UTRECHT MICROPALEONTOLOGICAL BULLETINS

JOSHUA R. SETIAWAN

FORAMINIFERA AND MICROFACIES OF THE TYPE PRIABONIAN

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Chapter I

INTRODUCTION

I.1. PURPOSE OF THE INVESTIGATION AND OUTLINE OF THE RESULTS

The Priabonian is generally recognized and accepted as a stage name for the uppermost Eocene. The name is derived from the small village of Priabona in the North Italian province of Vicenza (fig. 1). Since the underlying and overlying stages of the idealized chronostratigraphic scale are based on sections in completely different sedimentation areas in northwest Europe which are remote from each other and from Priabona, the correlation between the type sections, especially at the Eocene-Oligocene boundary has been a subject of much discussion.

The predominantly carbonate facies of the Priabonian deposits contain abundant larger foraminifera, and were therefore of great interest to paleontologists at the beginning of the 20th century. Unfortunately the groups represented belong to poorly defined lineages without distinct or sufficiently well-known evolutionary trends. In addition, the scarcity of planktonic organisms means that the type Priabonian is not very promising as a basis for establishing modern biostratigraphic correlations.

The primary object of this study is to provide an illustrated record of the smaller foraminifera, both benthonic and planktonic. The widest possible range of habitats was obtained by investigating the contents of three sections: the Buco della Rana section, thought to lie close to the Late Eocene shallow carbonate platform; the off-shore Bressana section; and the Priabona section, paleogeographically situated in an intermediate position on the slope between platform and off-shore area. An additional study has been carried out involving microfacies analysis of the carbonates and quantitative investigations of the benthonic faunas from intercalated marls. The purpose of this study was to obtain a better appreciation of the environments of the deposition and a correct biostratigraphic correlation of the three sections.

The original intention was to give a thorough account of biometrical data on the larger foraminifera, but this had to be restricted to a detailed study of certain assemblages of the Discocyclinidae.

Despite the extensive documentation of the micropaleontological contents of the type Priabonian presented here, the data do not provide sufficient information for delimiting this stage in interregional correlations. Nor do the larger foraminiferal species of *Asterocyclina* and *Discocyclina* give much opportunity for correlation of carbonate facies. Although there are reasonable indications as to which calcareous nannoplankton zones (Verhallen & Romein, see appendix) and to a lesser degree which planktonic foraminifera zones, are represented in the sections, the lower and upper limits of the Priabonian remain open in these zonations. This comes about because at the base of the type section there is a gap in the marine record as represented by basalt flows; furthermore it is impossible to use the top part of the section

