 687, pl. 3, figs 14–17.
1978 *Ammodiscus cretaceus* (Reuss); Krasheninnikov & Pflaumann: 569, pl. 2, fig. 7.
1992 *Ammodiscus cretaceus* (Reuss); Kaminski, Gradstein & Geroch: 252, pl. 2, fig. 2.
Remarks. With relatively broad whorls in a regular planispiral coil. Whorls moderately overlap the previous one. Surface smooth, the wall is siliceous, homogenous or with very fine grains.

Ammodiscus tenuissimus (Guembel, 1862)
(Pl. 1, figs 6–7)
1862 *Spirillina tenuissima* Guembel: 214, pl. 13, fig. 2.
1967 *Ammodiscus tenuissimus* (Guembel); Michael: 22, pl. 1, fig. 13.
1969 *Ammodiscus tenuissimus* (Guembel); Grün: 312, pl. 1, fig. 13 (with synonymy).
1972 *Ammodiscus tenuissimus* (Guembel); Neagu: 191, pl. 1, figs 19–20.
1974 *Ammodiscus tenuissimus* (Guembel); Bartenstein: 687, pl. 3, figs 7–13.
1990 *Ammodiscus tenuissimus* (Guembel); Geroch & Olszewska: 529, pl. 2, figs. 6–8.
1992 *Ammodiscus tenuissimus* (Guembel); Kaminski, Gradstein & Geroch: 252, pl. 2, fig. 3.

Bulbobaculites sp. A
(Pl. 3, figs 7–11)
1992 *Bulbobaculites inconstans* (Bartenstein & Brand); Kaminski, Gradstein & Geroch: 252–253, pl. 4, figs 9–10.
Remarks. Small stout forms with 1–3 chambers in the uniserial stage. Aperture terminal on a protruding neck. This form differs from the various subspecies of *Haplophragmoides inconstans* Bartenstein & Brand in its significantly smaller size, its shorter uniserial part and less elongated chambers in its uniserial part. These morphologic differences may be simply explained by environmental adaption to oligotrophic deep-sea conditions. However, since intermediate forms are not known so far, I prefer to keep the deep-sea forms in open nomenclature.

Gaudryina oblonga Zaspelova, 1948
(Pl. 4, figs 17–18)
1948 *Gaudryina oblonga* Zaspelova: 200, pl. 1, fig. 7.
1981 *Gaudryina oblonga* Zaspelova; Morgiel & Olszewska: 18, pl. 5, figs 2–3.
1984 *Gaudryina oblonga* Zaspelova; Geroch & Nowak, pl. 2, figs 6–7; pl. 7, figs 16–17.
Remarks. Ranges in the Polish External Carpathians from the Hauterivian to the Albian.

Glomospira charoides (Jones & Parker, 1860)
(Pl. 1, figs 8-9)
1860 *Trochammina squamata* Jones & Parker, var. *charoides* Jones & Parker: 304.
1928 *Glomospira charoides* (Jones & Parker) var. *corona* Cushman & Jarvis: 89, pl. 12, figs. 9–11.
Remarks. This species has recently been assigned to the genus *Usbekistanina* Suleymanov (Charnock & Jones, 1990). For the sake of consistency *G. charoides* is kept here in *Glomospira*.

Glomospira gordialis (Jones & Parker, 1860)
(Pl. 1, fig. 10)
1860 *Trochammina squamata* Jones & Parker var. *gordialis* Jones & Parker: 304.
Remarks. Irregularly coiled tubes, last whorl in general lying in one plane, diameter of the tube is low, characteristic is the smooth, very finely agglutinated wall.

Glomospira irregularis (Grzybowski, 1898)
(Pl. 1, figs 12–13)
1898 *Ammodiscus irregularis* Grzybowski: 285, pl. 11, figs 2–3.
1966 *Glomospira irregularis* (Grzybowski); Geroch, pl. 8, figs 11–12.

