Agglutinated foraminifera of western Mediterranean Upper Cretaceous pelagic limestones (Umbrian Apennines, Italy, and Betic Cordillera, Southern Spain)

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ABSTRACT: Agglutinated foraminifers of Upper Cretaceous pelagic limestones were studied from two road-sections near Gubbio (Italian Apennines) which are famous biostratigraphic and magnetostratigraphic standard sections for the Tethyan Upper Cretaceous, and from a section near Ronda (Penibetic Zone, southern Spain). HCl residues of the reddish "Scaglia Rossa" or "Capas Rojas" facies (Coniacian-Paleocene) of both sections consist almost completely of agglutinated foraminifers. In comparison with the "flysch-type" assemblages and the agglutinated assemblages of the abyssal variegated clays of the North Atlantic Ocean, the bathyal foraminiferal assemblages of the Western Mediterrenean pelagic limestones show strong similarities. Many of the species, decribed in this paper, are found also in flysch-type assemblages of the Alpine-Carpathian and Maghrebidian orogenic belts as well as in the variegated clays of the North Atlantic Plantagenet Formation.

A study of the stratigraphic distribution of these forms from the Turonian to Lower Paleocene led to the following results: 1) a lower part of the sequence (from the Cenomanian / Turonian boundary to Lower Coniacian in the Gubbio sections and to Middle / Upper Turonian in the Penibetic section) is almost devoid of agglutinants. A few samples contain indeterminable "tubes" and *Ammodiscus-Glomospira* morphotypes. Radiolarians and silicified planktonic foraminifera occur frequently in the HCl residues; 2) a characteristic assemblage of agglutinated foraminifera appears in the Coniacian and Santonian. This assemblage is delineated by *Haplophragmium problematicum* and *Uvigerinammina jankoi*. This change in biofacies is similar to observations carried out at Sites 603 and 641 in the North Atlantic; 3) a distinct change in the faunal composition is observed in the Lower Campanian. The following association is characterized by the frequent occurrence of *Spiroplectammina*. *Haplophragmium problematicum* and *Uvigerinammina jankoi* are absent in these assemblages. *Praecystammina* cf. *globigerinaeformis* and *Recurvoides* spp. become common elements of the fauna. In the upper part of this second agglutinated assemblage (Upper Campanian *G. calcarata* Zone to Maastrichtian) the species *Rzehakina epigona, Spiroplectammina israelskyi, Spiroplectammina* cf. *spectabilis*, and *Remesella varians* occur; 4) the K/T-boundary does not show an important taxonomic turnover in agglutinated foraminifers, but a sudden decrease in abundance and drastic quantitative change in the composition of the assemblages was detected in the Gubbio sections.

INTRODUCTION

Since agglutinated foraminifers may be the only group of organisms present in sediments beneath the oceanic lysocline, a correlation of their stratigraphic distribution to the geological time scale is important. Several DSDP/ODP sites in abyssal Upper Cretaceous sequences of the Pacific, Indian and North Atlantic oceans revealed deep water foraminiferal assemblages of excellent preservation (Krasheninnikov 1973, 1974; Krasheninnikov and Pflaumann 1978; Hemleben and Tröster 1984), and significant stratigraphical value (Moullade et al. 1988). Moreover, studies of Alpine and Carpathian agglutinated foraminiferal assemblages revealed the presence of several species of agglutinants which allow a local biostratigraphical zonation based on agglutinated foraminifers (Geroch and Nowak 1984). Hence, deep water agglutinated foraminifers are becoming an important group in biostratigraphic correlation and paleoenvironment interpretation of deep oceanic sequences. Since acid residues from Western Mediterranean pelagic limestones contain deep-water agglutinated foraminiferal assemblages which compare well to "flysch-type" assemblages of the Alpine Carpathian orogenic belt and to foraminiferal assemblages from the Plantagenet Formation in the North Atlantic, the Western Mediterranean deep water limestone sections provide an opportunity to directly calibrate the stratigraphical ranges of agglutinated deep-water foraminifers by means of a well-established planktonic foraminiferal zonation. Comparison of stratigraphic successions of agglutinated foraminifera and their chronostratigraphic correlation of various settings in the North Atlantic and the Western Tethys, which can be regarded as a single basin at least for the Upper Cretaceous (Morgiel and Olszewska 1982; Thurow and Kuhnt 1986, 1987) and in various paleoenvironments are a step to assess the use of agglutinated deep water foraminifera for biostratigraphy and the utility of benthic species for stratigraphic correlation.

METHODS

Fifty-three rock samples of pelagic limestones from two sections near Gubbio (Bottaccione and Contessa valley sections) and 30 samples from the Penibetic section of the Hacho de Montejaque near Ronda, Spain (text-fig. 1) have been studied in stratigraphic succession from Turonian to early Paleocene (text-fig. 2). These samples of 50g to 150g weight were dissolved completely in hydrochloric acid (HCl) and washed over a 63µm screen. This method caused a complete loss of calcareous benthic and planktonic foraminifers, which dominate in normally washed residues. The HCl residues consisted in most cases of agglutinated foramininifers of generally good preservation. Only a few samples showed etched and fragmented specimens partly due to calcitic particles which have been agglutinated (e.g. tests of planktonic foraminifera). In some cases mechanical destruction of fragile tests by gas bubbles during the strong reaction of the acid with the lime-

TEXT-FIGURE 1
Location and structural position of the selected deep-water limestone sections in the western Mediterranean. Legend: 1. Stable Europe/Iberia; 2. Deformed European margins; 3. Stable Africa; 4. Deformed African margins; 5. Tethyan Mesozoic microcontinents; 6. Flysch zones (Mesozoic oceanic zones); 7. Subsiding margins (Atlantic coastal basins; 8. Overthrust of the Betic-Rif-Tellian nappes. R: Hacho de Montejaque section (Penibetic zone, near Ronda); G: Contessa and Bottaccione sections (Umbrian Apennines, near Gubbio).

stones was observed. These fragmented tests caused problems for a statistic treatment of the assemblages, especially for tube-shaped forms, the portion of which could only be roughly estimated.

In addition to agglutinated foraminifera, some samples from the lower part of the studied sections (Turonian-Coniacian), where chertification has been observed, contain silicified molds of planktonic foraminifers and radiolarians. The stratigraphic position of the studied agglutinated assemblages, which is correlated in the Bottaccione section to magnetostratigraphy by mounted signs (Arthur and Fischer, 1977), is constrained by planktonic foraminifers, studied in acetate peels (Italian sections) and in washed residues from the more marly Spanish Capas Rojas facies.

## ENVIRONMENTAL CHARACTERISTICS OF THE PELAGIC LIMESTONES (SCAGLIA FACIES)

Sediment lithology and biofacies

The Upper Turonian through Paleocene sediments of the *Gubbio* sections record highly oxygenated conditions at the seafloor. No organic carbon values higher than 0.1% occur in the sequence and most values are near 0.01% (Arthur 1979). Nodular radiolarian chert and chert layers occur from the Turonian to the Santonian part of the sequence. The cherts are more frequent in the Turonian, and less frequent in the Coniacian and Santonian. Evidence from carbon isotopes, sediment accumulation rates and trends in oxydation state indicates that surface productivity may have been high during the middle to late Cretaceous (Arthur 1979).

The changes in sediment color and sedimentation rates of the Bottaccione and Hacho de Montejaque sections are summarized in text-figure 2. In general, the limestones of the Turonian to Santonian interval are variegated with light colors (gray, yellow gray, pink Scaglia Rossa limestone). In the Lower Campanian, a few meters above the top of the chert formation, the main transition from gray and pink colors to red and red-brown colors occurs. Arthur (1979) interpreted the colors of the *Gubbio* limestone-sequence as a direct indication for the original oxygenation state of the seafloor, concluding that increasing oxydation caused the red colors of the upper part of the section. This is confirmed by the intense burrowing, lack of lamination, pyrite and preserved organic carbon in this part of the section. This observation is reflected by the composition of benthic agglutinated foraminiferal assemblages. In the gray-white, chertified lower part of the Gubbio sequence (Lower Turonian to Coniacian) and the Penibetic sequence (Lower Turonian to Middle/Upper Turonian) agglutinated foraminifers are absent or rare, and comprised of low-diversity assemblages which are dominated by "primitive" tubular forms. In the red, well-oxygenated upper part of both sections the agglutinated assemblages show increased abundance and diversity, and contain species which are characteristic for the well-oxygenated deep-
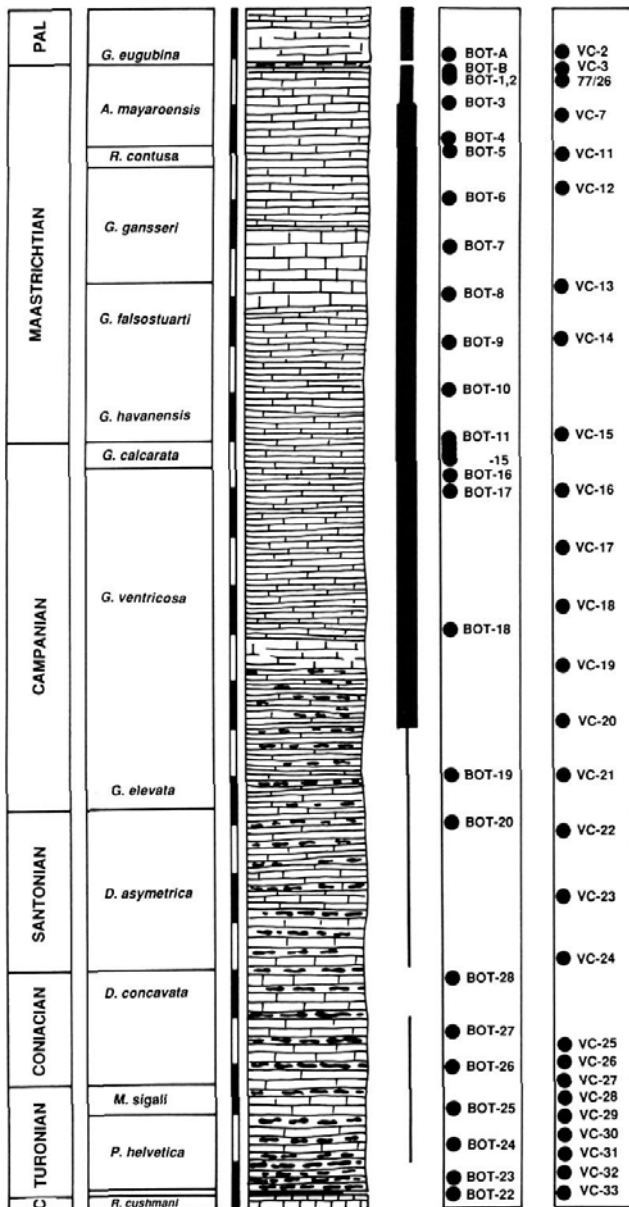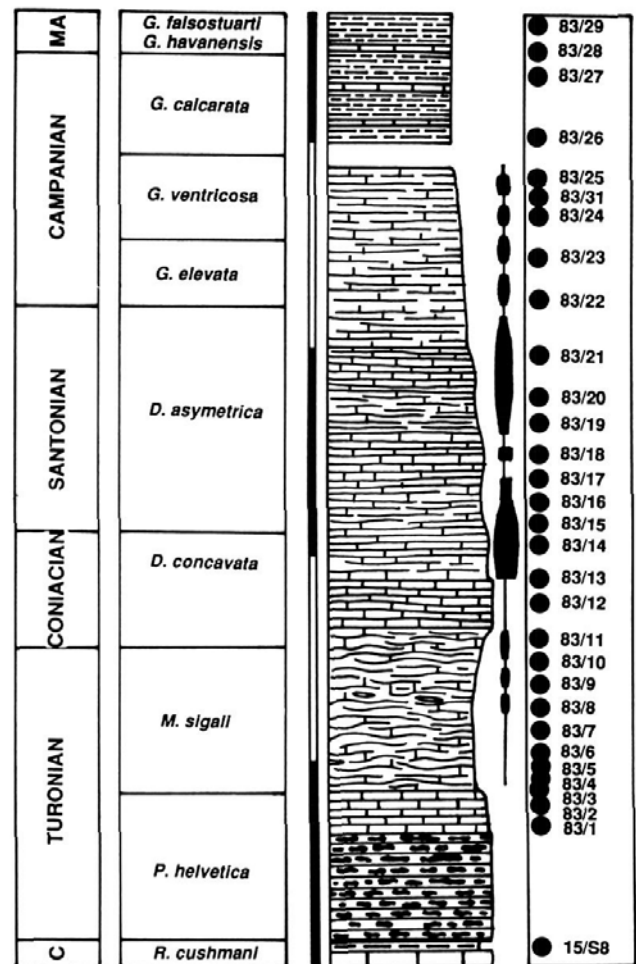
TEXT-FIGURE 2

Lithologic log and planktonic foraminiferal zonation of the studied sections with stratigraphic position of samples. Black dots in the lithologic column are chert; the black bars indicate sediment color (no black bar: white; thin bar: yellowish to rose-colored; thick bar: red). Gubbio section modified after Arthur (1979). Scale bar equals 10m. Note that in both sections rich and highly diverse agglutinated assemblages correspond with red sediment colors indicating well-oxygenated bottom water conditions.

sea environment of the North Atlantic variegated clays (Moullade et al. 1988).

There is no direct relationship between the sediment color and the sedimentation rate in the limestone sequence, which is in general low (sedimentation rates range from 2m/my in the Paleocene to 15m/my in the Maastrichtian). The most rapid deposition was during the Turonian-Santonian with a decrease

in the Campanian, an increase in the Maastrichtian and a decrease again in the Paleocene (Arthur 1979). The bulk of this sedimentation is made up of primary biogenic carbonate production in the surface waters (planktonic foraminifers and nannoplankton).

Remains of terrigenous detrital material in grain fractions above 63μm has not been observed. The clay-mineral content of the

Scaglia limestones is low in the Gubbio sections, and somewhat higher in the marly limestones of the Penibetic section. Generally, in both areas the habitat space of the benthic deep-sea biota seems not affected by terrigenous detrital input and substrate disturbance by turbidity or other bottom currents.

Paleobathymetry

The pelagic limestones of the Upper Cretaceous Scaglia-facies at Gubbio were deposited in a deep-water continental margin basin well above the calcium carbonate compensation depth (CCD), which might have been at about 3000m water depth during the late Cretaceous (Tucholke and Vogt 1979). The environment of the Penibetic late Cretaceous "Capas Rojas" facies was quite similar, but deposition took place in a tectonically unstable area with rapidly subsiding blocks. Evidence for local tectonic uplift since the late Campanian is given by a rapid change of the sedimentation and biofacies towards slope sequences. Arthur and Premoli Silva (1982) estimated the paleobathymetric setting of the Gubbio sequence at depths shallower than about 2000m. Labude (1984) calculated the late Cretaceous water depth of the Gubbio area using a direct comparison of the local burial curve with the standard age-depth curve for thermal subsidence of oceanic crust. This method revealed a late Cretaceous water depth of about 3000m, which I consider a maximum value, because the Gubbio limestones do not show any evidence for deposition below the carbonate lysocline.

Little paleobathymetric information is given by planktonic foraminifers and trace fossils. Planktonic foraminifers (mainly large keeled morphotypes of the genera *Helvetoglobotruncana*, *Dicarinella*, *Marginotruncana*, *Globotruncana*, *Globotruncanita*, *Rosita*, *Gansserina* and *Abathomphalus* additionally late Maastrichtian deep-dwelling non-keeled forms like *Pseudotextularia* and *Racemiguembelina*) make up about 99% of the foraminiferal assemblage in the Scaglia facies. A minimum water depth of about 1000m is generally assumed for such assemblages (Butt 1981; Hagn and Herm 1983). In the Coniacian and Santonian of the Penibetic Hacho de Montejaque section a typical ichnofauna of the *Zoophycos* Ichnofacies (Seilacher 1967) has been observed, which also indicates a bathyal paleobathymetric position of the post-Turonian part of this section (Kuhnt 1987).

The agglutinated foraminiferal assemblage from the Upper Cretaceous Scaglia limestones is unique. It includes elements of mixed calcareous and agglutinated bathyal assemblages (*Remesella varians*, *Spiroplectammina laevis*, *Spiroplectammina israelskyi* and *Rzehakina inclusa/epigona*), elements of purely agglutinated "flysch-type" assemblages (e.g. *Aschemocella carpathica*, *Rhizammina indivisa*, *Rhabdammina* sp., *Paratrochamminoides* spp., *Subreophax scalaris*, *Uvigerinammina jankoi*, and *Recurvoides* spp.), and forms which are typical for Upper Cretaceous abyssal assemblages in the North Atlantic Plantagenet Formation (e.g. *Haplophragmium problematicum*, *Haplophragmoides* cf. *perexplicatus*, *Pseudobolivina* cf. *munda*, *Pseudobolivina lagenaria*, and *Praecystammina globigerinaeformis*). The depositional environment of this formation was below the CCD and back-tracked water depth was generally deeper than 4000m (Jansa et al. 1979). Flysch-type agglutinated assemblages probably inhabited a relatively broad range of bathymetric settings in the bathyal and abyssal realm (Gradstein et al. 1983; Kuhnt 1988). However, several species (e.g. *Uvigerinammina jankoi*, which is the dominant form in the Coniacian and Santonian part of the

Penibetic Hacho de Montejaque section) are characterizing lower bathyal or abyssal environments in low latitudinal areas. In high latitudinal areas, e.g. in Labrador Shelf wells, the same forms may also occur in upper to middle bathyal settings (Gradstein and Berggren 1981; Kaminski 1988). Furthermore, the "Scaglia-type" assemblages contain elements of abyssal agglutinated assemblages. Therefore a deep bathyal bathymetric position in a water depth between 1500m and 2500m can be estimated for the depositional environment of the Scaglia Rossa limestones in the western Mediterranean area.