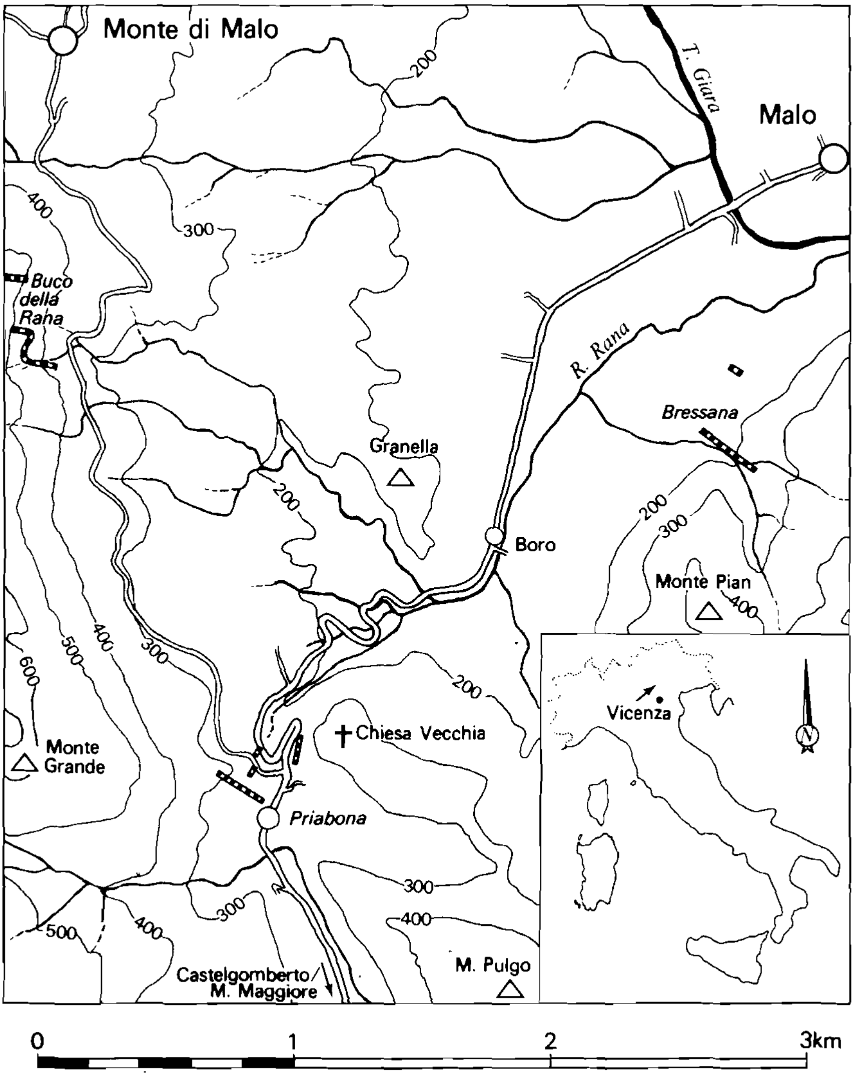

Fig. 1 The type-area of the Priabonian.

for biostratigraphic correlation because of the gradual change into the algal facies of the Castelgomberto Limestone Formation which is generally assigned to the Oligocene.

I.2. HISTORICAL REVIEW

The uniquely fossiliferous deposits around Priabona have attracted the attention of paleontologists and geologists for more than a century. Suess (1868) is generally thought to have given the first detailed description of the strata around and at Priabona. We summarize the following succession from top to bottom, as given by Suess:

7. Marls with abundant bryozoan remains
6. Rather indurate, blue, nodular beds
5. Blue marl with less abundant "*Orbitulinen*" but with abundant *Operculina ammonea*
4. Marls with "*Orbitulina*", echinids and *Turritella*
3. Thick limestones with echinids
2. Some limestone layers with *Cerithium giganteum*, difficult to separate from the underlying
1. Basaltic tuff, full of pebbles, with *Anomia*, oyster fragments and remnants of possibly *Halitherium* bones.

According to Suess the "Priabona Group" (= Formation) included only units 3 to 6. He dated the succession as being younger than that exposed at Biarritz, but his opinion was based mainly on the regional lithological sequence.

Using Suess' materials Gümbel (1868) described several species of orbitoidal larger foraminifera from Priabona and Granella: *Discocylina ephippium*, *D. aspera* n.sp., *D. applanata* n.sp., *Actinocyclina tenuicostata* n.sp., *Asterocyclina stella* n.sp. and *A. priabonensis* n.sp.

In 1893, Munier Chalmas and de Lapparent defined the Priabonian Stage formally (p. 477, 479): "Pour éviter toute discussion et toute confusion nous chercherons dans la région méditerranéenne un equivalent nummulitique de l'Eocène supérieur du Nord. Du nom de Priabona dans les Colli Berici, où les couches de l'Eocène Supérieur prennent un beau développement, nous tirerons le nom de Priabonien . . ."

"Le Priabonien des Colli Berici présente la constitution suivante:

1. Assises de la Granella (Italie) à formes très voisines des *Cerithium plicatum*, *Cer. conjunctum*, *Cer. diaboli*, *Bayania semidecussata*
2. Groupe des couches a *Orbitoides* de Priabona, caracterisées par *Ostrea brongniarti*, *Spondylus cisalpinus*, *Leiopedina tallavignesi*, *Echinanthus scutella*, *Schizaster lucidus*, *Metalia lonigensis*, *Euspatangus ornatus*
3. Marnes de Brendola passant à l'Oligocène et caractérisées par *Spondylus*

cisalpinus, Ostrea brongniarti, Clavulina szaboi, Nummulites sub-tournoueri".