Glomospirella gaultina (Berthelin, 1880)
(Pl. 1, fig. 11)
1880 *Ammodiscus gaultinus* Berthelin: 19, pl.1, fig. 3a–b.
1978 *Glomospirella gaultina* (Berthelin); Krasheninnikov & Pflaumann: 568, pl. 2, fig. 5.
Remarks. Differs from *G. gordialis* in possessing at least two planispiral coils.

Haplophragmoides cf. *concavus* (Chapman, 1892)
(Pl. 2, figs 15–16)
1892 cf. *Trochammina concava* Chapman: 327, pl. 6, fig. 14a-b.
1960 *Haplophragmoides* cf. *concava* (Chapman); Geroch: 127, pl. 5, fig. 2.
1988 *Haplophragmoides* cf. *concavus* (Chapman); Moullade *et al.*: 364, pl. 8, figs. 8–9.

Explanation of Plate 2

Figs 1–9. *Pseudoreophax cisovnicensis* Geroch 1961, sample E30/10, 1-3: ×240, 4-5: ×170, 6-9: ×200. **Figs 10–11.** *Haplophragmoides* sp.A, sample E30/10, ×170. **Figs 12–13.** *Haplophragmoides* sp.B, sample E30/10, ×170. **Fig. 14.** *Trochammina* sp.A, sample E30/10, ×200. **Figs 15–16.** *Haplophragmoides* cf. *concavus* (Chapman 1892), sample E30/11, ×240.
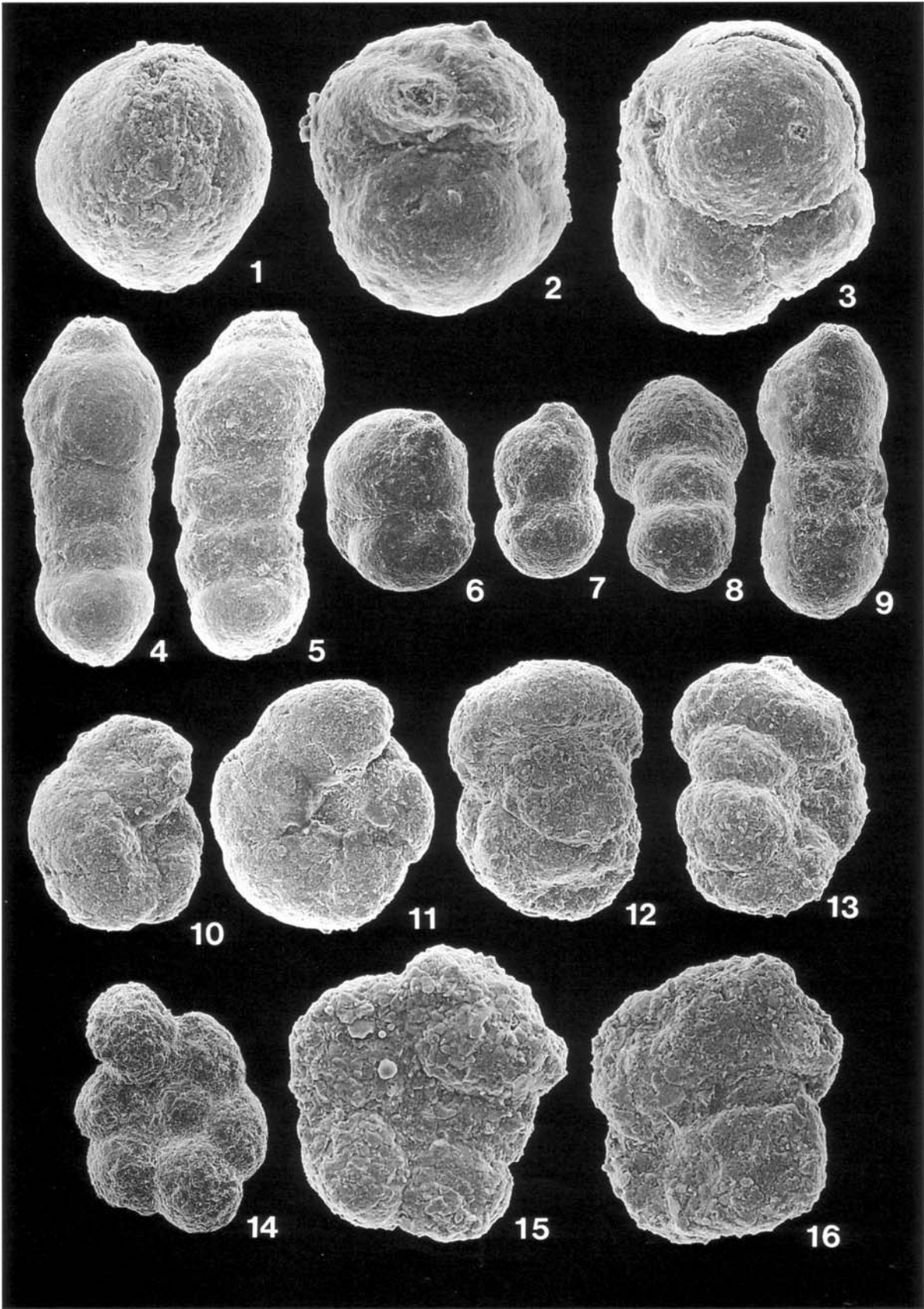
Plate 2