PALEOECOLOGY AND COMPARISON WITH FLYSCH-TYPE AND ABYSSAL AGGLUTINATED FORAMINIFERAL ASSEMBLAGES

The following environmental characteristics and lithologies of the host sediment for Upper Cretaceous deep-water agglutinated foraminiferal assemblages form a basis for comparison with Scaglia-type assemblages:

1. Abyssal environment of the North Atlantic Ocean (Plantagenet Formation, Jansa et al. 1979):
   - low detrital input
   - abyssal water depths (4000m)
   - deposition below the CCD
   - well oxygenated environment, no restricted bottom water circulation

2. Turbiditic environment ("flysch") of the Gibraltar Arch Area:
   - high to medium detrital input by turbidity currents (Thurow 1987)
   - bathyal to abyssal water depths (Thurow 1987; Kuhnt 1988)
   - deposition close to or below a local CCD (Thurow and Kuhnt 1986)
   - in general restricted, O_2-depleted environments in the bathyal (proximal) sequences (black-green laminated or bioturbated "Flammen"-claystones), in the distal/deep sequences may occur also red/multicolored claystones comparable to the deep sea facies of the North Atlantic (Kuhnt 1988)

3. Pelagic limestone environment of the Scaglia-facies (Gubbio section):
   - low detrital input
   - bathyal water depth of about 2000m (Arthur and Premoli Silva 1984)
   - deposition above the CCD
   - well oxygenated environment, no restricted bottom water circulation.

The relative abundance of the most common genera of deep-water agglutinated foraminifera within these environments is compiled in text-figure 3. Although on a first view the taxonomic composition of these assemblages seems to be similar, some important differences have to be pointed out:

1. The different size and agglutination of the specimens (very small and smooth forms in the Atlantic sites, more coarsely agglutinated and large forms in the flysch deposits—the Gubbio fauna appears to be intermediate in this aspect).

2. Occurrence of several characteristic forms in the deep Atlantic sites which are restricted to this environment (faunas of the "deep oceanic type" first described by Krasheninnikov (1973, 1974)).

3. Restriction of the genera *Remesella* and *Spiroplectammina* and probably *Rzehakina* to bathyal environments in the Gubbio section, as well as in the Gibraltar Arch area.

4. A general trend to increased diversity of agglutinants towards the deeper settings.

5. In environments where detrital input plays an important role, or in turbidite layers (Kaminski et al. 1988b; Schröder 1988), often high dominances of certain "tube-shaped" or linear chambered morphotypes (*Reophax, Hormosina*) can be observed.

Gradstein and Berggren (1981) differentiated between two main types of deep marine agglutinated foraminiferal assemblages which correspond to different paleoenvironments:

Type A assemblage (flysch-type assemblage):

Occurrence: Pacific and Atlantic Ocean basins, quite similar are assemblages from the Alpine-Carpathian Basins, Labrador Shelf, North Sea Basin.

Characteristic: contains many relatively robust and coarse-grained taxa.

Characterizing genera: *Rhizammina, Bathysiphon/Rhabdammina, Ammodiscus, Glomospira, Hormosina, Reophax, Kalamopsis, Haplophragmoides, Trochamminoides, Recurvoides, Paratrochamminoides, Trochammina*. The also listed genera *Spiroplectammina, Dorothia*, and *Rzehakina* seem to be absent in the deepest flysch settings of the Gibraltar Arch area; *Cyclammina* is restricted to the Cenozoic part of the sections.

### Type B assemblage (oceanic assemblage):

Occurrence: Indo-Pacific and Atlantic Cretaceous deep-sea cores (sites 196, 198A, 260, 261, 391C).

Characteristic: Specimens of small size with a thin, smooth wall.

Characterizing (frequent) genera: *Haplophragmoides, Paratrochamminoides, Haplophragmium, Trochammina, Praecystammina, Plectorecurvoides, Pseudobolivina*.

The taxonomic composition of late Campanian/Maastrichtian agglutinated assemblages of the Scaglia facies in comparison to abyssal, flysch-type and bathyal assemblages is listed in table 1. The largest similarity in taxonomic composition can be observed to tropical deep-bathyal assemblages (e.g. from the North African Margin in the Moroccan Rif or from Trinidad) and flysch-type assemblages. But Scaglia assemblages also contain taxa, which are generally restricted to abyssal assemblages of the North Atlantic Plantagenet Formation like evolute deep-water morphotypes of the genus *Haplophragmoides* (listed as *Haplophragmoides perexplicatus* s.l.), *Hormosinella distans, Saccammina sphaerica, Subreophax guttifer* and *Turritellella shoneana*. Several taxa, e.g. some species of the genera *Reophax* and *Pseudobolivina* as well as *Saccorhiza* cf. *ramosa* and forms which resemble modern Komokiacea (listed as *Tolypammina* ?) are unique to the Late Cretaceous Scaglia assemblages.

According to Gradstein and Berggren (1981) three main factors appear to control the distribution of flysch-type assemblages along continental margins:
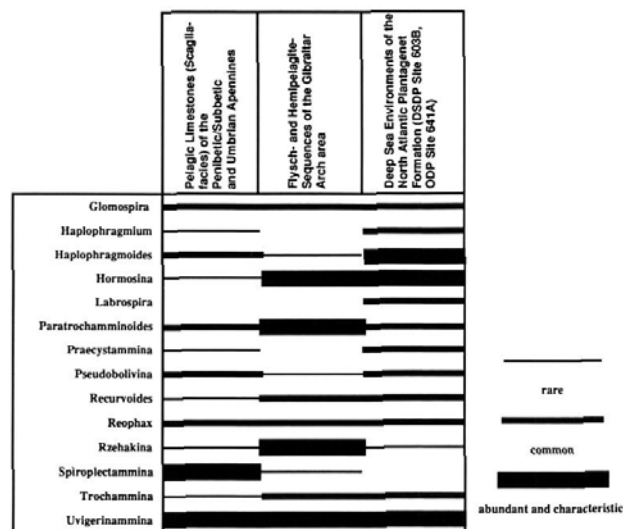
TEXT-FIGURE 3
Distribution of some important genera of agglutinated deep-sea foraminifers in selected environments. The pattern gives evidence for at least two important factors controlling the distribution of deep-sea agglutinants: 1. Nutrients and/or availability of carbonate (deposition above or below CCD) seem to be the controlling factors for absence of the genera *Rzehakina, Spiroplectammina*, and *Remesella* in the abyssal sequences and the absence of the abyssal forms *Labrospira* and some species of the genera *Haplophragmoides* and *Pseudobolivina* in the Flysch- and Scaglia-facies. 2. O_2-depletion and/or terrigenous detrital input probably control the distribution of *Praecystammina* and some species of the genus *Haplophragmium* (restricted to oxic environments with low detrital input) and, probably, *Hormosina* which seems to prefer a carbonate-free, finely detrital substrate.

1. Deposition of silts and clays with a relatively high concentration of slow decaying organic matter (which mainly occurs in areas of poor circulation).

2. O_2-depletion and raised CO_2-levels (in part as a result of factor 1) which hampers calcification and fossilization of calcium carbonate tests and impedes aerobic bacterial activity and further oxidation of organic matter.

3. Low pH (low alcalic, 7.8 or acidic, <7.0) which together with the low oxygen values (i.e. reducing conditions) leads to low positive or negative E_h-values, at or just below the sediment surface.

Observations on modern deep sea benthic foraminiferal assemblages give evidence for additional factors to control benthic community structures along continental margins, e.g. the availability of carbonate nutrients (Greiner 1969 and Lutze et al. 1986).

Most of these environmental factors, controlling the composition of deep-water benthic foraminiferal assemblages, are entirely different for flysch-type assemblages (type A), abyssal oceanic (type B) and the agglutinated assemblages of the Scaglia facies, which are:

1. Paleobathymetric settings in the lower bathyal realm, i.e. below at least 1500m water depth.

TABLE 1

Comparison of the distribution of Campanian - Maastrichtian agglutinated foraminifers in HCl residues of western Mediterranean pelagic limestones ("Scaglia-type" assemblage), from abyssal DSDP/ODP Sites of the North Atlantic (Hemleben and Tröster 1984; Moullade et al. 1988; Kuhnt et al. 1989), from "flysch-type" assemblages of the Gibraltar Arch area (Kuhnt 1987; Kuhnt and Kaminski 1989), from boreal bathyal environments of the Labrador Margin (Kaminski 1988), and from tropical bathyal environments of Trinidad (Kaminski et al. 1988) and the Moroccan Rif (Kuhnt and Kaminski 1989).

	SCAGLIA	ABYSSAL	FLYSCH	BOREAL BATHYAL	TROPIC BATHYAL
Ammodiscus cretaceus	X	X	X	X	X
Ammosphaeroidina pseudopauciloculata	X	X	X	X	X
Glomospira charoides	X	X	X	X	X
Glomospira gordialis	X	X	X	X	X
Glomospira irregularis	X	X	X	X	X
Glomospirella gaultina	X	X	X	X	X
Haplophragmoides cf. walteri	X	X	X	X	X
Hormosina gigantea	X	X	X	X	X
Hormosina ovulum	X	X	X	X	X
Hormosina velascoensis	X	X	X	X	X
Hyperammina elongata	X	X	X	X	X
Hyperammina dilatata	X	X	X	X	X
Kalamopsis grzybowskii	X	X	X	X	X
Karreriella conversa	X	X	X	X	X
Plectorecurvoides / Recurvoides spp.	X	X	X	X	X
Rhabdammina spp.	X	X	X	X	X
Rhizammina indivisa	X	X	X	X	X
Subreophax scalaris	X	X	X	X	X
Trochammina spp.	X	X	X	X	X
Saccammina grzybowskii	X	X	X	X	X
Saccammina placenta	X	X	X	X	X
Ammodiscus pennyi	X	X	X		X
Glomospira serpens	X	X	X		X
Hormosina ovuloides	X	X	X		X
Paratrochamminoides spp.	X	X	X		X
Hormosina crassa	X	X	X		
Hyperammina subdiscreta	X	X	X		
Paratrochamminoides sp.2	X	X	X		
Praecystammina(?) cf. globigerinaeformis	X	X	X		
Pseudobolivina lagenaria	X	X	X		
Pseudobolivina munda	X	X	X		
Rhizammina cf. algaeformis	X	X	X		
Saccammina cf. placenta	X	X	X		
Trochamminoides cf. dubius	X	X	X		
Haplophragmoides cf. concavus	X	X	X		X
Haplophragmoides sp.1	X	X	X		X
Haplophragmoides perexplicatus s.l.	X	X			
Hormosinella distans	X	X			
Praecystammina globigerinaeformis	X	X		?	
Saccammina sphaerica	X	X			
Subreophax guttifer	X	X			
Turritellella shoneana	X	X			
Ammodiscus glabratus	X		X	X	X
Ammodiscus planus	X		X	X	X
Haplophragmoides ex gr. suborbicularis	X		X	X	X
Lituotuba lituiformis	X		X	X	X
Paratrochamminoides irregularis	X		X	X	X
Reophax sp.2	X		X	X	X
Subreophax splendidus	X		X	X	X
Trochammina deformis	X		X	X	X
Paratrochamminoides heteromorphus	X		X		X
Rzehakina epigona	X		X		X
Rzehakina inclusa	X		X		X
Trochamminoides cf. proteus	X		X		X
Trochamminoides dubius	X		X		X
Ammodiscus sp.1	X		X		
Aschemocella carpathica	X		X		
Subreophax sp.1	X		X		
Matanzia varians	X			X	X
Spiroplectammina aff. dentata	X			X	X
Spiroplectammina aff. spectabilis	X			X	X
Reophax cf. subnodulosus	X				X
Spiroplectammina laevis	X				X
Spiroplectammina israelskyi	X				X
Verneuilinoides polystrophus	X				X
Cribrostomoides sp. 1	X				
Paratrochamminoides sp.1	X				
Pseudobolivina sp.3	X				
Pseudobolivina sp.4	X				
Reophax sp.3	X				
Reophax sp.4	X				
Reophax sp.5	X				
Saccorhiza ramosa cf.	X				
Spiroplectinata (?) sp.1	X				
Tolypammina (?) sp. 1	X				
Tolypammina (?) sp. 2	X				
Tolypammina (?) sp. 3	X				

TABLE 2

Distribution of agglutinated foraminifers in HCl residues from the Bottaccione section. HCl residues from the Turonian to Lower Santonian interval yielded only radiolarians and silicified molds of planktonic foraminifers. This may be a result of sampling too close to chertified levels. Legend: • (present) 1 specimen; **R** (rare), 2–3 specimens; **F** (few), 4–9 specimens; **C** (common), 10–50 specimens; **A** (abundant), more than 50 specimens.

SPECIES (columns, left to right):

Remesella varians, *Tolypammina sp. 3*, *Tolypammina sp. 2*, *Spiroplectammina dentata*, *Spiroplectammina israelskyi*, *Spiroplectammina laevis*, *Rhizammina indivisa*, *Reophax sp. 2*, *Subreophax scalaris*, *Subreophax guttifer*, *Glomospira charoides*, *Ammodiscus cretaceus*, *Trochamminoides cf. dubius*, *Haplophragmoides suborbicularis*, *Trochammina deformis + spp.*, *Tolypammina (?) sp. 1*, *Saccammina sphaerica*, *Saccammina placenta + cf. placenta*, *Rhizammina cf. algaeformis*, *Rhabdammina sp.*, *Reophax sp. 3*, *Reophax sp. 1*, *Praecystammina (?) cf. globigerinaeformis*, *Praecystammina globigerinaeformis*, *Recurvoides / Plectorecurvoides spp.*, *Paratrochamminoides sp. 2*, *Paratrochamminoides sp. 1*, *Hormosina velascoensis*, *Hyperammina subdiscreta*, *Glomospira serpens*, *Glomospira gordialis*, *Ammosphaeroidina cf. pseudopauciloculata*, *Ammodiscus planus*, *Kareriella (?) sp. 1*, *Rzehakina epigona*, *Saccorhiza cf. ramosa*, *Saccammina grzybowskii*, *Trochamminoides dubius*, *Pseudobolivina lagenaria*, *Glomospira irregularis*, *Subreophax splendidus*, *Ammodiscus glabratus*, *Trochamminoides alf. proteus*, *Haplophragmoides sp. 2*, *Reophax submodulosus*, *Paratrochamminoides heteromorphus*, *Pseudobolivina cf. munda*, *Turritellella sp.*, *Paratrochamminoides irregularis*, *Ammodiscus sp. 1*, *Haplophragmoides cf. walteri*, *Hyperammina elongata*, *Rzehakina inclusa*, *Cribrostomoides sp.*, *Glomospirella gaultina*, *Reophax sp. 5*, *Kareriella conversa*, *Ammodiscus cf. pennyi*, *Lituotuba lituiformis*, *Spiroplectinata (?) sp. 1*, *Hormosinella distans*, *Pseudobolivina sp. 3*, *Katamopsis sp.*, *Uvigerinammina jankoi*, *Haplophragmium problematicum*, *Radiolarians*

Sample rows (age / zone / sample):

- PALEOC. lower *eugubina* — BOT-A
- MAAS. upper *maya.* — BOT-B
- MAAS. upper *maya.* — BOT-1
- MAAS. upper *maya.* — BOT-2
- MAAS. upper *maya.* — BOT-3
- MAAS. upper *maya.* — BOT-4
- MAAS. upper *cont.* — BOT-5
- MAAS. middle *gans.* — BOT-6
- MAAS. middle *gans.* — BOT-7
- MAAS. lower *tric.* — BOT-8
- MAAS. lower *tric.* — BOT-9
- MAAS. lower *tric.* — BOT-10
- CAM. upper *calca.* — BOT-11
- CAM. upper *calca.* — BOT-12
- CAM. upper *calca.* — BOT-13
- CAM. upper *calca.* — BOT-14
- CAM. upper *calca.* — BOT-15
- CAM. upper *calca.* — BOT-16
- CAM. middle *vent.* — BOT-17
- CAM. lower *elev.* — BOT-18
- CAM. lower *elev.* — BOT-19
- SAN. upper *asym.* — BOT-20

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TABLE 3

Distribution of agglutinated foraminifers in HCl residues from the Contessa section. Legend: • (present) 1 specimen; **R** (rare) 2–3 specimens; **F** (few) 4–9 specimens; **C** (common) 10–50 specimens; **A** (abundant) more than 50 specimens.