It should be noted that Munier Chalmas and de Lapparent indicated a relatively precise type locality for the stage (Priabona – even though this village is not in the Colli Berici). They also sowed the seeds of future confusion by mentioning in the same breath the localities Granella and Brendola; the first quite close to Priabona, the latter, however, at a considerable distance and representing a different sedimentary environment. Correlations with various localities elsewhere were based, as was normal in those days, on macrofossils, mainly pelecypods, gastropods and echinids.

They also suggested a three-fold division; the lower portion exposed at Granella, the middle at Priabona and the top at Brendola in the Colli Berici. This trilogy became established through the widely used and authoritative treatises of Haug (1907, 1908–1911), Gignoux (1950), Fabiani (1952), Azzaroli & Cita (1967), and the Lexique Stratigraphique International (1956). Fabiani (1915, 1952) equated this division with a Lower, Middle and Upper Priabonian, at the same time interpreting the sequence as the expression of a transgression in the basal portion, with brackish influences, followed by an open marine middle part and ending with a regressive trend.

Numerous authors have described the fossil contents of the Priabonian in or near its type area, including deposits exposed in the Colli Berici. An important monograph was published by Oppenheim (1901), illustrating a large number of macrofossils and listing (without illustrations) a number of foraminifera: *Nummulites intermedius, N. fichteli, N. veronensis* n.sp., *N. bouillei, Assilina madaraszi, Orthophragmina ephippium, O. applanata, O. tenuicostata, O. stellata, O. priabonensis.* The benthonic smaller foraminifera include *Clavulina szaboi, Truncatulina dutemplei, T. propinqua, T. granosa,* and the planktonics *Globigerina bulloides* and *G. triloba.* Oppenheim is possibly the only author of importance to favour an Oligocene age for the Priabonian.

In the twentieth century paleontologists' attention has been increasingly drawn towards the rich microfossil fauna, in particular the larger foraminifera. Fabiani (1915) was probably the first to suggest a stratigraphic distribution of various taxa in the succession: the Middle Priabonian with *Orthophragmina* (= *Discocyclina*) *sella, O. fortisi, Nummulites fabianii* and *N. striata;* the upper part ("Bryozoa Beds") with *Orthophragmina* (= *Actinocyclina*) *radians* and *N. fabianii.*

Douvillé (1922) listed a number of larger foraminifera from the Priabona area, but it was not until 1954 that a more systematic treatment of the *Discocyclina* and *Asterocyclina* of the Priabonian was published by Schweighäuser as a part of a monograph of the Eocene of the Vicenza Province. Although the term Priabonian was used by this author, no fossils from the actual type section at Priabona were taken into account. Most of his material was derived from several localities in the Colli Berici, for which a two-fold division of the Priabonian was applied: a lower part consisting of blue marls including *Nummulites fabianii* and *Discocyclina augustae, Spiroclypeus,* several *Asterocyclina* and *Actinocyclina;* and an upper part with abundant *Discocyclina, Pellatispira* and small, smooth *Nummulites.*

The first serious discussion of the position and boundaries of the Priabonian as a stage, and of its type-section and reference sections, was presented by Cita and Piccoli on the occasion of the Colloque sur le Paléogène in Bordeaux 1962 (published 1964). In that paper they raised the question of which part the Upper Eocene is represented by the Priabonian. In their view the Priabonian represented the very latest part of the series; the boundary with the Oligocene was supposed to be present somewhere near the top of the type-section, possibly within the Bryozoan marls.