1990 *Haplophragmoides* cf. *concavus* (Chapman); Kuhnt: 312, pl. 4, fig. 13.
Remarks. Differs from typical *H. concavus* in its smaller size and in its sometimes roughly finished wall surface.

Haplophragmoides sp. A
(Pl. 2, figs 10–11)
Remark. Test small, smooth, with four to five chambers in the last whorl and a rounded periphery.

Haplophragmoides sp. B
(Pl. 2, figs 12–13)
1992 *Haplophragmoides kirki* Wickenden; Kaminski, Gradstein & Geroch: 253, pl. 4, figs 1a–b, 2.
Remarks. This form resembles *Haplophragmoides kirki* Wickenden, a shallow-water form from the Upper Cretaceous of Alberta, in its planispiral test with four or five globular chambers in the last whorl. *Haplophragmoides* sp. B is kept separate here because of its significantly smaller size, and its different stratigraphic and environmental distribution.

Hippocrepina depressa Vasicek, 1947
(Pl. 1, fig. 5)
1947 *Hippocrepina depressa* Vasicek: 243, pl. 1, figs 1–2.
1979 *Hippocrepina depressa* Vasicek; Sigal, pl. 1, fig. 5.
1980 *Hippocrepina depressa* Vasicek; Sliter, pl. 1, figs 2–3.
1981 *Hippocrepina depressa* Vasicek; Morgiel & Olszewska: 7, pl. 1, figs 1, 2.
1982 *Hippocrepina depressa* Vasicek; Morgiel & Olszewska, pl. 1, figs 1, 2.
1984 *Hippocrepina depressa* Vasicek; Geroch & Nowak: 228, pl. 1, fig. 7, pl. 5, fig. 4–5.
1986 *Hippocrepina depressa* Vasicek; Bartenstein & Bolli: 947-948, pl. 1, figs 9–10.
1989 *Jaculella depressa* (Vasicek); Riegraf & Luterbacher: 1085–1986, pl. 1, figs 4–6.
Remarks. *H. depressa* is a very characteristic species of the Lower- to Mid-Cretaceous 'flysch' and pelitic series of the Polish Carpathians and the Gibraltar Arch area. Specimens of Leg 50 DSDP in the eastern North Atlantic belong to a deep-sea foraminiferal assemblage of Berriasian(?)–Valanginian age with water depths of 2000 m and more (Sliter, 1980). It is not yet clear, whether this species can be included in the living *Hippocrepina* or is more related to the Palaeozoic genus *Hyperamminoides* Cushman & Waters, 1928, which belongs to the Palaeozoic to Lower Cretaceous family *Hyperamminoididae* Loeblich & Tappan, 1984. The type species of *Hyperamminoides* (*Hyperamminoides elegans* Cushman & Waters, 1928 from the Upper Carboniferous of Texas) closely resembles *H. depressa* in having a very fine-grained arenaceous wall with polished surface that probably was somewhat flexible in life, as fossil specimens are generally compressed, whereas other foraminifers in the same assemblages are not compressed (Loeblich & Tappan, 1988).