The table presents the stratigraphic distribution (stage/sample columns: PAL lower VC-2; MAA upper VC-3; MAA upper 77/26; MAA upper VC-7; MAA VC-11; MAA VC-12; MAA VC-13; MAA lower VC-14; CAM upper VC-15; CAM VC-16; CAM VC-17; CAM VC-18; CAM VC-19; CAM VC-20; CAM lower VC-21; SAN upper VC-22; SAN VC-23; SAN VC-24; CON VC-25; CON VC-26; TUR upper VC-27; TUR upper VC-28; TUR upper VC-29; TUR middle VC-30; TUR middle VC-31) of the following species:

Ammodiscus glabratus; Glomospira charoides; Glomospira glomerata; Glomospira gordialis; Glomospira irregularis; Hyperammina (?) sp. (narrow glassy tubes); Remesella varians; Paratrochamminoides sp. 2; Recurvoides / Plectorecurvoides spp.; Reophax sp. 2, 4, 5; Reophax sp. 3; Rhizammina cf. algaeformis; Rhizammina indivisa; Saccammina placenta; Saccammina cf. ramosa; Spiroplectammina cf. spectabilis; Spiroplectammina ex gr. dentata; Subreophax scalaris; Tolypammina sp. 2; Trochamminoides cf. dubius; Lituotuba lituoliformis; Tolypammina (?) sp. 1; Spiroplectammina israelskyi; Spiroplectammina ex gr. laevis; Saccammina sphaerica; Saccammina grzybowskii; Subreophax guttifer; Pseudobolivina lagenaria; Paratrochamminoides sp. 1; Hormosina crassa; Haplophragmoides sp. 1; Ammosphaeroidina pseudopauciloculata; Ammodiscus planus; Pseudobolivina sp. 4; Trochammina deformis; Hyperammina elongata; Hormosinella distans; Pseudobolivina cf. munda; Hyperammina subdiscreta; Glomospirella gaultina; Glomospira serpens; Aschemocella carpathica; Ammodiscus cretaceus; Kalamopsis grzybowskii; Subreophax sp. 1; Verneuilinoides polystrophus; Paratrochamminoides irregularis; Rhabdammina sp.; Trochamminoides proteus; Trochamminoides dubius; Saccammina cf. placenta; Haplophragmoides cf. walteri; Ammodiscus pennyi; Tolypammina sp. 3; Ammodiscus sp. 1; Paratrochamminoides heteromorphus; Praecystammina (?) cf. globigerinaeformis; Karreriella conversa; Hyperammina dilatata; Trochamminoides cf. proteus; Pseudobolivina sp. 3; Haplophragmoides concavus; Uvigerinammina jankoi; Haplophragmium problematicum; Gaudryina ex gr. filiformis; Trochammina sp. A (4-chamb. flattened).

TABLE 4

Distribution of agglutinated foraminifers in HCl residues of the Hacho de Montejaque section (section S8, Penibetic). Stratigraphic framework based on planktonic foraminiferal biostratigraphy (Kuhnt 1987). Legend: • (present) 1 specimen; **R** (rare), 2–3 specimens; **F** (few), 4–9 specimens; **C** (common), 10–50 specimens; **A** (abundant), more than 50 specimens.

TUR middle 83/3	TUR 83/6	TUR 83/8	CON 83/12	CON upper 83/14	SAN lower 83/15	SAN 83/18	SAN 83/19	SAN upper 83/21	CAM lower 83/22	CAM 83/31	CAM 83/25	SPECIES
	F		F	R	C	R	F	•	C	R	R	*Ammodiscus cretaceus*
C	F	F	C	C	F	A	A	C	A	A	A	*Rhizammina indivisa*
				•							•	*Trochamminoides cf. dubius*
				F	F	F	R	R	C	R	•	*Reophax scalaris*
R	•		R	R	F	R	C	•	F	R	•	*Glomospira charoides*
				F	C	C	C	C	C	C	C	*Rhabdammina sp.*
											R	*Hyperammina dilatata*
				F			R		•	R	•	*Ammodiscus glabratus*
		•			•	F	F	R	F	R	R	*Trochammina deformis*
				R		•			R(cf.)	•	•	*Reophax sp. 2*
											•	*Subreophax guttifer*
	C			R	F	F	C	R	A		F	*Recurvoides / Plectorecurvoides spp.*
							R				R	*Pseudobolivina sp. 3*
											•	*Praecystammina globigerinaeformis*
				•		•			•		R	*Paratrochamminoides sp. 2*
			F						R		•	*Paratrochamminoides sp. 1*
									R		•	*Hormosina velascoensis*
					F		•	•	•		•	*Lituotuba lituiformis*
			F	R	C	C	F	F			C	*Karreriella conversa*
				•					•	•	R	*Kalamopsis grzybowskii*
			•	R	F	F	C	R	F		•	*Haplophragmoides cf. walteri*
R		R	F	F	C	C				R	•	*Glomospira gordialis*
			R	C		C					R	*Ammosphaeroidina pseudopauciloculata*
											F	*Ammodiscus cf. pennyi*
R				F	R	F	C			R		*Glomospirella gaultina*
										F		*Spiroplectammina laevis*
										R		*Rhizammina cf. algaeformis*
				R			C			R		*Pseudobolivina cf. munda*
			R				R		R	C		*Paratrochamminoides sp. 3*
			R						F	R		*Karreriella sp. 1*
				F					F	•		*Haplophragmoides cf. perexplicatus*
			•	R	R					R		*Cribrostomoides sp. 1*
R			F		•	F	R	F			*Ammodiscus planus*
							F		•			*Tolypammina sp. 2*
				R					•			*Saccammina cf. placenta*
									C			*Pseudobolivina sp. 4*
									R			*Hormosina ovuloides*
			F	C	F	C	R	F			*Glomospira irregularis*
		F	C	A	A	A	F	R			*Uvigerinammina jankoi*
				R	•		R				*Trochamminoides cf. proteus*
			C	C	C	C	•				*Haplophragmium problematicum*
			R		•	F					*Tolypammina (?) sp. 1*
						R					*Saccammina sphaerica*
						F					*Reophax sp. 4*
				R		F					*Hyperammina subdiscreta*
						F					*Hyperammina elongata*
					•						*Saccammina grzybowskii*
				F	•						*Reophax subnodulosus*
				•							*Haplophragmoides sp. 1*
				F							*Haplophragmoides concavus*

2. Oxidizing conditions within the benthic layer, probably higher pH and E_h.

3. Composition of the substratum is characterized by high availability of calcium carbonate.

4. Relative position well above CCD and / or calcium carbonate lysocline.

5. Sedimentation rates are low in comparison to the classical flysch basins. This may result in higher abundance of foraminiferal tests due to less dilution by fine-grained terrigenous sediment and better preservation of the tests due to slow post-diagenetic burial of the pelagic limestones.

6. Absence of turbiditic events: An important factor in the distribution pattern of deep sea agglutinated foraminifera is their
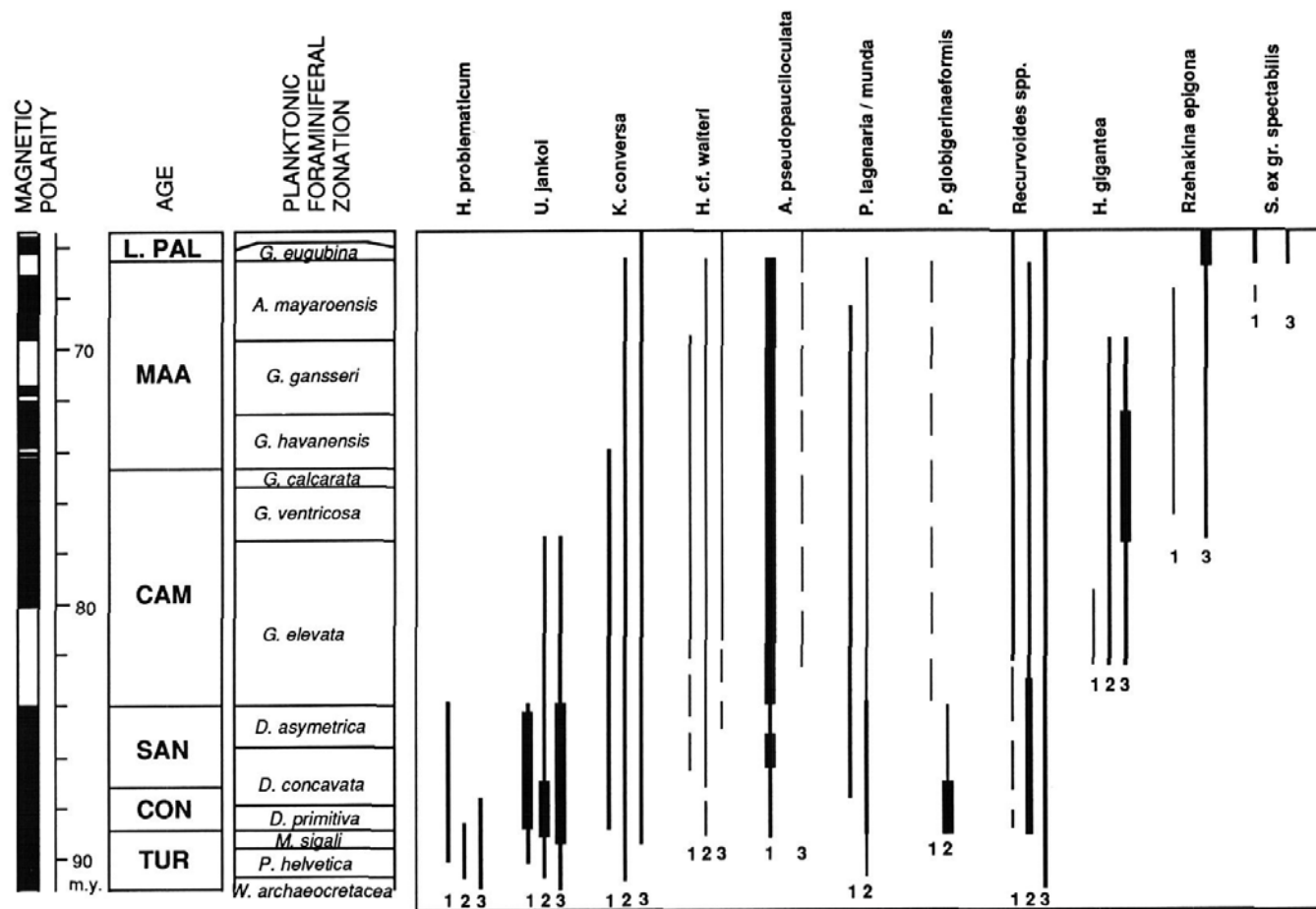
TEXT-FIGURE 4

Comparsion of stratigraphic ranges of selected Upper Cretaceous agglutinated foraminifers in the Gubbio sections, in the North Atlantic (data from Moullade et al. 1988) and in the Polish Carpathians (data from Geroch and Nowak 1984). Legend: 1. Gubbio sections, 2. abyssal North Atlantic, 3. Polish Carpathian Flysch.

capability to recolonize an abiotic substrate (Grassle 1977, 1978; Kminski 1985). Forms with a high capability for dispersal are well adapted to clastic (e.g. turbiditic) environments, whereas less successful colonizers would be restricted to distal environments with less frequent turbiditic detrital input. Kaminski et al. (1988a) have observed a rapid recolonization among recent benthic agglutinated deep sea foraminifera. According to these authors the most successful colonizer is *Reophax*, a genus living predominantly infaunal. In contrast, tube-shaped morphotypes like *Dendrophrya*, live epifaunal and show low capability for dispersal. The high abundance of tube-shaped agglutinated foraminifers in the detritus-free environment of the Upper Cretaceous Scaglia facies is in good accordance with these recent observations.

7. The paleoceanographic conditions (water temperature, surface productivity and resulting plankton input, bottom water circulation) are still relatively ambiguous in Upper Cretaceous pelagic environments. There have been probably several distinct changes in surface productivity, bottom water circulation and water temperature (Scholle and Arthur 1980; Cool 1982), which also influenced the deep-water benthic faunal assemblages

(Moullade et al. 1988; Kuhnt et al. 1989). The occurrence of flysch-type agglutinated foraminifera in the well-oxygenated detritus-free environment of the western Mediterranean deep-water limestone sequence may be evidence for the importance of watermass properties on distribution patterns of Upper Cretaceous deep-water foraminifers, in addition to the composition of sediment substrate.

BIOSTRATIGRAPHIC UTILITY OF AGGLUTINATED DEEP-WATER FORAMINIFERS

In the three studied sections, the majority of agglutinated taxa occur continuously over the whole interval from Turonian to lower Paleocene (tables 2–4). However, some species have restricted stratigraphic distribution and permit a local biostratigraphic correlation based on agglutinated foraminifers. The most important of these biostratigraphic marker species are listed below. Their approximate biostratigraphic ranges are shown in text-figures 4 and 5.

1. *Haplophragmium problematicum*: last appearance near the Santonian / Campanian boundary.
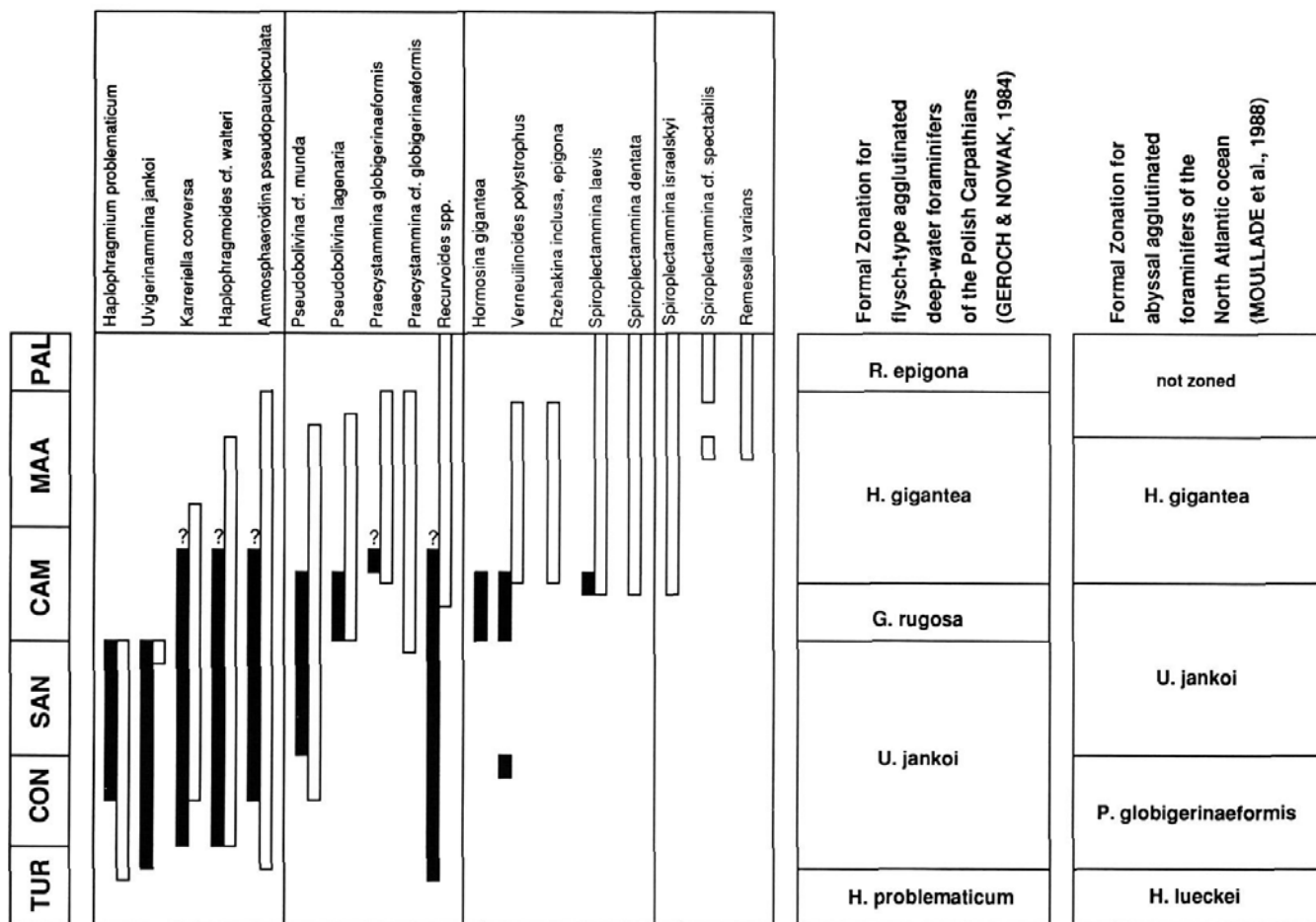
TEXT-FIGURE 5
Stratigraphic ranges of some important agglutinated foraminifers in dissolution residues of Scaglia limestones from the Gubbio sequence (white bars) and from the Hacho de Montejaque section (black bars). Note that the absence of "Scaglia-type" agglutinates since late Campanian in the Penibetic section is due to the local tectonic history; compare with the proposed agglutinant-zonations from Geroch and Nowak (1984) for the Polish External Carpathians, and Moullade et al. (1988) for the Plantagenet Formation of the North Atlantic Ocean (Leg 93, DSDP and Leg 103, ODP).

2. *Uvigerinammina jankoi* (which is scarce and badly preserved in the Gubbio sections, but abundant and well preserved in the Hacho de Montejaque section of the Penibetic Zone): last appearance near the Santonian / Campanian boundary.

3. *Praecystammina* cf. *globigerinaeformis:* acme in the Campanian.

4. *Spiroplectammina* cf. *laevis:* first occurrence in the Lower Campanian.

5. *Spiroplectammina israelskyi:* first occurrence in the Upper Campanian.

6. *Spiroplectammina* aff. *spectabilis:* first occurrence in the Middle Maastrichtian.

7. *Haplophragmoides* cf. *walteri:* first occurrence in the Lower Campanian.

8. *Recurvoides* spp.: acme in the upper part of the section (Upper Campanian - Maastrichtian)

9. *Hormosina gigantea:* only in the Penibetic section, very rare, and restricted to the Campanian.

10. *Rzehakina epigona:* first occurrence in the Upper Campanian.

11. *Rzehakina inclusa:* first occurrence in the Middle Maastrichtian.

12. *Remesella varians:* first occurrence in the Maastrichtian.

13. *Hormosina velascoensis:* first occurrence in the Lower Campanian.