The Colloque sur l'Eocène, held in Paris in 1968, which included an excursion to Priabona, led to a number of detailed studies on various aspects of the fauna and flora of the section at Priabona and of several sections considered to be "reference sections" or "para-stratotypes". Piccoli & Massari Degasperi (1968) published a paper on the molluscs from the immediate vicinity of Priabona (essentially the same section as studied in this paper). Hardenbol (1968) published a preliminary paper on the results of his study of larger en smaller foraminifera of the Priabona section and some sections in the immediate vicinity. In this paper the Priabona section was described as being nearly as complete as could be found anywhere in the vicinity, and therefore the type section for the stage was chosen at Priabona itself. This proposal was duly accepted by the congress and published. The localities Granella, Ghenderle (= Bressana in our paper), Brendola, Mossano and Possagno were added as reference-sections (Cita, 1969).

An agreement was also reached on the stratigraphical position of the stage Priabonian. It is equivalent to the entire post-Lutetian Upper Eocene and corresponds with the *Nummulites fabianii* s.l. Zone, with the *Globigerapsis semiinvoluta, Globorotalia cerroazulensis* and *Globigerina gortanii* Zones in the planktonic foraminiferal biostratigraphy, and with the upper part of the *Discoaster tani nodifera* Zone and the *Isthmolithus recurvus* Zone of the nannoplankton zonation (Cita, 1969; Colloque sur l'Eocène, proposition no. 6).

Since 1969 little news has reached us about the type Priabonian. A study on discocyclinids has been carried out by Sirotti (1978).

I.3. GEOLOGICAL SETTING

The "linea di Schio" (= "Vicenza fault" De Boer, 1963) is one of the most important tectonic lines in the Vincentinian Alps. Near Malo this NNW-SSE fault is accompanied by a second, more or less parallel tectonic line (fig. 2): the Malo fault (De Boer, 1963). This direction is widespread in the whole area; most of the faults or the joints measured show it. N-S faults also occur; these resulted from shearing forces during movements of a western and an