Stratigraphic range: according to Geroch & Nowak (1984) this species ranges from Upper Hauterivian (*D. hauteriviana* Zone) to Upper Cenomanian (*B. problematicus* Zone). In the Gibraltar Arch area *H. depressa* is observed in Hauterivian to Cenomanian deep water sequences. Also recovered in DSDP-cores from the North Atlantic (e.g. Sigal (1979), Site 398 from the Hauterivian; Sliter (1980), Site 416 from the Valanginian). Characterizing deep-water assemblages.

Hyperammina gaultina Ten Dam, 1950
1950 *Hyperammina gaultina* Ten Dam: 5, pl. 1, fig. 2.
1974 *Hyperammina gaultina* Ten Dam; Bartenstein: 685, pl. 1, figs 5–30, 35, 36; pl. 2, figs 1–4 (with synonymy).
1990 *Hyperammina gaultina* Ten Dam; Geroch & Olszewska: 529, pl. 1, figs 1–18, 25–27; pl. 4, figs 1–15 (with synonymy).

Hyperammina cf. *dilatata* Grzybowski, 1896
(Pl. 1, fig. 4)
1896 cf. *Hyperammina dilatata* Rzehak; Grzybwoski: 274–275, pl. 8, fig. 17.
1988 cf. *Hyperammina dilatata* Grzybowski; Kaminski *et al.*: 184, pl. 2, figs 1-2.
Remarks. Differs from typical *Hyperammina dilatata* in possessing a more coarsely agglutinated wall with a rough surface.

Pseudobolivina cf. *munda* Krasheninnikov, 1973
(Pl. 4, figs 4–6)
1973 cf. *Pseudobolivina munda* Krasheninnikov: 210, pl. 2, figs 10–11.
Remarks. Differs from the typical Late Cretaceous *P. munda* in possessing a slightly twisted initial portion. Differs from *P. variabilis* Vasicek 1947 in possessing an apertural neck. Morphologically similar forms of the genus *Plectinella* do not possess a terminal aperture produced on a short neck.

Pseudobolivina sp. A
(Pl. 4, figs 9–11)
Remarks. After an initial regular biserial stage with a tendency to becoming uniserial with the last 3 chambers. Differs from *Pseudobolivina variabilis* Vasicek 1947 in its tendency to a uniserial final stage and in a twisted chamber arrangement.

Pseudoreophax cisovnicensis Geroch, 1961
(Pl. 2, figs 1–9; Pl. 3, fig. 12)
1961 *Pseudoreophax cisovnicensis* Geroch, p. 159, pl. 17, figs 1–5.