Several of these species are found also in flysch-type assemblages of the Alpine-Carpathian and Maghrebidian orogenic belts (Geroch 1960; Neagu 1962, 1968, 1970;Hanzlikova 1966, 1969, 1972, 1973; Sandulescu 1973, 1975; Butt 1981; Geroch and Nowak 1984; Kuhnt 1987; Geroch and Koszarski 1988) as well as in the variegated clays of the North Atlantic Plantagenet Formation (Krasheninnikov and Pflaumann 1978; Hemleben and Tröster 1984; Moullade et al. 1988). In these different

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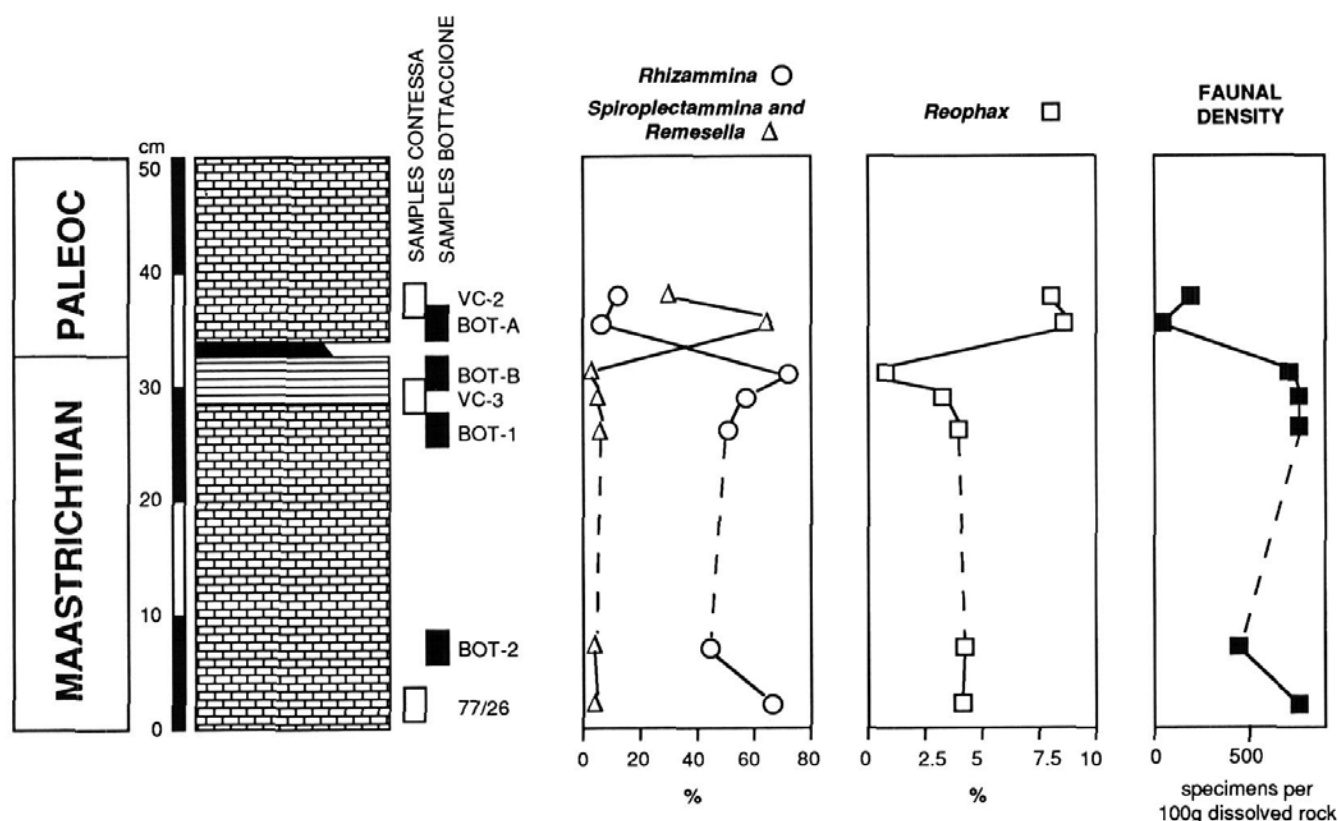
TEXT-FIGURE 6
Quantitative distribution of agglutinated foraminifers around the K/T boundary in the Gubbio area (Bottaccione and Contessa sections).

paleoenvironments, biostratigraphic zonations of the Upper Cretaceous (based on agglutinated foraminifera) have been proposed by Geroch and Nowak (1984) and Moullade et al. (1988). Some of the forms which occur in the Scaglia limestones have been used in these zonations as marker fossils. A comparison of the existing zonal schemes with the ranges of the Gubbio species is given in text-figure 5.

A similar pattern in stratigraphic distribution can be observed from the comparison of the ranges of some forms which occur also in the Gubbio sections (text-fig. 4). However, it can be speculated that the different bathymetric position of the Gubbio sections in respect to the CCD may cause shorter stratigraphic ranges for deep-sea species, which come to the limit of their habitat and probably longer ranges for species which are optimally adapted to slope-environments and a carbonate substrate.

Local stratigraphic ranges seems to be the case for *Uvigerinammina jankoi* which shows a constant occurrence from Turonian to Lower/Middle Campanian in the Central North Atlantic as well as in tethyan flysch deposits of the Alpine-Carpathian orogenic belt (Moroccan Rif: Morgiel et al. 1980; Kuhnt 1987; Polish Carpathians: Geroch 1957; Bieda et al. 1963; Geroch et al. 1967, Birkenmajer and Geroch 1961; Morgiel and Olszewska 1981; Huss 1966; Geroch and Nowak 1984; Romanian Carpathians: Sandulescu 1973; Neagu 1968, 1970; Tschechoslovakian Carpathians: Salaj 1961; Hanzlikova

1973). In a high latitude occurrence and a less deep paleobathymetric setting, the same form has been observed even in the Maastrichtian (Labrador Shelf: Miller et al. 1982). In the Gubbio sequence this species seems to be restricted to a few samples near the Santonian-Campanian boundary, but it forms a very distinct biozone with high abundance in the Coniacian to Santonian and a clear extinction near the Santonian/Campanian boundary in the Penibetic sequence.

Another stratigraphic problem arises for the *Praecystammina globigerinaeformis* group. It is limited to a relatively small interval in the Upper Turonian to Coniacian in the material from DSDP Leg 93, and ODP Leg 103, and has been used to define the local *Praecystammina globigerinaeformis* Total Range Zone (TRZ) (Moullade et al. 1988). Apparently the same forms, or very similar forms, which do not allow a differentiation on a specific level, occur up to the Upper Maastrichtian in the Gubbio sequence and in the tropical Atlantic (Hemleben and Tröster 1984) and even up to the early Eocene in the Central North Sea (Gradstein et al. 1988).

A problem in understanding the local ranges is seen in the limited knowledge about taxonomic comparability of several agglutinated deep sea foraminifers from different environments. For example, *Haplophragmium lueckei* (Cushman and Hedberg 1941) is originally described from a slope faunal assemblage of Upper Cretaceous Colon Formation of Colombia. The name has been used for morphologically similar forms from abyssal

assemblages of the Indian Ocean by Krasheninnikov (1974) and for specimens from Upper Cretaceous slope and flysch-type assemblages by various authors (e.g. Sliter 1968; Neagu 1970; Hanzlikova 1972). However, the taxonomic identity of all these forms is doubtful. The deep sea specimens from the North Atlantic differ from the original description and figure of Cushman and Hedberg (1941) in their apertural features (Moullade et al. 1988). These abyssal forms would be better included in the flysch species *Haplophragmium problematicum* (Neagu), which has a distinct stratigraphic range from Cenomanian to Coniacian/Santonian in the Polish and Romanian Carpathian deep-water sequences (Neagu 1970; Geroch and Nowak 1984). Thus, the scattered stratigraphic and environmental distribution of *Haplophragmium lueckei/Haplophragmium problematicum* may result from lumping different species with a similar morphology, size and mode of agglutination.

Nevertheless, comparing the stratigraphic ranges of agglutinated foraminifers in the three studied sections exhibits several consistent datum levels, which enable a biostratigraphic correlation for the Western Mediterranean deep-water limestones based on agglutinated foraminifers (text-fig. 5).

This biostratigraphic frame is certainly limited to sites in a stable environment in the same basin, at comparable latitude and paleobathymetric position and in lithologies lacking detrital input. A comparison of this biostratigraphic frame with data from other basins which experienced different subsidence and depositional histories, may enable the use of agglutinated deep water foraminifera for biostratigraphic correlation on more than a regional scale, once the taxonomical comparability of the species is carefully considered.

INFLUENCE OF UPPER CRETACEOUS PALEOCEANOGRAPHIC EVENTS

During the Mid- to Late Cretaceous and Paleocene, the evolution of oceanic biota in surface waters underwent a period characterized by three possibly global paleoceanographic events:

- the Cenomanian/Turonian boundary event,
- an early Campanian event,
- the Cretaceous/Tertiary (K/T) boundary event.

The influence of these events on the evolution of marine zooplankton has already been demonstrated (e.g. planktonic foraminifers and radiolarians: Luterbacher and Premoli Silva 1962; Wonders 1980; Caron 1985; Kuhnt et al. 1986). Both the Cenomanian/Turonian and the early Campanian events in the deep-sea environments are characterized by radiolarian blooms, with a peculiar taxonomic composition of the radiolarian assemblages (Thurow and Kuhnt 1986; Thurow 1988). This may indicate periods of enhanced plankton productivity in the surface waters, which may have led to short-term enhanced oxygen minima or even bottom water anoxia.

The effects of these events on agglutinated abyssal foraminiferal assemblages have already been shown for the North Atlantic Plantagenet Formation (Moullade et al. 1988, Kuhnt et al. 1989). The same events over the same time intervals appear to coincide with significant faunal breaks also in the pelagic limestone sequences of the western Mediterranean.

The Cenomanian/Turonian boundary event

The late Cenomanian/early Turonian is characterized by predominating biosiliceous sedimentation and shows distinct and marked anoxic facies in the deep-sea (Herbin et al. 1986; Kuhnt et al. 1986; Thurow et al. 1988). The event is accompanied by important taxonomic changes in deep-water benthic foraminifers (Geroch and Nowak 1984; Kuhnt 1987; Moullade et al. 1988; Kuhnt et al. 1989). In the deep-water limestones of the western Mediterranean the organic-carbon-rich Cenomanian/Turonian boundary layer ("Bonarelli horizon") is devoid of benthic foraminifers and overlying beds are characterized by rare and low-diverse agglutinated assemblages of indeterminable "tubes" and species of the family Ammodiscidae (tables 2 and 3). The HCl residues consist almost completely of radiolarians and (secondarily) silicified planktonic foraminifers. In recent oceans the oxygen-minimum zone on continental slopes below high productivity surface waters is characterized by specially adapted benthic communities (Lutze and Coulbourn 1984; Lutze et al. 1986) or appears rather barren of in situ foraminiferal fauna (Zobel 1973). This may be a possible model for the rare occurrence and low diversity of agglutinants in the Lower Turonian beds, which exhibit important chertification and slightly more reducing environments than the sequence up-section.

The reoccurrence of benthic foraminifers began in Middle Turonian (table 3, sample VC-31, table 4, sample 83/3), more diversified benthic assemblages can be observed since Upper Turonian (*M. schneegansi* Zone), with a characteristic *Uvigerinammina jankoi* assemblage (table 4, sample 83/8). This evolution is quite similar to the evolution in the North Atlantic Plantagenet Formation.

The early Campanian faunal change

The early Campanian timespan is characterized by the intercalation of a biosiliceous facies in the Tethyan deep-water basins (Neagu 1968; Herm 1962; Butt 1981; Kuhnt 1987). A predominantly radiolarian biofacies across this interval has also been observed in the zeolitic clays (sub-CCD deposits of the Plantagenet Formation) of the North Atlantic Ocean (Thurow 1988; Moullade et al. 1988). In both cases this biosiliceous event coincides with a major faunal change in agglutinated foraminifers: the *Uvigerinammina jankoi* assemblage, which dominates the Turonian-Santonian sequences, is replaced by a *Hormosina gigantea* assemblage which characterizes Upper Campanian and Maastrichtian biofacies in flysch series and zeolitic claystones deposited below the CCD. In the pelagic limestone sequences of the Gubbio area and the Penibetic Zone, no prominent biosiliceous signal has been observed in the Lower Campanian (compare text-fig. 2). However, a similar turnover in the composition of agglutinated foraminiferal assemblages is observed.

The Cretaceous/Tertiary (K/T) boundary event

The late Cretaceous assemblages of deep marine benthic organisms differ only slightly from those in the Paleocene. Numerous benthic species persisted across the K/T boundary with little or no changes (Beckmann 1960; Tjalsma and Lohmann 1983; Hsü et al. 1984) but there is evidence for a reduction of the benthic biomass. The uppermost Maastrichtian and the lower Paleocene sediments are much bioturbated, but the boundary clay separating the two is commonly laminated, for example at Site 516 (Dailey 1983). This lack of bioturbation suggests a mass mortality of burrowing organisms (Hsü et al. 1984; Hsü 1986).

There have been few investigations of the distribution of deep-sea benthic foraminifers across the K/T boundary:

1. Upper Cretaceous Guayaguayare and Paleocene Lizard Springs formations (Trinidad) show relatively little benthic change across the boundary (Beckmann 1960). An extinction rate of 18% has been determined by Webb (1973) for the Trinidad Maastrichtian benthic fauna.

2. DSDP Site 208, Lord Howe Rise, Tasman Sea revealed a benthic level of extinction of 54% across the K/T boundary (Webb 1973)

3. A census study of middle bathyal to lower bathyal benthic foraminifers at DSDP Site 516 in the western South Atlantic (Dailey 1983) revealed major changes in benthic faunal composition at the Cretaceous/Tertiary boundary transition. At this site the K/T boundary was a time of rapid taxonomic turnover in deep bathyal benthos, with the extinctions of numerous species and the introduction of many new species. Overall, species diversity decreased about 20%, and approximately one-third of the latest Maastrichtian species did not survive to the end of the Cretaceous (Dailey 1983). Most striking is the accelerated rate of last occurrences during the final 2 million years of the Maastrichtian, which was only partly compensated by first appearances.

4. Moullade et al. (1988) observed a significant faunal break in deep-water agglutinated foraminifers more or less coinciding with the K/T boundary in the North Atlantic Plantagenet Formation. However, the position of the K/T boundary in the Atlantic Plantagenet Formation is not sufficiently confirmed and in the sites studied the Paleocene portion of the sequence revealed only few and poor foraminiferal assemblages. A confirmation of these findings requires additional study.

The available data is still ambiguous as to whether or not the deep sea benthos had been strongly affected by the K/T boundary event. This information is important to discriminate between the different proposed models to explain the cause of this major event.

Changes in agglutinated assemblages across the K/T boundary in the Gubbio area can be seen in comparing the composition of 4 samples from the Bottaccione section (BOT-2, BOT-1, and BOT-B from the *A. mayaroensis* Zone and BOT-A from the *G. eugubina* Zone) and 3 samples from the Contessa section (77/26 and VC-3 from the *A. mayaroensis* Zone and VC-2 from the *G. eugubina* Zone). Although the sample base is still small, some meaningful changes in the following values have been observed (text-fig. 6): Faunal density (number of specimens per g dissolved limestone), faunal diversity, and changes in the relative abundance of taxa between assemblages.

These data point to some influence of the K/T boundary event on benthic life in the deep sea. The quantitative composition of the faunal assemblages changes drastically in both sections between the last Cretaceous sample from the whitish (leached?) zone in the upper part of the *A. mayaroensis* Zone and the first sample from the red limestones of the *G. eugubina* Zone. The most striking changes at the K/T boundary are a decrease in the abundance of agglutinants in general and especially a strong decrease in tube-shaped agglutinants (mainly *Rhizammina indivisa*) which make up about 90% of the upper Cretaceous assemblages. Also, other typical flysch-type agglutinants like *Praecystammina, Recurvoides,* and *Paratrochamminoides* disappear or become very rare across the K/T boundary. The most important genera of the lowest Paleocene samples are

Spiroplectammina and *Reophax.* Interestingly enough, a similar change in deep-water agglutinated foraminiferal assemblages is observed at the K/T boundary of the Caravaca section in southern Spain. Here spiroplectamminids are the only benthic foraminifers occurring in the first layer above the K/T boundary (Fabbrucci 1989). One possible explanation for this shift in species composition of agglutinated assemblages may be seen in the epibenthic habitat of tubular forms and their low capability to recolonize the substrate (Kaminski et al. 1988b).

CONCLUSION

Pelagic deep-water limestones of the western Mediterranean area yield a rich faunal assemblage of at least 93 species of agglutinated foraminifers. The composition of the foraminiferal assemblage is unique. It includes elements of flysch-type agglutinated assemblages, elements of slope assemblages, and forms which are typical of Upper Cretaceous abyssal associations of the North Atlantic Plantagenet Formation. This new "Scaglia-type" biofacies of agglutinated foraminifers seems to be typical for Upper Cretaceous deep bathyal depositional environments of low latitudes, which are well oxygenated, lack terrigenous detrital input, and are placed well above the CCD. The Umbrian Scaglia Rossa limestones and the Penibetic "Capas Rojas" marly limestones are examples of this characteristic Tethyan litho- and biofacies-type in the western Mediterranean area.