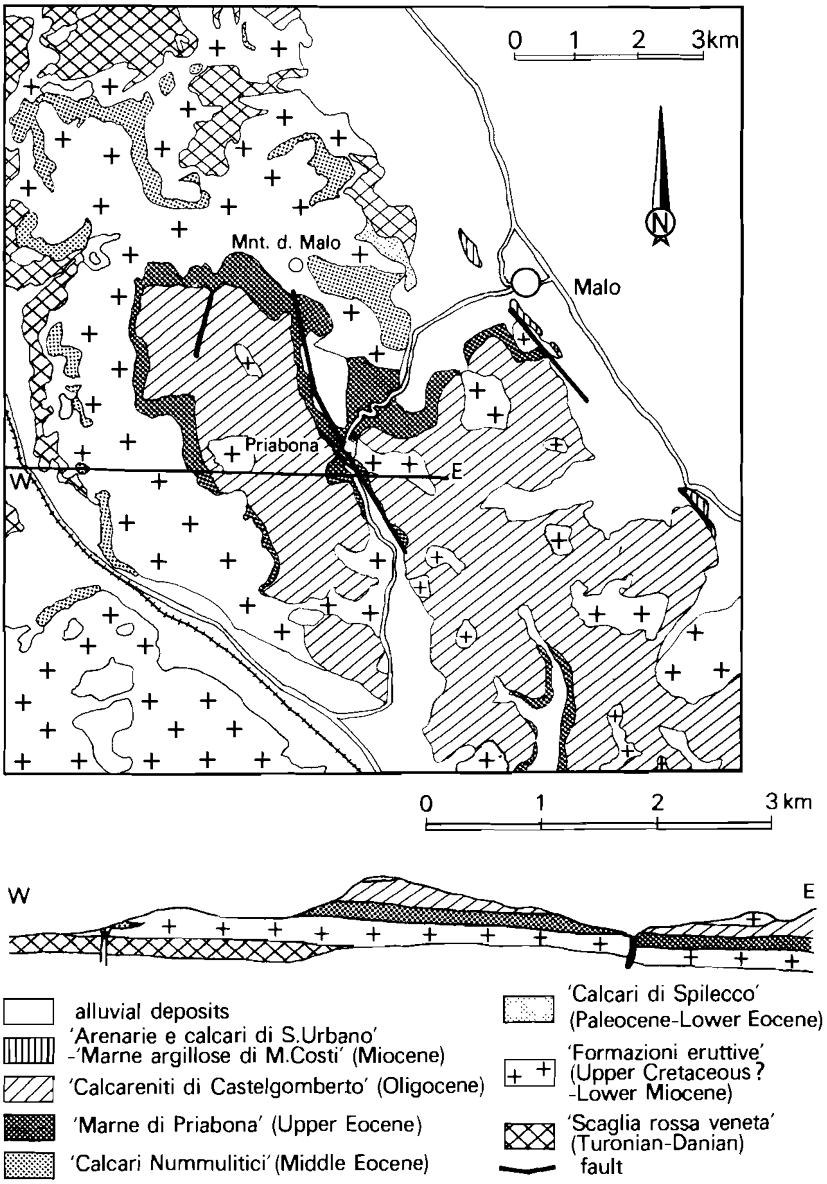

Fig. 2 Geological map and east-west cross section of the Malo area (redrawn from sheets 49 (Verona) and 37 (Schio) geological maps 1 : 100,000).

eastern block (De Boer, 1963). In the opinion of De Boer such a N-S direction should be found in the area halfway between Malo and Monte di Malo.

Vegetation and tectonic complications often obscure the geological setting in the neighbourhood of the studied sections. The assumedly underlying deposits crop out near Calcara, a quarry about 1.5 km to the SW of Malo. The lower part is formed by extremely badly exposed limestone rich in larger *Nummulites* (with a diameter up to 1.5 cm) and *Alveolina*. Above these strata, cross-laminated sand, horizontally laminated sand, sandy limestone and bedded limestone are exposed from bottom to top in the quarry (situation June 1979). The larger *Nummulites* as well as planktonic foraminifera in the bedded limestone suggest a Middle Eocene age ("Calcari Nummulitici"). No direct contact with the studied strata has been recognized.

The deposits overlying the formations assigned to the Priabonian are generally considered as being Oligocene ("Calcareniti di Castelgomberto"); they are rich in algae and debris of other sessile organisms. These strata are very thick in all three sections investigated. Their lowermost part will be included in this study.

I.4. ACKNOWLEDGEMENTS

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I am extremely grateful to E. Flügel (Erlangen), H. Hagn (Munich) and Mrs. Y. Le Calvez (Paris) who helped me by discussing various aspects and by examining my material.

I am indebted to A. J. T. Romein and P. J. J. M. Verhallen for their contributions relating to calcareous nannoplankton, and to G. J. van der Zwaan for discussing the paleoecological interpretations of benthonic foraminifera. The quantitative analyses were carried out using computer programs compiled by M. M. Drooger.

J. de Groot and his staff prepared the thin sections; G. J. van 't Veld, G. C. Ittmann and C. W. van de Dood supplied wash-residues of samples; drawings were provided by P. Hoonhout, T. van Hinte and A. van Doorn; W. de Hartog and J. A. Schiet took charge of the photographic work.

I should also like to thank Miss S. M. McNab for linguistic advice.

The financial support given by the Netherlands Organization for the Advancement of Pure Research (ZWO) during the years 1980, 1981 and 1982 is gratefully acknowledged. Stichting Molengraaff-fonds is thanked for providing travel-grants in 1979.

This study is dedicated to my wife Imanda and my son Daniel.