Explanation of Plate 3

Figs 1–3. *Trochammina quinqueloba* Geroch 1959, sample E30/10, ×240. **Figs 4–6.** *Thalmannammina* cf. *neocomiensis* Geroch 1962, sample E30/11, ×240. **Figs 7–11.** *Bulbobaculites* sp. A, sample E30/10, 7-9: ×240, 10: ×170, 11: ×240. **Fig. 12.** *Pseudoreophax cisovnicensis* Geroch 1961, sample E30/10, ×170. **Fig. 13–14.** *Uvigerinammina* sp. 1, sample E30/10, ×170.
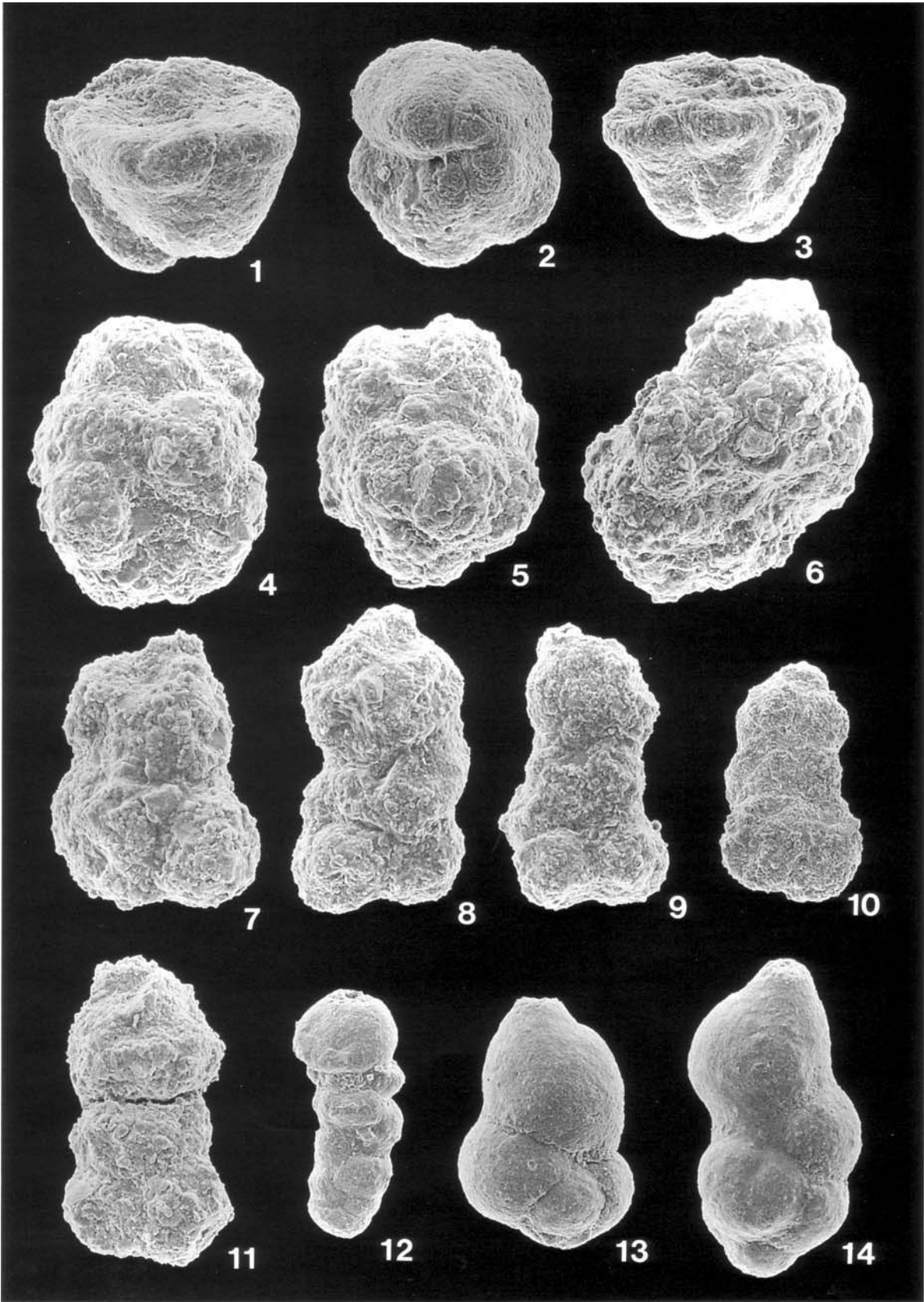
Plate 3

1966 *Pseudoreophax cisovnicensis* Geroch; Geroch, pl. 11, fig. 5a–c.

1980 *Ammobaculites irregularis* (Guembel); Sliter, pl. 2, fig. 14.

1983 *Bigenerina jurassica* (Haeusler); Gradstein, pl. 1, fig. 1.

1984 *Pseudoreophax cisovnicensis* Geroch; Geroch & Nowak, pl. 3, figs 14–18, pl. 7, figs 26–29.

1989 *Pseudoreophax cisovnicensis* Geroch; Riegraf & Luterbacher: 1093, pl. 2, fig. 22.

1990 *Pseudoreophax cisovnicensis* Geroch; Geroch & Olszewska: 531, pl. 3, figs 1–11, 17; pl. 4, figs 16–18, 23, 24, 28, 29, 33, 34.