For several species of agglutinated foraminifers a comparable stratigraphic distribution in three studied sections in central Italy and southern Spain has been observed, i.e. over a distance of more than 1000km. Some of these biostratigraphic marker forms have been also used for biostratigraphic correlation in the Upper Cretaceous sub-CCD sequences of the North Atlantic Plantagenet Formation (*Haplophragmium problematicum, Uvigerinammina jankoi, Praecystammina globigerinaeformis,* and *Hormosina gigantea*). An examination of their distribution in sections with reliable stratigraphic control by planktonic foraminifers and magnetostratigraphy contributes to a better chronostratigraphic calibration of a deep-water agglutinated foraminiferal zonation. The stratigraphic distribution of these forms shows a certain correlation of major taxonomic changes in deep-water benthic foraminifers to paleoceanographic events, for example, the anoxic phase at the Cenomanian/Turonian boundary, a poorly investigated Lower/Middle Campanian biosiliceous event and possibly also the K/T boundary event which seem to have affected benthic life in the deep sea.

TAXONOMIC NOTES

Ammodiscus cretaceus (Reuss 1845)
Plate 1, figures 2–3

Operculina cretacea REUSS 1845, p. 35, pl. 13, figs. 64, 65
Ammodiscus cretaceus (Reuss).— KRASHENINNIKOV 1974, p. 643, pl. 7, fig. 8.— MOULLADE et al. 1988, p. 363, pl. 1, fig. 7.
Ammodiscus sp. 2, LABUDE 1984, p. 69, pl. 1, fig. 7.

Test composed of 8–10 relatively broad whorls showing a regular planispiral coiling. Surface smooth, or with fine radiate striations; wall siliceous, homogenous or including very fine grains. Proloculus generally visible. In several samples occur forms, which differ from the typical *Ammodiscus cretaceus* in a smaller size, more involute coiling and generally possessing more whorls. These forms, which resemble closely *Ammodiscus*

glabratus Cushman and Jarvis 1928, have herein not been separated from *A. cretaceus.*

Ammodiscus cf. *pennyi* Cushman and Jarvis 1928
Plate 1, figure 6

Ammodiscus pennyi CUSHMAN and JARVIS 1928, p. 87, pl. 12, figs. 4–5.— KRASHENINNIKOV and PFLAUMANN 1977, p. 576, pl. 2, figs. 10–11.— KAMINSKI et al. 1988, pp. 184–185, pl. 3, figs. 9–10.
Test large, with numerous, slightly irregular coils. Wall thick and coarsely agglutinated. The forms from the Scaglia material seem to be intermediate to *Lituotuba* or *Glomospira* (*Tolypammina?*) *irregularis,* but differ from these forms in an only slightly irregular planispiral coiling.

Ammodiscus planus Loeblich 1946
Plate 1, figure 5

Ammodiscus planus LOEBLICH 1946, p. 133, pl. 22, fig. 2.— KAMINSKI et al. 1988, p. 185, pl. 3, fig. 13.
Ammodiscus sp. 1 LABUDE 1984, pp. 68–69, pl. 1, fig. 6

Small specimens with thin, finely arenaceous walls; surface smooth, with an almost hyaline appearance; color whitish.

Ammodiscus sp. 1
Plate 1, figure 7

Test large, with slightly irregular planispiral coiling. Surface smooth. Indications of weak constrictions may be present. This species may be regarded as an intermediate form to *Trochamminoides dubius.*

Ammosphaeroidina pseudopauciloculata (Mjatliuk 1966)
Plate 5, figure 1

Trochammina pauciloculata Brady.— GRZYBOWSKI 1896, p. 23, pl. 8, figs. 51, 52.
Cystammina pauciloculata (Brady).— GEROCH 1960, p. 66, pl. 6, fig. 8.
Cystamminella pseudopauciloculata MJATLIUK 1966, p. 264, pl. 1, figs. 5–8; pl. 2, fig. 6; pl. 3, fig. 3.

Test finely agglutinated, strongly compressed with three to four slightly elongated chambers visible on each side. No aperture visible due to the strong compression. Differs from *P. globigerinaeformis* in its larger size (Mjatliuk 1966 gives dimensions of his specimens from 200 to 700µm). *A. pseudopauciloculata* from the Gubbio material has a maximum diameter up to 600µm whereas *P. globigeriniformis* is typically small, with a maximum diameter of less than 300µm. *A. pseudopauciloculata* differs from *C. pauciloculata* in its less elongated chambers.

The only difference between *Cystamminella* Mjatliuk 1966 and *Ammosphaeroidina* Cushman 1910 is seen in the wall structure: finely agglutinated for *Ammosphaeroidina* and siliceous for *Cystamminella.* The Gubbio specimens thus belong to the genus *Ammosphaeroidina. Cystamminella* probably is a junior synonym of *Ammosphaeroidina .*

Aschemocella carpathica (Neagu 1964)
Plate 3, figure 13

Aschemonella carpathica NEAGU 1964, pp. 582–586, text-figs. 2.2–4, 3.1–3, 4.1–6.— KUHNT 1987, pl. 48, fig. C; pl. 51–2, figs. 10–11.— LOEBLICH and TAPPAN 1988, p. 55, pl. 42, figs. 14–16.
Aschemonella ex gr. *grandis* Grzybowski.— KAMINSKI et al. 1988, p. 186, pl. 2, figs. 11–13.

Test large, branched, composed of numerous irregularly ovoid chambers. Fragments of this form resemble *Aschemonella* ex gr. *grandis* Grzybowski of Kaminski et al. (1988) in its large size and in its morphological outline. *A. carpathica* differs from *Aschemocella grandis* (Grzybowski 1898) in possessing more irregularly shaped, elongate chambers.

Cribrostomoides sp. 1
Plate 4, figures 19–20

Planispiral test with four chambers in the last whorl. Apertural face low, aperture consisting of a number of low openings at the base of the last chamber. Coiling is involute; a slight tendency towards streptospirality may be only a result of diagenetic compression.

Glomospira charoides (Jones and Parker 1860)
Plate 1, figure 11

Trochammina squamata Jones and Parker var. *charoides* JONES and PARKER 1860, p. 304.
Glomospira charoides (Jones and Parker) var. *corona* CUSHMAN and JARVIS 1928, p. 89, pl. 12, figs. 9–11.
Glomospira cf. *charoides* (Jones and Parker).— LABUDE 1984, pp. 69–70, pl. 2, fig. 2.
Glomospira charoides (Jones and Parker).— MOULLADE et al. 1988, p. 363, pl. 1, fig. 6.

Glomospira corona Cushman and Jarvis 1928 is here considered as just a further growth stage of the long ranging species *G. charoides.*

Glomospira gordialis (Jones and Parker 1860)
Plate 1, figure 9–10

Trochammina squamata Jones and Parker var. *gordialis* JONES and PARKER 1860, p. 304.
Glomospira cf. *gordialis* (Jones and Parker) LABUDE 1984, p. 69, pl. 2, fig. 1.
Glomospira gordialis (Jones and Parker) MOULLADE et al. 1988, p. 363, pl. 1, fig. 4.

Irregularly coiled tube, the last whorl of which is generally lying in one plane; diameter of the tube is small, characteristic is the smooth, very finely agglutinated wall.

Glomospira (*Tolypammina ?*) *irregularis* (Grzybowski 1898)
Plate 1, figure 12

Ammodiscus irregularis GRZYBOWSKI 1898, p. 285, pl. 11, figs. 2, 3.
Glomospira? (*Tolypammina*) *irregularis* (Grzybowski).— HEMLEBEN and TRÖSTER; 1984, p. 519, pl. 1, fig. 22.

This long ranging species differs from all other species of the genus agglutinating coarser material.

Glomospira serpens (Grzybowski 1898)
Plate 1, figure 4

Ammodiscus serpens GRZYBOWSKI 1898, p. 285, pl. 10, figs. 31–33.
Glomospira serpens (Grzybowski).— HEMLEBEN and TRÖSTER 1984, p. 519, pl. 1, fig. 23.— MOULLADE et al. 1988, p. 363, pl. 1, figs. 2, 3.

This species has been partly described as *Glomospirella gaultina,* which has a similar mode of coiling but a circular and not an elongated ellipsoid outline.

Glomospirella gaultina (Berthelin 1880)
Plate 1, figure 8

Ammodiscus gaultinus BERTHELIN 1880, p. 19, pl. 1, fig. 3a–b.
Glomospira gordialis (Jones and Parker) var. *diffundens* CUSHMAN and RENZ 1946, p. 15, pl. 1, fig. 30.
Glomospira grzybowskii JURKIEWICZ 1960, p. 342, pl. 38, figs. 7, 10, 11.
Glomospirella gaultina (Berthelin).— KRASHENINNIKOV and PFLAUMANN 1978, p. 568, pl. 2, fig. 5.
Ammodiscus sp. 1.— LABUDE 1984, p. 68–69, pl. 1, fig. 6.
Glomospirella gaultina (Berthelin).— MOULLADE et al. 1988, p. 353, pl. 1, fig. 5.

All specimens with irregularly coiled initial part and with two or more planispiral whorls have been included in this species.

Haplophragmium problematicum (Neagu 1962)
Plate 4, figures 3–9

not *Ammobaculites lueckei* CUSHMAN and HEDBERG 1941, p. 84, pl. 21, fig. 4a, b.
Ammobaculites agglutinans (d'Orbigny) ssp. *problematicus* NEAGU 1962, p. 61, pl. 2, figs. 22–24.
? *Haplophragmium aequicameratum* HUSS 1966, p. 32, pl. 9, figs. 10–25.
Haplophragmium lueckei Cushman and Hedberg.— KRASHENINNIKOV 1974, p. 639, pl. 4, figs. 3a, b, 4a, 5a.
Ammobaculites problematicus Neagu.— GEROCH and NOWAK 1984, pl. 1, figs. 17–18; pl. 6, fig. 23.
Haplophragmium lueckei Cushman and Hedberg.— MOULLADE et al. 1988, p. 363, pl. 3, figs. 1–6.

The type-material of *H. problematicum* in the Neagu collection reveals a very wide variability in shape and chamber arrangement of this species, including a streptospirally coiled early

portion. Generally Turonian-Coniacian specimens tend to decrease the number of chambers in the uniserial part and to have a more rectilinear uniserial part. Some specimens show an initial nearly planispiral coiling, followed by an uncoiled part which consists of three to four subcylindrical chambers. Specimens observed in the Scaglia material and in the Plantagenet Formation of the North Atlantic fall into this variability. Some specimens in the lower part of the sections show a different arrangement of chambers: they are characterized by a longer uniserial part, which is not exactly rectilinear. These specimens have been assigned to *Haplophragmium problematicum* with a question mark in the distribution charts.

Haplophragmoides cf. **concavus** (Chapman 1892)
Plate 4, figure 13

Trochammina concava CHAPMAN 1892, p. 327, pl. 6, fig. 14a–b.
Haplophragmoides cf. *concava* (Chapman).— GEROCH 1960, p. 127, pl. 5, fig. 2.
Haplophragmoides sp. cf. *concavus* (Chapman).— MOULLADE et al. 1988, p. 364, pl. 8, figs. 8, 9.

Planispiral, completely flattened and finely agglutinated tests with three to five chambers in the last whorl. Comparable with *H. walteri* by its narrow compressed rim, but with less chambers in the last whorl and a lobate outline.

Haplophragmoides cf. **perexplicatus** Krasheninnikov 1973
Plate 4, figure 14

Plate 1

1   *Rhizammina* cf. *algaeformis* Brady, sample BOT-17, Middle Campanian, ×152.

2   *Ammodiscus cretaceus* (Reuss), sample BOT-15, Upper Campanian, ×128.

3   *Ammodiscus cretaceus* (Reuss), sample S8/83/25, Campanian, ×104. Slightly compressed specimen with strongly overlapping whorls, showing morphologic similarities to *Ammodiscus glabratus* Cushman and Jarvis.

4   *Glomospira serpens* Grzybowski, sample BOT-7, Middle Maastrichtian, ×120.

5   *Ammodiscus planus* Loeblich, sample BOT-17, Middle Campanian, ×240.

6   *Ammodiscus* cf. *pennyi* Cushman and Jarvis, sample S8/83/25, Campanian, ×48.

7   *Ammodiscus* sp. 1, sample BOT-14, Upper Campanian, ×64.

8   *Glomospirella gaultina* (Berthelin), sample S8/83/22, Lower Campanian, ×96.

9   *Glomospira gordialis* (Jones and Parker), sample BOT-15, Upper Campanian, ×128.

10 *Glomospira gordialis* (Jones and Parker), sample BOT-5, Upper Maastrichtian, ×128.

11 *Glomospira charoides* (Jones and Parker), sample BOT-1, Upper Maastrichtian, ×128.

12 *Glomospira (Tolypammina?) irregularis* (Grzybowski), sample BOT-11, Upper Campanian, ×96.

13 *Rhizammina indivisa* Brady, sample BOT-14, Upper Campanian, ×48. Rare specimen with a loop-shaped morphology, generally this species is only preserved as tube-shaped fragments.

14 *Turritellella shoneana* (Siddall), sample BOT-5, Upper Maastrichtian, ×96.

15 *Tolypammina* sp. 1, sample BOT-1, Upper Maastrichtian ×96.

16 *Tolypammina* sp. 2, sample BOT-2, Upper Maastrichtian, ×120.

17 *Lituotuba lituiformis* (BRADY), sample BOT-14, Upper Campanian, ×152.

18 *Lituotuba lituiformis* (BRADY), sample S8/83/15, Lower Santonian, ×152.

Haplophragmoides perexplicatus KRASHENINNIKOV 1973, p. 208, pl. 1, fig. 6a, b.— KRASHENINNIKOV 1974, p. 635, pl. 1, fig. 5a, b.— MOULLADE et al. 1988, p. 364, pl. 5, figs. 4–6.
A very rare species in the Gubbio material.

Haplophragmoides aff. *suborbicularis* (Grzybowski 1896)
Plate 4, figures 16–17

Cyclammina suborbicularis Rzehak.— GRZYBOWSKI 1896, p. 24, pl. 9, figs. 5–6.
Haplophragmoides suborbicularis suborbicularis (Grzybowski).— JURKIEWICZ 1967, p. 77, pl. 4, figs. 12–13.
Haplophragmoides ex gr. *suborbicularis* (Grzybowski).— KAMINSKI et al. 1988, p. 189, pl. 5, figs. 12–13b.

Test large, inflated, involute, with 6 chambers in the last whorl. Wall coarsely agglutinated. Aperture (areal slit or oval on Grzybowski's figure of the holotype is not visible on the few specimens from Gubbio).

Haplophragmoides cf.*walteri* (Grzybowski 1898)
Plate 4, figures 10–12

Trochammina walteri GRZYBOWSKI 1898, p. 290, pl. 11, fig. 31.
Haplophragmoides cf. *walteri* (Grzybowski).— HEMLEBEN and TRÖSTER 1984, p. 519, pl. 3, fig. 6.
Haplophragmoides sp. cf. *walteri* (Grzybowski).— MOULLADE et al. 1988, p. 364, pl. 8, fig. 7.

Test planispiral, involute, strongly compressed, with a spherical outline. Sutures indistinct. Wall siliceous, surface smooth.

Differs from *H. concavus* in possessing more than 5 chambers in the last whorl. Differs from the typical *H. walteri* in its smaller size and in having generally less chambers in the last whorl.

Haplophragmoides sp. 1
Plate 4, figure 15

Test small, wall finely agglutinated, smooth, with a brown color. Four to five chambers in the last whorl. Depressed umbilicus. Often distorted by compression.

Differs from *H.* cf. *concavus* in its more evolute planispiral coiling and in possessing a deepened umbilicus.

Hormosina crassa Geroch 1966
Plate 2, figure 5

Hormosina ovulum crassa GEROCH 1966, p. 438, figs. 6 (19, 21–26), 7 (21–23).— HEMLEBEN and TRÖSTER 1984, p. 520, pl. 2, figs. 8, 9.
Reophax distans Brady.— LABUDE 1984, p. 72, pl. 3, fig. 2.
Hyperammina cf. *dilatata* Grzybowski.— HEMLEBEN and TRÖSTER 1984, p. 520, pl. 1, fig. 11.
Hormosina crassa Geroch.— MOULLADE et al. 1988, p. 364, pl. 2, figs. 4–6.

Test more coarsely agglutinated than in other species of the genus *Hormosina*, with spherical chambers linked by thick connections.

Hormosina gigantea Geroch 1960
Plate 2, figures 18–19

Hormosina ovulum (Grzybowski) var. *gigantea* GEROCH 1960, p. 43, pl. 2, figs. 18–19.
Hormosina gigantea Geroch.— MORGIEL and OLSZEWSKA 1981, p. 9, pl. 2, fig. 8.— MOULLADE et al. 1988, p. 364, pl. 2, fig. 11.

Plate 2

1   *Saccammina placenta* (Grzybowski), sample BOT-5, Upper Maastrichtian, ×152.

2   *Saccammina* cf. *placenta* (Grzybowski), sample S8/83/15, Lower Santonian, ×152.

3   *Saccammina grzybowskii* (Schubert), sample S8/83/18, Santonian, ×144.

4   *Hyperammina subdiscreta* (Grzybowski), sample BOT-10, Upper Campanian, ×264.

5   *Hormosina crassa* Geroch, sample BOT-19, Lower Campanian, ×120.

6   *Saccorhiza* cf. *ramosa* (Brady), sample BOT-1, Upper Maastrichtian, ×128.

7   *Saccorhiza* cf. *ramosa* (Brady), sample BOT-10, Upper Campanian, ×160.

8–9   *Saccammina sphaerica* Sars, sample BOT-2, Upper Maastrichtian, ×128.

10–11   *Hyperammina dilatata* Grzybowski, sample S8/83/25, Campanian, ×104.

12   *Hyperammina elongata* Brady, sample S8/83/19, Santonian, ×144.