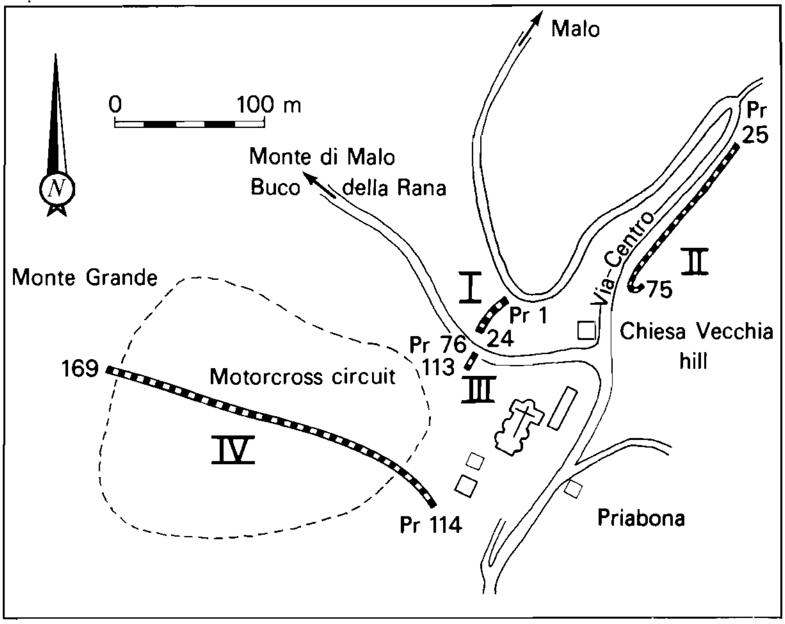


Fig. 3 Location of outcrops and samples at Priabona.

Chapter II

SECTION PRIABONA

II.1. GENERAL DESCRIPTION

Our section Priabona covers a total sediment thickness of about 80 m and is composed of four exposures. The four successive outcrop units wil be described separately. Their geographical positions are indicated in figures 1, 3 and 4; a composite lithostratigraphic column is depicted in figure 5. The strata show a gentle dip of 3 to 6 degrees to the north-east, except those of outcrop II which dip about 10 degrees to the south.

Outcrop I

This lowest outcrop is exposed directly north of Priabona on the slope above the road from Priabona to Malo and below the road from Priabona to Monte di Malo (figs. 3, 4). It is at least partly identical to the sections studied by previous authors (Hardenbol 1968, Piccoli and Massari Degasperi 1968, Sirotti 1978).

The following lithostratigraphic units are exposed from bottom to top.

a. Basaltic conglomerates (estimated thickness about 3 m). These partly weathered deposits are composed of mostly rounded, rather tightly packed basaltic components with a grain-size ranging from coarse sand to pebbles of up to 3 cm in diameter. Some tuffaceous gravels are present. In the uppermost part, which shows indications of bioturbation, the matrix is clayey. Here, we found some oyster fragments and carbonized plant remains. The basaltic components show a decrease in grain-size in the upward direction.

b. Nodular, brittle limestone (thickness about 1.5 m), greyish light brown in colour. The contact with the underlying conglomerate is visible near a spring, at which place we found some gastropods and pelecypods.

c. Massive to nodular, poorly stratified, indurated limestones, light to middle dark greyish brown in colour. Total thickness about 9.5 m. The nodular aspect is partly due to large horizontal burrows which are more or less concentrated at certain levels with slightly bedded limestone in between. This lithological unit is poorly exposed on the vegetated, steep slope. The uppermost reaches and the contact with the overlying strata containing *Discocyclina,* are much better exposed in recent, relatively unweathered exposures along the main road in the village of Priabona.