1992 *Pseudoreophax cisovnicensis* Geroch; Kaminski, Gradstein & Geroch: 255, pl. 7, figs 5–6.

Remarks. Occurrences: Tithonian to Barremian of the Polish Carpathians (Geroch & Nowak, 1984).

Rhabdammina cylindrica Glaessner, 1937
Pl. 1, fig. 2

1937 *Rhabdammina cylindrica* Glaessner: 354, pl. 1, fig. 1.

1990 *Rhabdammina cylindrica* Glaessner; Kaminski *et al.*: 364, pl. 1, figs 4a–b.

1992 *Rhabdammina cylindrica* Glaessner; Morlotti & Kuhnt: 223, pl. 2, fig. 1.

Remarks. Straight tubular fragments with a circular cross-section. The available material does not allow the identification of a central chamber. It can not be excluded, however, that these fragments may be radiating tubular arms of *Rhabdammina abyssorum* Carpenter, 1869.

Rhizammina cf. *indivisa* Brady, 1884
(Pl. 1, fig. 1)

1884 *Rhizammina indivisa* Brady: 277, pl. 29, figs 5–7.

1981 *Rhizammina indivisa* Brady; Gradstein & Berggren: 240, pl. 1, figs 1–3.

Remarks. The assignment to the flexible, loosely agglutinated Recent species *R. indivisa* is doubtful (Charnock & Jones, 1990). However, the species differs from *Nothia excelsa* (Grzybowski) in its smaller size, a thin wall composed of small quartz grains with much cement, and a generally strongly compressed outline, indicating that the individuals originally may have been flexible.

Saccammina grzybowskii (Schubert, 1902)
(Pl. 1, fig. 14)

1898 *Reophax difflugiformis* Brady; Grzybowski: 255, pl. 10, figs 11–12.

1902 *Reophax grzybowskii* Schubert: 20, pl. 1, fig. 13.

1912 *Pelosina complanata* Franke: 107, pl. 3, fig.1a–b.

1928 *Pelosina complanata* Franke; Franke: 10, pl. 1, fig. 6a–b.

1946 *Pelosina complanata* Franke; Cushman & Renz: 13, pl. 1, fig.8.

1984 *Saccammina grzybowskii* (Schubert); Hemleben & Tröster: 522, pl. 1, fig. 14.

1988 *Saccammina complanata* (Franke); Kaminski *et al.*: 183, pl. 2, fig. 8.

1989 *Pelosina complanata* Franke; Riegraf & Luterbacher: 1085, pl. 1, fig.1.

1990 *Saccammina grzybowskii* (Schubert); Kuhnt: 325, pl. 2, fig. 3.

Remarks. *Pelosina complanata* Franke 1928 is regarded as a junior synonym of *Saccammina grzybowskii*.

Thalmannammina cf. *neocomiensis* Geroch, 1962
(Pl. 3, figs 4–6)

1962 cf. *Thalmannammina neocomiensis* Geroch: 288, pl. 1, fig. 3(5–8).

1981 cf. *Thalmannammina neocomiensis* Geroch; Morgiel & Olszewska: 12, pl. 3, figs 12–13.

1984 cf. *Thalmannammina neocomiensis* Geroch; Geroch & Nowak, pl. 3, fig. 19, pl. 6, figs 3, 4.

Remarks. The coarse agglutination of the specimens in the Complex à Aptychus fauna does not allow a certain assignment to this species. However, the 'thalmannammine' U-shaped type of coiling can be recognized in some specimens. *Thalmannammina neocomiensis* ranges in the Polish External Carpathians from the Berriasian/-Valanginian to Cenomanian (Morgiel & Olszewska, 1981; Geroch & Nowak 1984).

Trochammina quinqueloba Geroch, 1959
(Pl. 3, figs 1-3)

1959 *Trochammina quinqueloba* Geroch: 118, pl. 12, figs 1–3.

1962 *Trochammina quinqueloba* Geroch; Neagu: 63, pl. 2, figs 34–36.