13   *Hormosina velascoensis* (Cushman), sample BOT-B, Uppermost Maastrichtian, ×64.

14   *Hormosina velascoensis* (Cushman), sample BOT-6, Middle Maastrichtian, ×120.

15   *Kalamopsis grzybowskii* (Dylazanka), sample S8/83/14, Upper Coniacian, ×144.

16   *Hormosina ovuloides* (Grzybowski), sample S8/83/22, Lower Campanian, ×152.

17   *Hormosina ovulum* (Grzybowski), sample S8/83/22, Lower Campanian, ×152.

18   *Hormosina gigantea* Geroch, sample S8/83/22, Lower Campanian, ×96.

19   *Hormosina gigantea* Geroch, sample S8/31, Campanian, ×96. The length of this specimen is about 500µm.

Hormosina ovulum gigantea Geroch.— GEROCH and NOWAK 1984, pl. 1, fig. 20, pl. 5, figs. 15 16.

Differs from *Hormosina ovulum* (Grzybowski) in its larger size and a more globular outline of the chambers. Its stratigraphic range is restricted to Campanian to Maastrichtian in the Gibraltar Arch area, lower Campanian to early Paleocene in the Carpathian flysch according to Geroch (1960) and Geroch and Nowak (1984). In the abyssal zone of the North Atlantic Ocean *H. gigantea* has been used to define Zone 4 of the preliminary zonal scheme of Moullade et al. (1988): LAD of *Uvigerinammina jankoi* to LAD of *Hormosina gigantea* , which corresponds to late Campanian–early / middle Maastrichtian. *H. gigantea* is very rare in Scaglia-type assemblages; it is absent in the Gubbio material and occurs only rarely in the Campanian of the Penibetic section.

Hormosina ovuloides (Grzybowski 1901)
Plate 2, figure 16

Reophax ovuloides GRZYBOWSKI 1901, p. 223, pl. 8, fig. 3.
Hormosina ovuloides (Grzybowski).— HEMLEBEN and TRÖSTER 1984, p. 520, pl. 2, fig. 6.— MOULLADE et al. 1988, p. 364, pl. 2, fig. 10.

Test composed of more elongated and asymmetrical chambers than in *Hormosina ovulum*. Connections of chambers are relatively broad. A rare species in the Scaglia material.

Hormosina ovulum (Grzybowski 1898)
Plate 2, figure 17

Reophax ovulum GRZYBOWSKI 1896, p. 276, pl. 8, figs. 19–21.
Hormosina ovulum (Grzybowski).— MOULLADE et al. 1988, p. 364, pl. 2, figs. 7–9.

Test similar to *Hormosina gigantea* by its very smooth surface and very narrow connections between chambers, but having a smaller size (200–400 microns) and more elongated chambers.

Though intermediate forms appear to exist, the two species have different stratigraphic ranges (Geroch and Nowak 1984). The extremely elongated specimens show some similarities with *Hormosina ovuloides,* but are distinguished from this species by their narrow connections between chambers and by a more symmetrical egg-like shape. A rare species in the Scaglia material.

Hormosina velascoensis (Cushman 1926)
Plate 2, figures 13–14

Nodosinella velascoensis CUSHMAN 1926, p. 583, pl. 20, fig. 9.
Hormosina velascoensis (Cushman).— NEAGU 1970, p. 35, pl. 2, fig. 16.
Reophax velascoensis (Cushman).— HEMLEBEN and TRÖSTER 1984, p. 521, pl. 2, fig. 12.
Nodellum velascoense (Cushman).— KAMINSKI et al. 1988, p. 187, pl. 1, figs. 21–22.
Nodellum velascoense (Cushman).— KUHNT 1988, pl. 2, fig. 6.

Linear arrangement of distinctly overlapping flattened chambers. Wall generally smooth, glassy. This species is in Trinidad generally more common in non-calcareous shales (Kaminski et al. 1988a) but occurs also in mixed calcareous and agglutinated assemblages of the North African margin in the Moroccan Rif.

Hormosinella cf. *distans* (Brady 1881)
Plate 3, figure 1

cf. *Reophax distans* BRADY 1881, p. 50.— BARKER 1960, pl. 31, figs. 18–22.— SCHRÖDER 1986, p. 44, pl. 16, figs. 3–5, 9.
cf. *Hormosinella distans* (Brady).— LOEBLICH and TAPPAN 1988, p. 57, pl. 44, figs. 6–9.

Test small, consisting of two or three rounded or elongated chambers, connected by a thin fragile neck. Finely agglutinated. Specimens from the Gubbio material differ from the recent *H. distans* in its smaller test, finer agglutination and its variable chamber shape.

Plate 3

1 *Hormosinella* cf. *distans* (Brady), sample VC-18, Campanian, ×152.

2 *Subreophax guttifer* (Brady), sample BOT-11, Upper Campanian, ×96.

3 *Subreophax guttifer* (Brady), sample BOT-1, Upper Maastrichtian, ×128.

4 *Subreophax scalaris* (Grzybowski), sample BOT-2, Upper Maastrichtian, ×96.

5 *Subreophax scalaris* (Grzybowski), sample BOT-7, Middle Maastrichtian, ×96.

6 *Reophax* cf. *subnodulosus* Grzybowski, sample S8/83/15, Lower Santonian, ×104.

7 *Reophax* sp. 2, sample BOT-11, Upper Campanian, ×128.

8–9 *Reophax* sp. 2, sample BOT-1, Upper Maastrichtian, ×128

10 *Reophax* sp. 3, sample BOT-1, Upper Maastrichtian, ×128.

11 *Reophax* sp. 5, sample BOT-10, Lower Maastrichtian, ×96.

12 *Reophax* sp. 4, sample S8/83/19, Santonian, ×96.

13 *Aschemocella carpathica* (Neagu), sample 77/26, Upper Maastrichtian, ×22.4.

14 *Subreophax* sp. 1, sample BOT-7, Middle Maastrichtian, ×72.

15 *Subreophax* aff. *splendidus* (Grzybowski), sample BOT-7, Middle Maastrichtian, ×72.

16 *Subreophax* aff. *splendidus* (Grzybowski), sample BOT-7, Middle Maastrichtian, ×48.
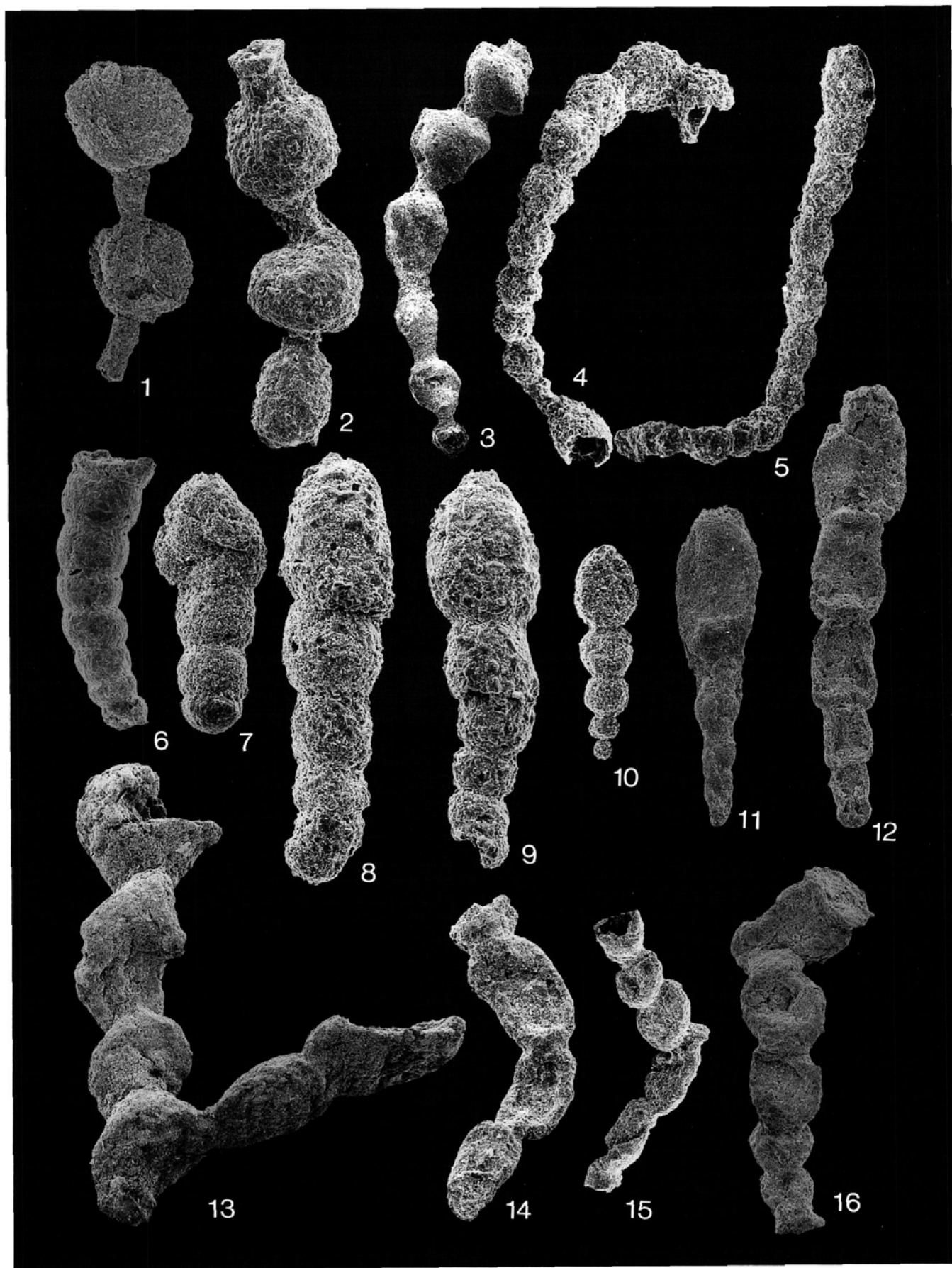
Hyperammina dilatata Grzybowski 1896
Plate 2, figures 10–11

Hyperammina dilatata GRZYBOWSKI 1896, pp. 274–275, pl. 8, fig. 17.— KAMINSKI et al. 1988, p. 184, pl. 2, figs. 1–2.

Large unilocular chambers with thick, smooth, finely agglutinated wall. Differs from *H. ovuloides* in having a broader apertural opening. Differs from *H. excelsa* in never possessing two openings and in its more irregular "sack-like" shape.

Hyperammina elongata Brady 1884
Plate 2, figure 12

Hyperammina elongata BRADY 1884, p. 257, pl. 23, figs. 4, 7–10.— KUHNT 1988, pl. 4, fig. 3.

Test without constrictions in the linear part of the chamber; wall smooth, glassy. Occurs rarely in samples of the Penibetic section.

Hyperammina subdiscreta (Grzybowski 1896)
Plate 2, figure 4

Rhabdammina subdiscreta Rzehak.— GRZYBOWSKI 1896, p. 275, pl. 8, figs. 5, 6.— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 1, figs. 1, 2.
Hyperammina subdiscreta (Grzybowski).— LISZKA and LISZKOWA 1981, p. 164, pl. 1, figs. 2a,b.— MOULLADE et al. 1988, p. 365, pl. 2, figs. 1–3.
Hyperammina cf. *dilatata* Grzybowski.— HEMLEBEN and TRÖSTER 1984, p. 520, pl. 1, fig. 10.

Coarsely agglutinated tubes, with constrictions and globular, ovoid widenings. Differs from *Hyperammina dilatata* by showing broader tubular sections, a smaller proloculus, and generally coarser agglutinated particles. Slightly curved forms show similarities with *Hyperammina nodata* Grzybowski 1896.

Hyperammina subdiscreta differs from *Hormosina crassa* by its more irregularly shaped ovoid widenings, whereas *H. crassa* has globular, separated chambers. In this latter species the tubes between the chambers are narrow or broken away.

Kalamopsis grzybowskii (Dylazanka 1923)
Plate 2, figure 15

Hyperammina grzybowskii DYLAZANKA 1923, pp. 65–66.— GEROCH 1960, p. 39, pl. 1, figs. 22–23; pl. 10, fig. 7.
Kalamopsis grzybowskii (Dylazanka).— HEMLEBEN and TRÖSTER 1984, p. 550, pl. 2, figs. 3–5.

In the Scaglia material only unusually small specimens have been observed.

Karreriella conversa (Grzybowski 1901)
Plate 6, figures 9–10

Gaudryina conversa GRZYBOWSKI 1901, p. 285, pl. 7, figs. 15, 16.
Plectina aff. *conversa* (Grzybowski).— HEMLEBEN and TRÖSTER 1984, p. 521, pl. 4, fig. 24.
Karreriella conversa (Grzybowski).— KAMINSKI et al. 1988, p. 196, pl. 9, figs. 17–18b.
Plectina conversa (Grzybowski).— MOULLADE et al. 1988, p. 365, pl. 9, figs. 1–3.

Elongate test with an initial trochospiral and a later biserial, slightly twisted stage, consisting of four or more pairs of chambers. Because of lacking an apertural tooth, this species, commonly referred as *Plectina conversa* has been assigned to the genus *Karreriella*.

Lituotuba lituiformis (Brady 1879)
Plate 1, figures 17–18

Trochammina lituiformis BRADY 1879, p. 59, pl. 5, fig. 16.
Lituotuba lituiformis (Brady).— CUSHMAN and JARVIS 1928, p. 90, pl. 12, fig. 15a, b.— KAMINSKI et al. 1988, p. 190, pl. 4, figs. 14–15.

Plate 4

1   *Rzehakina epigona* (Rzehak), sample BOT-1, Upper Maastrichtian, ×124.

2   *Rzehakina inclusa* (Grzybowski), sample BOT-17, Middle Campanian, ×144.

3–5   *Haplophragmium problematicum* (Neagu), sample BOT-19, lowermost Campanian, ×128.

6   *Haplophragmium problematicum* (Neagu), sample S8/8/15, Lower Santonian, ×160.

7–8   *Haplophragmium problematicum* (Neagu), sample VC-21, lowermost Campanian, ×144.

9   *Haplophragmium problematicum* (Neagu), sample VC-21, lowermost Campanian, ×1600. Detail view, aperture of specimen from figures 7–8.

10   *Haplophragmoides* cf. *walteri* (Grzybowski), sample S8/83/12, Coniacian, ×96.

11–12   *Haplophragmoides* cf. *walteri* (Grzybowski), sample S8/83/15, Lower Santonian, ×96.

13   *Haplophragmoides* cf. *concavus* (Chapman), sample S8/83/15, Lower Santonian, ×144.

14   *Haplophragmoides* cf. *perexplicatus* Krasheninnikov, sample BOT-20, Upper Santonian, ×128.

15   *Haplophragmoides* sp.1, sample S8/83/15, Lower Santonian, ×144.

16–17   *Haplophragmoides* aff. *suborbicularis* (Grzybowski), sample BOT-16, Upper Campanian, ×144.

18   *Recurvoides* sp., sample BOT-5, Upper Maastrichtian, ×128.

19–20   *Cribrostomoides* sp. 1, sample S8/83/14, Upper Coniacian, ×144.
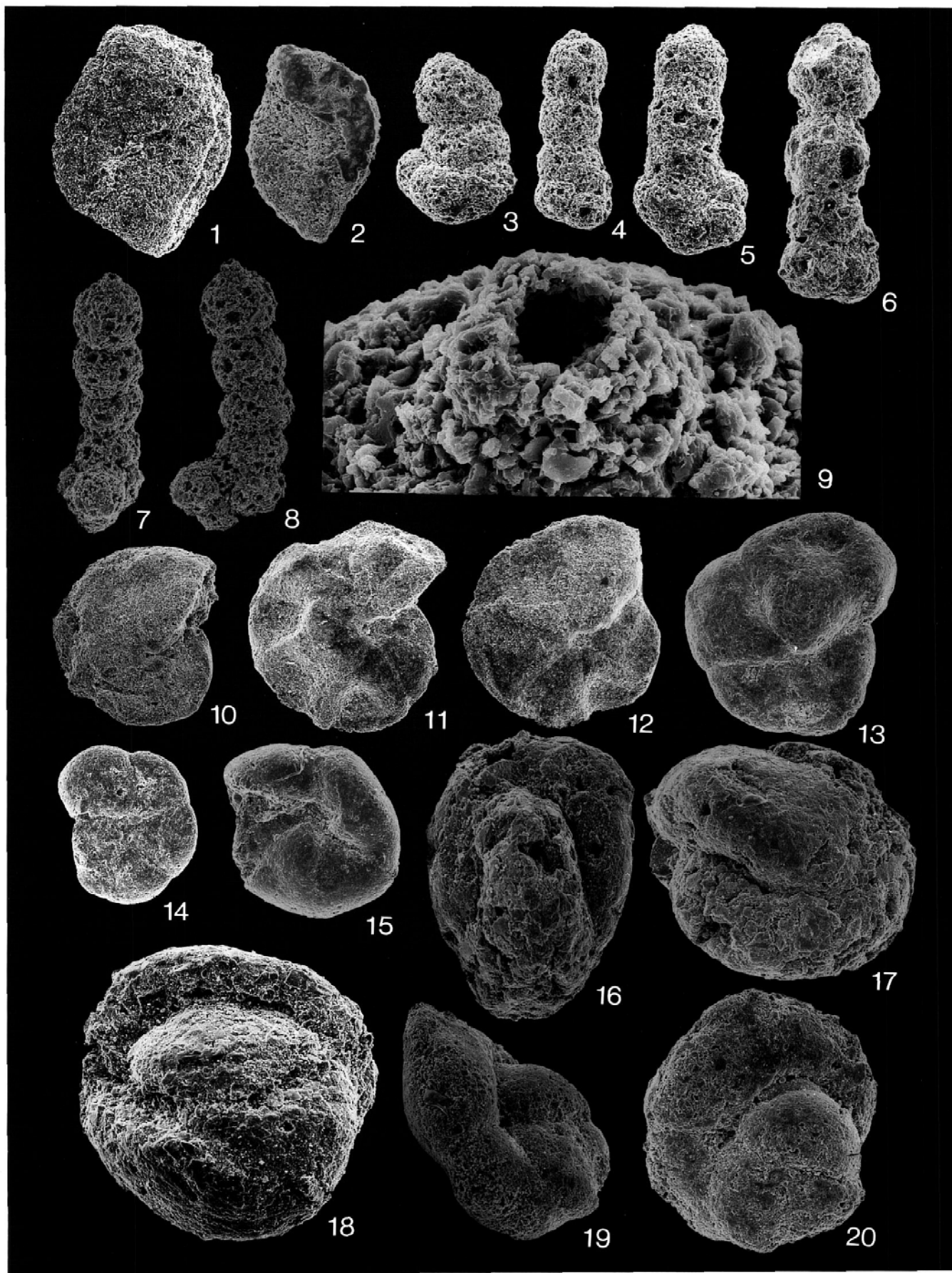
Trochamminoides lituiformis (Brady).— JURKIEWICZ 1967, pp. 65–67, pl. 3, figs. 2–3, text-fig. 12a–g

Test with irregularly coiled initial portion and an uncoiling later part. Wall coarsely agglutinated.