1974 *Trochammina quinqueloba* Geroch; Kuznetsova, pl. 1, fig. 5.

1980 *Trochammina quinqueloba* Geroch; Sliter, pl. 3, figs 16–19.

1983 *Trochammina quinqueloba* Geroch; Gradstein, pl. 1, figs 10–11.

1989 *Trochammina quinqueloba* Geroch; Riegraf & Luterbacher: 1092–1093, pl. 2, figs 6–9.

1990 *Trochammina quinqueloba* Geroch; Geroch & Olszewska: 531, pl. 3, figs 19–21, 23–25; pl. 4, figs 25–27, 30–32.

1992 *Trochammina quinqueloba* Geroch; Kaminski, Gradstein & Geroch: 256, pl. 6, figs 3, 4a–b.

Trochammina sp.A
(Pl. 2, Fig. 14)

Remarks. Test small, low trochospiral, with up to six globular chambers in the last whorl.

Explanation of Plate 4

Figs 1–3. *Trochamminoides* cf. *variolarius* (Grzybowski 1898), sample E30/10, ×170. **Figs 4–6.** *Pseudobolivina* cf. *munda* Krasheninnikov 1973, sample E30/10, 4: ×170, 5–6: ×240. **Figs 7–8.** *Dorothia praehauteriviana* Dieni & Massari 1966, sample E30/20 (redeposited assemblage), ×65. **Figs 9–11.** *Pseudobolivina* sp. A, sample E30/10, ×200. **Figs 12–16.** *Verneuilinoides neocomiensis* (Mjatliuk 1939), samples E30/10 and E30/11, ×170. **Figs 17–18.** *Gaudryina oblonga* Zaspelova, 1948, sample E30/10, 17: ×200, 18: ×125.
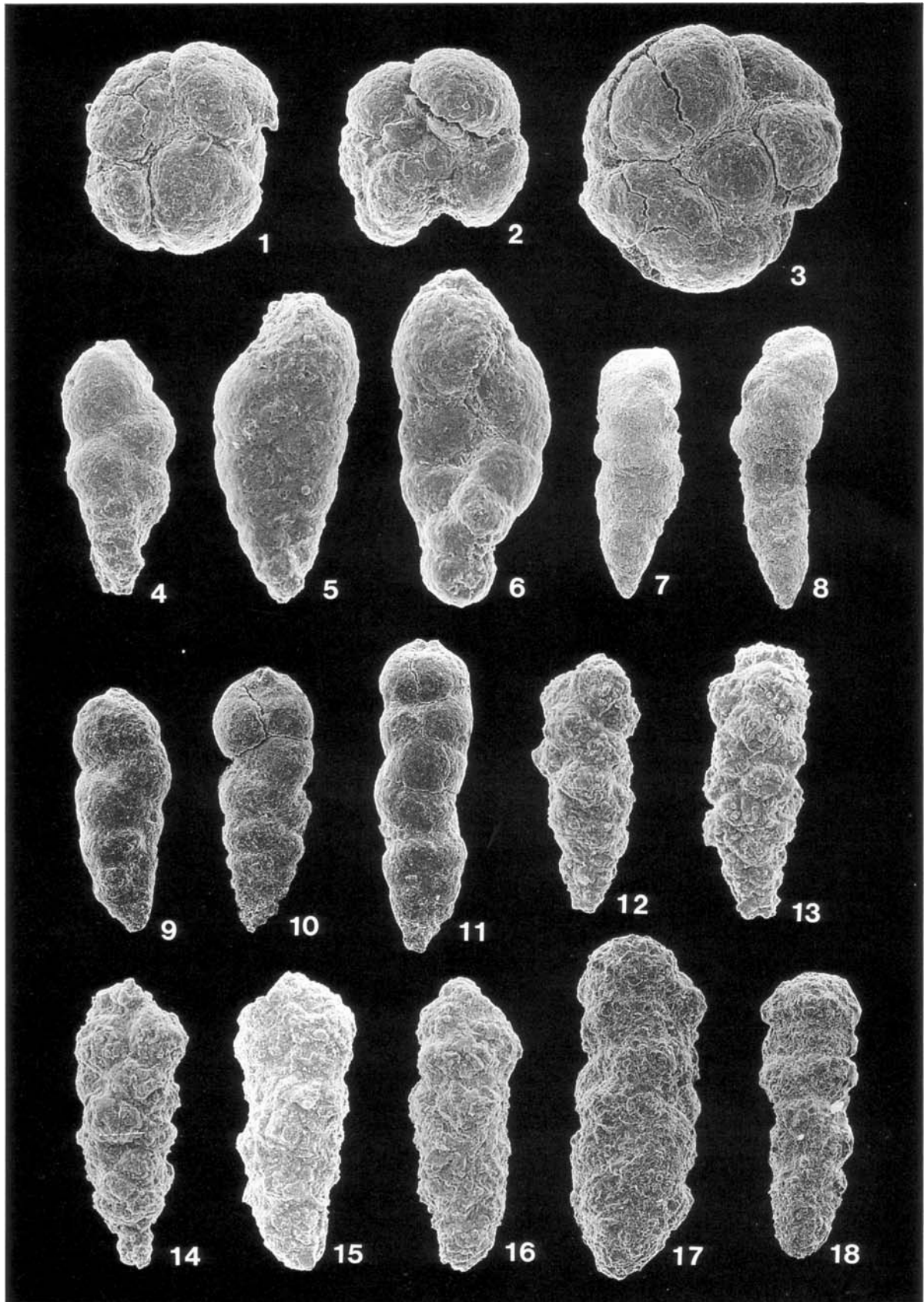
Plate 4