Remesella varians (Glaessner 1937)
Plate 6, figures 19–21

Textulariella ? varians GLAESSNER 1937, pp. 366–367, pl. 2, fig. 15.
Textulariella trinitatensis CUSHMAN and RENZ 1946, p. 23, pl. 3, figs. 1–4.
Remesella mariae VASICEK 1947, p. 246, pl. 2, fig. 14a–b.
Remesella varians (Glaessner).— BECKMANN et al. 1982, p. 118, pl. 6, figs. 37 -38.— LOEBLICH and TAPPAN 1988, p. 146, pl. 153, figs. 1–3.
Matanzia varians (Glaessner).— KAMINSKI et al. 1988, p. 196, pl. 9, fig. 14a–b, pl. 10, fig. 14.

Test finely agglutinated, consisting of ovoid, inflated chambers arranged in a trochospiral coil. Incomplete internal longitudinal partitions of the chambers are clearly visible in wettened or broken specimens.

Paratrochamminoides heteromorphus (Grzybowski 1898)
Plate 5, figure 18

Trochammina heteromorpha GRZYBOWSKI 1898, p. 286, pl. 11, fig. 16.
Trochamminoides heteromorphus (Grzybowski).— JEDNOROWSKA 1968, p. 51–52, pl. 6, figs. 1–4.

Large-sized *Paratrochamminoides* with an irregularly coiled initial part and a tendency to become linear in the last chambers.

Paratrochamminoides irregularis (White 1928)
Plate 5, figure 10

Trochamminoides irregularis WHITE 1928b, p. 307, pl. 42, fig. 1.— GLAESSNER 1937, p. 360, pl. 1, fig. 9a–b.— HANZLIKOVA 1972, p. 44, pl. 8, fig. 1.— KAMINSKI et al. 1988, p. 191, pl. 4, fig. 18.

Test streptospirally coiled with few, large, flattened chambers. Surface rough, medium to coarsely agglutinated. Test is generally compressed due to compaction.

Paratrochamminoides sp. 1
Plate 5, figures 12–13

Chambers elongated to tubular; test oval, flattened; sutures indistinct. Some of these forms exhibit similarities to the deep-sea forms *Paratrochamminoides semipellucidus* Krasheninnikov and *Paratrochamminoides corpulentus* Krasheninnikov and to the flysch-form *Trochamminoides dubius* Grzybowski.

Paratrochamminoides sp. 2
Plate 5, figures 14–16

Chambers spherical, with depressed sutures. The test shape shows similarities to the deep-sea forms *Paratrochamminoides intricatus* Krasheninnikov and *Paratrochamminoides vitreus* Krasheninnikov. In this group have been included large sized specimens with more than 10–15 chambers (similar to the flysch-form *Paratrochamminoides uviformis* (Grzybowski)).

Plate 5

1   *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), sample BOT-6, Middle Maastrichtian, ×96.

2-3   *Praecystammina (?) cf. globigerinaeformis* Krasheninnikov, sample BOT-19, Lower Campanian, ×128.

4   *Praecystammina globigerinaeformis* Krasheninnikov, sample BOT-11, Upper Campanian, ×128.

5   *Praecystammina globigerinaeformis* Krasheninnikov, sample BOT-1, Upper Maastrichtian, ×128.

6   *Praecystammina globigerinaeformis* Krasheninnikov, sample BOT-10, Lower Maastrichtian, ×360, areal aperture visible.

7   *Trochammina deformis* Grzybowski, sample VC-7, Upper Maastrichtian, ×96.

8   *Trochamminoides* cf. *dubius* (Grzybowski), sample S8/8/15, Lower Santonian, ×104.

9   *Trochamminoides* cf. *proteus* (Karrer), sample S8/8/15, Lower Santonian, ×104.

10   *Paratrochamminoides irregularis* (White), sample BOT-5, Upper Maastrichtian, ×64.

11   *Trochamminoides dubius* (Grzybowski), sample BOT-15, Upper Campanian, ×128.

12   *Paratrochamminoides* sp. 1, sample BOT-5, Upper Maastrichtian, ×96.

13   *Paratrochamminoides* sp. 1, sample BOT-15, Upper Campanian, ×128.

14   *Paratrochamminoides* sp. 2, sample BOT-19, Lower Campanian, ×128.

15   *Paratrochamminoides* sp. 2, sample BOT-15, Upper Campanian, ×128.

16   *Paratrochamminoides* sp. 2, sample BOT-11, Upper Campanian, ×128.

17   *Paratrochamminoides* sp. 3, sample S8/83/12, Coniacian, ×96.

18   *Paratrochamminoides heteromorphus* (Grzybowski), sample BOT-6, Middle Maastrichtian, ×56. Note the agglutinated planktonic foraminiferal test (*Pseudotextularia* or *Racemiguembelina*).

Paratrochamminoides sp. 3
Plate 5, figure 17

Large specimens with elongated chambers arranged in several irregular whorls.

Plectorecurvoides sp.
Test biserial, in contrast to the uniserial *Recurvoides*. In many cases a differentiation between these two genera is not possible due to the bad preservation of the material, which does not allow the distinguishing of the single chambers.

Praecystammina globigerinaeformis Krasheninnikov 1973
Plate 5, figures 4–6

Praecystammina globigerinaeformis KRASHENINNIKOV 1973, p. 211, pl. 3, fig. 1a–c, 2.— HEMLEBEN and TRÖSTER 1984, p. 521, pl. 4, fig. 8.— MOULLADE et al. 1988, p. 365, pl. 7, fig. 6.
? *Praecystammina globigerinaeformis* Krasheninnikov.— GRADST-EIN and BERGGREN 1981, p. 258, pl. 9, figs. 11–15.
? *Cystammina globigerinaeformis* (Krasheninnikov).— MILLER et al. 1982, p. 21, pl. 2, figs. 13, 17, 21.

Test very small, globigerina-like, the last whorl consists of three inflated subspherical or oval chambers; wall very finely agglutinated, glassy, smooth; aperture areal, oval.

P. globigerinaeformis is regarded as a good stratigraphic marker in the abyssal sub-CCD sequence of the Pacific and North Atlantic oceans (defines Krasheninnikov's "upper assemblage of agglutinated foraminifera" and has been used by Moullade et al. (1988) to define the *Praecystammina globigerinaeformis*

total range zone). In the Gubbio sequence a wider stratigraphic range (up to the uppermost Maastrichtian) is observed for this species. Also in DSDP Hole 543A *P. globigerinaeformis* is reported from the Maastrichtian (Hemleben and Tröster 1984). An even longer stratigraphic range (up to the Paleocene) has been observed for this species in bathyal sequences of the Central North sea area (Gradstein et al. 1988). However, these specimens from such boreal localities as the Labrador margin and the Central North Sea tend to be generally larger than the typical *P. globigerinaeformis*.

Praecystammina (?) cf. **globigerinaeformis** Krasheninnikov 1973
Plate 5, figures 2–3

Praecystammina(?) sp. cf. *globigerinaeformis* Krasheninnikov.— MOULLADE et al. 1988, p. 366, pl.7, fig. 5.

Test finely agglutinated, strongly compressed, with three slightly elongated chambers visible on each side. No aperture visible due to the strong compression. Diamater: 200–300 microns. These forms most probably represent flattened (by diagenetic compaction) specimens of *Praecystammina globigerinaeformis* Krasheninnikov.

Pseudobolivina lagenaria Krasheninnikov 1974
Plate 6, figures 3–4

Pseudobolivina lagenaria KRASHENINNIKOV 1974, pp. 639–640, pl. 5, figs. 1a–b, 2c.— MOULLADE et al. 1988, p. 366, pl.9, figs. 7–8.

Plate 6

1–2   *Pseudobolivina* cf. *munda* Krasheninnikov, sample S8/83/18, Santonian, ×152.

3   *Pseudobolivina lagenaria* Krasheninnikov, sample S8/31, Campanian, ×152.

4   *Pseudobolivina lagenaria* Krasheninnikov, sample S8/83/22, Lower Campanian, ×152

5   *Pseudobolivina* sp. 3, sample BOT-11, Upper Campanian, ×128.

6–7   *Pseudobolivina* sp. 4, sample S8/83/22, Lower Campanian, ×104.

8   *Spiroplectinata* (?) sp. 1, sample BOT-13, Upper Campanian, ×96.

9   *Karreriella conversa* (Grzybowski), sample S8/82/12, Coniacian, ×96.

10   *Karreriella conversa* (Grzybowski), sample S8/82/18, Santonian, ×96.

11   *Verneuilinoides polystrophus* (Reuss), sample BOT-3, Upper Maastrichtian, ×104.

12   *Uvigerinammina jankoi* Majzon, sample S8/83/18, Santonian, ×136.

13   *Uvigerinammina jankoi* Majzon, sample S8/83/18, Santonian, ×152.

14   *Spiroplectammina dentata* (Alth), sample BOT-A, lowermost Paleocene, ×96.

15   *Spiroplectammina* cf. *laevis* (Roemer), sample BOT-6, Middle Maastrichtian, ×112.

16–17   *Spiroplectammina israelskyi* Hillebrandt, sample BOT-6, Middle Maastrichtian, ×72.

18   *Spiroplectammina* aff. *spectabilis* (Grzybowski), sample VC-2, lowermost Paleocene, ×144.

19   *Remesella varians* (Glaessner), sample BOT-6, Middle Maastrichtian, ×96

20   *Remesella varians* (Glaessner), sample BOT-6, Middle Maastrichtian, ×144. Crushed specimen, showing longitudinal partitions of the chambers.

21   *Remesella varians* (Glaessner), sample BOT-6, Middle Maastrichtian, ×68.
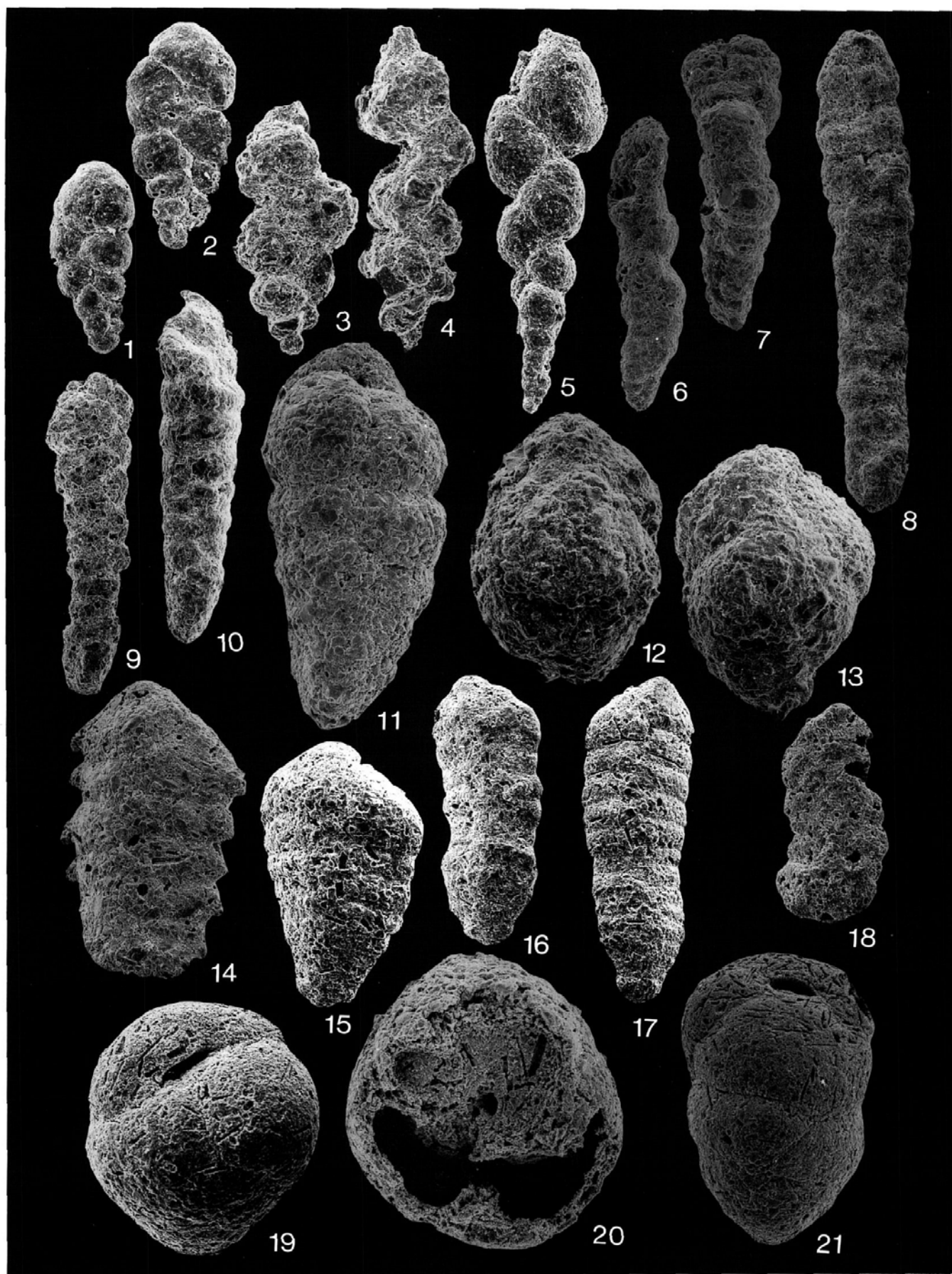
This species is characterized by its tendency to a uniserial arrangement of the last chambers and a distinct apertural neck. Specimens from the Hacho de Montejaque section are almost identical with the North Atlantic material, described by Moullade et al. (1988).

Pseudobolivina cf. *munda* Krasheninnikov 1973
Plate 6, figures 1–2

Pseudobolivina munda KRASHENINNIKOV 1973, p. 210, pl. 2, figs. 10, 11.— HEMLEBEN and TRÖSTER 1984, p. 521, pl. 4, fig. 3.— MOULLADE et al. 1988, p. 366, pl. 9, figs. 9, 10.

Narrow, wedge-shaped, elongated test. Chambers oval, elongated in the direction of the growth, slowly increasing in size as added.

Pseudobolivina sp. 3
Plate 6, figure 5

Narrow, wedge-shaped, elongated test. Chambers oval, elongated in the direction of the growth, slowly increasing in size as added. Biserial chamber arrangement twisted in direction of growth at about 90°.

Pseudobolivina sp. 4
Plate 6, figures 6–7

A *Pseudobolivina* with a distinct uniserial part; consisting of 6–7 pairs of chambers in the biserial part, up to four chambers in the uniserial part (often flattened or broken). Common species in the early Campanian of the Penibetic section. This species resembles closely *Pseudobolivina parvissima* Neagu 1970 from the Turonian of the eastern Carpathians (Romania).

Recurvoides sp.
Plate 4, figure 18

Because of the bad preservation no specific determination within the genus *Recurvoides* has been possible.

Reophax cf. *subnodulosus* Grzybowski 1898
Plate 3, figure 6

Reophax subnodulosa GRZYBOWSKI 1898, p. 279, pl. 10, figs. 17–18.— GEROCH 1960, p.122, pl. 3, fig. 11.— GEROCH and NOWAK 1984, pl. 1, fig. 4; pl. 5, fig. 7a,b.

Test consisting of numerous regular shaped chambers, slowly increasing in size as added. The connections between the chambers are broad and marked by depressed sutures. Wall finely agglutinated. In the Scaglia material only slightly bent fragments of this species have been observed.

Reophax sp. 2
Plate 3, figures 7–9

? *Reophax splendidus* Grzybowski.— JEDNOROWSKA 1968, p. 45, pl. 1, figs. 3,4.
Reophax sp. 2.— KAMINSKI et al. 1988, p. 187, pl. 3, figs. 2–3.

Test elongate, often compressed, comprised of four to five chambers which are partially embracing and gradually increasing in size. Some of these forms show some similarity to the recent species *Reophax dentaliniformis*.

Reophax sp. 3
Plate 3, figure 10

Reophax cf. *guttifer* Brady.— LABUDE 1984, p. 71, pl. 3, fig. 1.