Trochamminoides cf. variolarius (Grzybowski, 1898)
(Pl. 4, fig. 1–3)

1898 cf. *Trochammina variolaria* Grzybowski: 288, pl. 11, fig. 15.

1964 cf. *Trochamminoides variolarius* (Grybowski); Grün *et al.*: 267, pl. 4, figs 12, 14.

1990 cf. *Trochamminoides variolarius* (Grybowski); Kuhnt & Kaminski: 487, pl. 4, figs g–h.

Remarks. The test is coiled in a somewhat irregular low trochospire. Finely agglutinated wall with a mooth surface.

Verneuilinoides neocomiensis (Mjatliuk, 1939)
(Plate 4, figs 12–16)

1939 *Verneuilina neocomiensis* Mjatliuk: 50, pl. 1, figs 12–13.

1962 *Verneuilinoides neocomiensis* (Mjatliuk); Flandrin, Moullade & Porthault: 216, pl. 1, fig. 4; pl. 2, fig. 7.

1974 *Verneuilinoides neocomiensis* (Mjatliuk); Kuznetsova, pl. 1, figs 6a–c.

1984 *Verneuilinoides neocomiensis* (Mjatliuk); Geroch & Nowak, pl. 2, fig. 4, pl. 7, figs 13–14.

1992 *Verneuilinoides neocomiensis* (Mjatliuk); Kaminski, Gradstein & Geroch: 256, pl. 7, fig. 13.

Remarks. Triserial arrangment of chambers throughout. Reported stratigraphic range : Valanginian–Barremian in the Polish outer Carpathians (Geroch & Nowak, 1984) and latest Tithonian to earliest Valanginian at ODP Site 765 in the Indian Ocean (Kaminski *et al.*, 1992).

Uvigerinammina sp. 1
(Plate 3, figs 13–14)

1992 *Uvigerinammina* sp. Kaminski, Gradstein & Geroch: 256, pl. 7, figs 10–11.

Remarks. Differs from *Falsogaudryinella tealbyensis* (Bartenstein 1956) in its agglutinated wall with diagenetically silicified organic cement, its more rounded aperture and in its less elongated test morphology. The genera *Falsogaudryinella* and *Uvigerinammina* are separated mainly on the basis of cement type, with *Falsogaudryinella* possessing calcareous cement and *Uvigerinammina* organic cement (Kaminski *et al.*, in press).

and provided useful comments on the taxonomy of several species.

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