Small, rectilinear *Reophax*, with five ovoid chambers, gradually increasing in size as added. Chambers are separated by distinct constrictions.

Reophax sp. 4
Plate 3, figure 12

A *Reophax* with elongated chambers, thin-walled, flattened. Distinct sutures between the chambers.

Reophax sp. 5
Plate 3, figure 11

Test rectilinear, formed by up to six elongated chambers; wall thin, very finely agglutinated. Specimens are generally strongly compressed.

Rhabdammina sp.
Coarsely agglutinated, rectilinear tubes with a comparatively large diameter.

Rhizammina cf. *algaeformis* Brady 1879
Plate 1, figure 1

Rhizammina algaeformis BRADY 1879, p. 39, pl. 4, figs. 16–7.
Rhizammina ex gr. *algaeformis* Brady.— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 1, fig. 6.
Rhizammina cf. *algaeformis* Brady.— LABUDE 1984, p. 67, pl. 1, fig. 2.

Irregularly curved tubes with a constant diameter, dichotomous branching.

Rhizammina indivisa Brady 1884
Plate 1, figure 13

Rhizammina indivisa BRADY 1884, p. 277, pl. 29, figs. 5–7.— GEROCH 1966, pl. 1, figs. 1–7.— GRADSTEIN and BERGGREN 1981, p. 240, pl. 1, figs. 1–3.— KAMINSKI et al. 1988, p. 183, pl. 1, figs. 10–13.
Rhizammina cf. *indivisa* Brady.— LABUDE 1984, p. 67, pl. 1, fig. 3.
Rhabdammina sp.— LABUDE 1984, pp. 66–67, pl. 1, fig. 1.

Irregularly curved tubes with a constant diameter, no branching visible. Finely agglutinated. This form is one of the most common "tube-shaped" specimens of the Gubbio material.

Rzehakina epigona (Rzehak 1895)
Plate 4, figure 1

Silicina epigona RZEHAK 1895, p. 214, pl. 6, fig. 1.
Rzehakina epigona (Rzehak).— HILTERMANN 1974, p. 36–56, pl. 5, figs. 1–44, pl. 6, figs. 1–35, 39–41, with complete synonymy.
Rzehakina epigona epigona (Rzehak).— GEROCH and NOWAK 1984, pl.3, fig. 12; pl. 5, fig. 25.

Shows a distinct stratigraphic range in flysch sequences from Campanian to Paleocene (Geroch and Nowak 1984; Kuhnt 1987). In the Gubbio sections only two specimens have been observed in Upper Campanian and Upper Maastrichtian samples.

Rzehakina inclusa (Grzybowski 1901)
Plate 4, figure 2

Spiroloculina inclusa GRZYBOWSKI 1901, p. 260, pl. 7, fig. 20.
Rzehakina epigona inclusa (Grzybowski).— GEROCH and NOWAK 1984, pl. 3, fig. 11; pl. 5, fig. 26.

Differs from *R. epigona* in its more involute character. Geroch and Nowak (1984) report a stratigraphic range of this species in the Polish Carpathians from Campanian to Paleocene. In the

Gubbio sequence *R. inclusa* has been found only rarely in the Middle Campanian to Middle Maastrichtian part of the section.

Saccammina grzybowskii (Schubert 1901)
Plate 2, figure 3

Reophax difflugiformis Brady.— GRZYBOWSKI 1898, p. 255, pl. 10, figs. 11–12.— GRZYBOWSKI 1901, p. 266, pl. 7, fig. 4.
Reophax grzybowskii SCHUBERT 1901, p. 20, pl. 1, fig. 13.
Pelosina complanata FRANKE 1912, pl. 3, fig. 1. a–b.— CUSHMAN and RENZ 1946, p. 13, pl. 1, fig. 8.
Saccammina grzybowskii (Schubert).— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 1, fig. 14.

Differs from *S. placenta* in a smaller size, a more coarse agglutination, and having the aperture generally at the periphery, which suggests, that the test may not have been originally spherical.

Saccammina placenta (Grzybowski 1898)
Plate 2, figure 1

Reophax placenta GRZYBOWSKI 1898, pp. 276–277, pl. 10, figs. 9–10.
Saccammina placenta (Grzybowski).— KAMINSKI et al. 1988, p. 183, pl. 2, fig. 9.

Although not mentioned by Grzybowski (1898), this species has been shown to possess an aperture on a minute neck (Geroch 1960), thus belonging to the genus *Saccammina* and not to *Psammosphaera* as suggested by Elser (1982).

Differs from *Saccammina complanata* in its larger size, generally more finely agglutinated test, and an aperture, located at any position on the test surface. Thus *S. placenta* may have been originally more spherical.

Saccammina cf. *placenta* (Grzybowski 1898)
Plate 2, figure 2

Saccammina complanata (Franke).— KRASHENINNIKOV 1974, p. 644, pl. 7, fig. 10a, b.

Differs from *S. placenta* in its small size and coarser agglutination. Differs from *S. grzybowskii* in having its aperture anywhere on the test.

Saccammina sphaerica Sars 1872
Plate 2, figures 8–9

Saccammina sphaerica SARS 1872, p. 250.— CARPENTER 1875, p. 532, pl. 272a–c.— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 1, fig. 1.— MOULLADE et al. 1988, p. 366, pl. 2, fig. 12.
Saccammina complanata (Franke).— KRASHENINNIKOV 1974, p. 644, pl. 7, fig. 10a, b.
Saccammina cf. *sphaerica* Sars.— LABUDE 1984, p. 68, pl. 1, fig. 5.

Test sphaerical or slightly irregular ovoid with a single aperture; wall thin, rough.

Saccorhiza cf. *ramosa* (Brady 1879)
Plate 2, figures 6–7

Hyperammina ramosa BRADY 1879, p. 33, pl. 3, figs. 14–15.
Saccorhiza ramosa (Brady).— BARKER 1960, pl. 23, figs. 15–19.— SCHRÖDER 1986, p. 35, pl. 7, fig. 1 a–d.
Saccorhiza cf. *ramosa* (Brady).— LABUDE 1984, p. 68, pl. 4, fig. 4.

Test consisting of a round to ovoid proloculus and a long, in some specimens branching tube, which has a considerably smaller diameter than the proloculus. Small.

Spiroplectammina dentata (Alth 1850)
Plate 6, figure 14

Textularia dentata ALTH 1850, p. 262, pl. 13, fig. 13.
Spiroplectammina dentata (Alth).— MORGIEL and OLSZEWSKA 1981, p. 14, pl. 4, fig. 4.— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 3, fig. 20.

This species is characterized by its dentate outline and the straight sutures.

Spiroplectammina israelskyi Hillebrandt 1962
Plate 6, figures 16–17

Spiroplectammina sp. A, ISRAELSKY 1951, p. 13, pl. 3, figs. 17–19.
Spiroplectammina israelskyi HILLEBRANDT 1962, p. 30 -31, pl. 1, figs. 5a,b, 6a,b, 7a,b.
? *Spiroplectammina* cf. *semicomplanata* (Carsey).— BECKMANN 1978, p. 769, pl. 1. figs. 7, 13.
Spiroplectammina sp.— LABUDE 1984, p. 73, pl. 3, fig. 5.

Planispirally coiled initial part of variable size, with a large, elongate, biserial part, which possesses characteristic constrictions. Chambers increase very slowly in size as added. Coarsely agglutinated. Large size (up to a length of more than 800µm).

Spiroplectammina cf. *laevis* (Roemer 1842)
Plate 6, figure 15

Textularia laevis ROEMER 1842, p. 97, pl. 15, fig. 17.
Spiroplectammina laevis (Roemer).— CUSHMAN 1932b, p. 87, pl. 11, fig. 2a,b.
Spiroplectammina laevis (Roemer) var. *cretosa* CUSHMAN 1932b, pp. 87–88, pl. 11, fig. 3a,b.
Spiroplectammina cretosa Cushman.— HANZLIKOVA 1972, p. 47, pl. 10, fig. 9.

Under this species all varieties of *Spiroplectammina* are lumped, which have a strongly tapering test and a regular (no dentate) outline. Due to the relatively bad preservation of *Spirolectammina* in the HCl residues the shape of the sutures and apertural features cannot be clearly observed. Specimens from the Gubbio sections generally show a relatively coarsely agglutinated wall.

Spiroplectammina aff. *spectabilis* (Grzybowski 1898)
Plate 6, figure 18

Spiroplecta spectabilis GRZYBOWSKI 1898, p. 293, pl. 12, fig. 12.
Spiroplectammina spectabilis (Grzybowski).— HILTERMANN 1972, pp. 43–61, pl. 1, 2 (with synonomy).
Spiroplectammina spectabilis (Grzybowski).— KAMINSKI 1984, pl. 1, 2 (with synonymy).

The rare specimens observed in the Maastrichtian of the Bottaccione section and more common in the lowermost Paleocene of the Contessa section differ from *S. israelskyi* in its smaller size, in possessing a thinner, more fragile test and an acute peripheral margin. Several megalospheric specimens show an initial spiral part of approximately the some width as the biserial part.

Spiroplectinata(?) sp. 1
Plate 6, figure 8

Similar to *Karreriella conversa*, but with a uniserial chamber arrangement in the upper portion of the test. Uniserial part consisting of up to 6 chambers.

Subreophax guttifer (Brady 1881)
Plate 3, figures 2–3

Reophax guttifer BRADY 1881, p. 49.— BARKER 1960, pl. 31, figs. 10–15.— SCHRÖDER 1986, p. 44, pl. 15, figs. 12, 13.

Differs from *Hormosinella* cf. *distans* in its larger size, coarser agglutination, thicker connections between the chambers and in possessing more chambers. Because of the strong morphological similarities this form has been assigned to the recent species *S. guttifer*.

Subreophax scalaris (Grzybowski 1896)
Plate 3, figures 4–5

Reophax guttifera Brady var. *scalaria* GRZYBOWSKI 1896, p. 277, pl. 8, fig. 26.
Reophax scalaris Grzybowski.— HEMLEBEN and TRÖSTER 1984, p. 521, pl. 2, figs. 10–11.
Placopsilina sp.— LABUDE 1984, p. 72–73, pl. 3, fig. 4.
Subreophax scalaria (Grzybowski).— KAMINSKI et al. 1988, p. 187, pl. 2, figs. 16–17.

Test comprised of numerous disc-shaped, partially embracing chambers, slowly increasing in size. The test is not rectilinear, but bent or curved. Complete specimens as in plate 3, fig. 4 show an enlarged proloculus.

Subreophax aff. **splendidus** (Grzybowski 1898)
Plate 3, figures 15–16

Reophax splendida GRZYBOWSKI 1898, p. 278, pl. 10, fig. 16.
Reophax splendidus Grzybowski.— NEAGU 1970, p. 36, pl. 2, fig. 5.— BUTT 1981, pl. 1, fig. N.

Test large, bent or curved; wall coarsely agglutinated; chambers irregularly ovoid, flattened. Aperture small, terminal, with a very short protruding neck. Outline often irregular due to strong compression.

Differs from *S. scalaris* in possessing fewer and larger chambers, separated by distinctly depressed sutures, and a more coarsely agglutinated wall.

Because Grzybowski's original description and figure is only based on a three-chambered fragment, the species needs a more exact definition based on better preserved topotypic material.

Subreophax sp. 1
Plate 3, figure 14

Resembles *Subreophax scalaris* in its bent or curved test, but differs from typical specimens of this species in having more elongated chambers.

Tolypammina(?) sp. 1
Plate 1, figure 15

Tolypammina sp. 1.— LABUDE 1984, p. 70, pl. 2, fig. 3.

Test consisting of a tubular chamber, which is coiled in regular loops, resembling a cloverleaf in shape. Wall thin, smooth, very finely agglutinated, glassy. The generic assignment is doubtful, since the test appears to be free and not attached as in *Tolypammina*. The test morphology shows strong similarities to the recent superfamily Komokiacea Tendal and Hessler 1977.

Tolypammina(?) sp. 2
Plate 1, figure 16

Tolypammina sp. 1, LABUDE 1984, p. 70, pl. 2, fig. 4.

Tests with an ovoid proloculus and an irregular loosely coiled tubular chamber. Finely agglutinated. Abundant in the Gubbio material. Differs from *Glomospira* (*Tolypammina?*) *irregularis* in its loose coiling with free space between the single whorls and from *Tolypammina* (?) sp. 1 in its more irregular coiling.

Tolypammina(?) sp. 3
Test coiled in trochospirals, direction of coiling changing by 90° every two to four whorls.

Trochammina deformis Grzybowski 1898
Plate 5, figure 7

Trochammina deformis GRZYBOWSKI 1898, p. 288, pl. 11, figs. 20–22.

Four to six chambers in the last whorl; sutures depressed; peripherie rounded and lobulate. Wall coarsely agglutinated. Often distorted by compression.

Trochamminoides dubius (Grzybowski 1898)
Plate 5, figure 8

Ammodiscus dubius GRZYBOWSKI 1901, p. 274, pl. 8, figs. 12, 14.
?*Ammodiscus septatus* GRZYBOWSKI 1898, p. 283, pl. 11, fig. 1.
Ammodiscus cf. *septatus* Grzybowski.— JURKIEWICZ 1967, p. 58, pl. 2, fig. 22.
Trochamminoides velascoensis Cushman.— HANZLIKOVA 1972, p. 44, pl. 8, fig. 3.
Trochamminoides dubius (Grzybowski).— KAMINSKI et al. 1988, p. 191, pl. 4, figs. 16–17.

Irregular planispiral coil. Chambers strongly elongated, sutures indistinct. Wall finely agglutinated, surface smooth.

Trochamminoides cf. **dubius** (Grzybowski 1898)
Plate 5, figure 9

Irregular planispiral coil. Chambers strongly elongated, four chambers in the last whorl. Wall thick, relative coarsely agglutinated. Surface rough.

Differs from typical *T. dubius* in its rough surface and its thicker and more coarsely agglutinated walls.

Trochamminoides cf. **proteus** (Karrer 1866)
Plate 5, figure 10

Trochammina proteus KARRER 1866, pl. 1, fig. 8.
Trochamminoides proteus (Karrer).— WHITE 1928b, p. 308, pl. 42, fig. 2.— SAMUEL 1977, pp. 46–47, pl. 5, fig. 5a–b.— KAMINSKI et al. 1988, p. 192, pl. 4, fig. 20.

Test irregular planispirally to very low trochospitally coiled. Wall thick and coarsely agglutinated. Chambers elongate. Differs from typical specimens of *T. proteus* in having fewer and more elongated chambers. Constrictions between the chambers are less distinct.

Turritellella shoneana (Siddall 1878)
Plate 1, figure 14

Trochammina shoneana SIDDALL 1878, p. 46, figs. 1, 2.
Ammodiscus shoneanus Siddall.— BRADY 1881, p. 335.
not *Ammodiscus shoneanus* Siddall.— GRZYBOWSKI 1896, p. 281, pl. 8, fig. 46.
Turritellella shoneana (Siddall).— POKORNY 1953, p. 8, text-fig. 2.— BARKER 1960, p. 78, pl. 38, figs. 17–19.— HUSS 1966, p. 20, pl. 3, figs. 14–16.

Tubular test in a characteristic spiral coiling. The specimen figured by Grzybowski (1896) is chambered and probably corresponds to fragments of a *Karreriella* (Liszka and Liszkowa 1981). The specimen from the Middle Maastrichtian of Gubbio corresponds closely to the original description of the recent species *T. shoneana* as given by Siddall (1878): Test spiral, composed of a single series of close convolutions of a non-septate tube on a linear axis. Aperture terminal, large, rounded, somewhat constricted.

Uvigerinammina jankoi Majzon 1943
Plate 6, figures 12–13

Uvigerinammina jankoi MAJZON 1943, p. 158, pl. 2, figs. 15a, b.— GEROCH 1957, pp. 238–244, pl. 14, 15.— KRASHENINNIKOV 1974, p. 642, pl. 6, figs. 9a, b, 10a.— KRASHENINNIKOV and PFLAUMANN 1978, p. 569, pl. 3, figs. 12, 13.— HEMLEBEN and TRÖSTER 1984, p. 522, pl. 4, fig. 20.— GEROCH and NOWAK 1984, pl. 2, fig. 10; pl. 7, figs. 11–12.— MOULLADE et al. 1988, p. 367, pl. 10, figs. 1–6.

A common species in flysch-type agglutinated foraminiferal assemblages. Similar to the material from the North Atlantic DSDP/ODP Sites 603B and 641A (Moullade et al. 1988) forms with a subcircular section and elongated chambers co-exist with tests with a distinctly tricarinate outline. Recorded from Cenomanian to Maastrichtian with a distinct acme from Turonian to lower Campanian. The species is very rare in the Gubbio Sections, but abundant in the Hacho de Montejaque section. This difference may be due to enhanced fine-grained detrital input (clay minerals) in the marly sequence of the latter section.

Verneuilinoides polystrophus (Reuss 1846)
Plate 6, figure 11

Bulimina polystropha REUSS 1846, p. 109, pl. 24, fig. 53.
Verneuilina polystropha (Reuss).— CUSHMAN and JARVIS 1932, p. 15, pl. 4, fig. 3.
Verneuilinoides polystrophus (Reuss).— HANZLIKOVA 1972, p. 54, pl. 13, fig. 7.— KAMINSKI et al. 1988, p. 194, pl. 8, fig. 8.

Initial part of the test multiserial or trochospiral; final part triserial, consisiting of up to 4 sets of inflated chambers. Aperture formed by an interiomarginal arch. Differs from *Karreriella* in having an interiomarginal aperture.

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