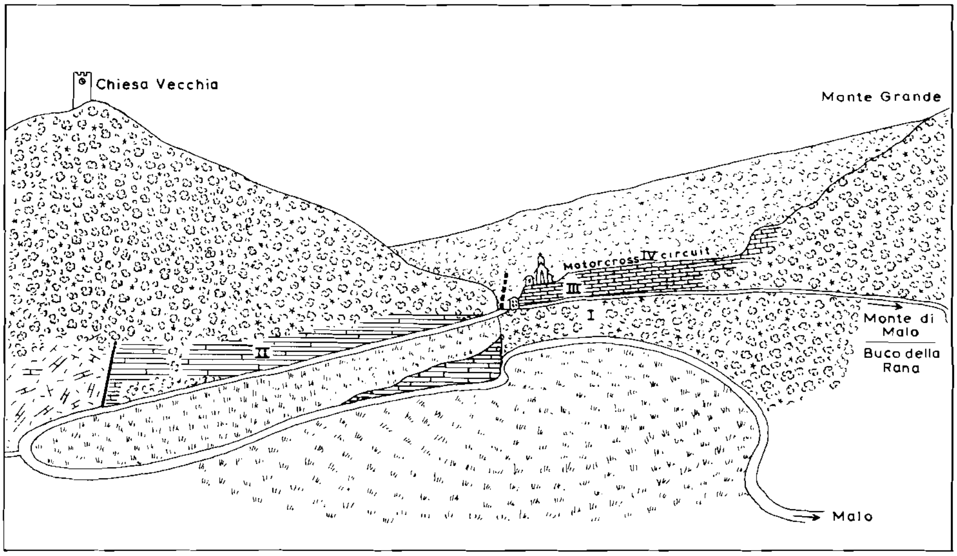


Fig. 4 Priabona as seen from NNE, showing the position of major outcrops.

Outcrop II: Via Centro

This outcrop along the main road starts at a fault, situated about 10 m south of the hairpin curve near the village entrance, and continues to the foot of Chiesa Vecchia hill just before the side road to Monte di Malo (fig. 3). The strata are continuously exposed and easily accessible. They show a total thickness of about 21 m. The relative stratigraphical position of outcrops I and II is based on the presence of abundant *Discocyclina* at corresponding levels. Because of the recent origin of this exposure, previous authors have not taken this stratigraphic segment into account in the same way.

The following lithostratigraphic units are exposed from bottom to top.

a. Relatively indurate, nodular to somewhat stratified limestones of middle dark greyish brown colour. The thickness is about 8.8 m. This unit is comparable to unit c of the first exposure.

b. Relatively brittle, nodular limestone, middle dark greyish brown in colour; thickness about 8.7 m. Thin, mostly irregular and discontinuous intercalations of clayey-silty material are widespread. This unit is characterized by abundant larger foraminifera, especially *Discocyclina* and *Nummulites.* Isolated specimens can easily be collected from two silty marl layers. Larger foraminifera decrease conspicuously in abundance in the upper three metres. Frequent pyrite concretions are another characteristic constituent of this unit. In the upper part, a somewhat indurate layer of about 90 cm thickness contains a level rich in gastropods.

c. An alternation of bedded to somewhat nodular limestones and silty marl layers of middle dark greyish brown colour and a total thickness of about 3.5 m. Generally the limestone-beds show a lighter colour than the somewhat softer layers. Although larger foraminifera are present, they are not an important part of the total faunal content. Only in the uppermost of this unit larger foraminifera are frequent again. They often occur in nodules that consist almost entirely of foraminiferal tests, showing orientations parallel to the outline of the nodules. A badly exposed, bedded limestone above this unit, on the slope of Chiesa Vecchia Hill, can be correlated to our exposure III along the road to Monte di Malo.

Outcrop III: road to Monte di Malo

This outcrop unit is situated along and mainly above the road to Monte di Malo, about 40 m from the road junction with the Via Centro of Priabona (fig. 3). The lithology and faunal contents of the lowermost two metres of this exposure correspond to the levels rich in larger foraminifera of unit IIc. This part was only locally accessible below road level. From road level to the top of the very steep slope, the strata are better exposed, showing the following lithological units:

a. Bedded limestones with thin silty marl layers in between (thickness about 3 m), light greyish brown in colour. Larger foraminifera are common, but less frequent than in outcrop II. The average thickness of the limestone beds is about 25 cm and of the intercalated silty marl layers about 5 cm.

b. Bedded limestones with irregular, discontinuous intercalations of somewhat clayey layers and a total thickness of about 9.25 m. Most of the indurate beds reveal loadcasts at their lower bedding-planes. In the lower reaches, there are two carbonate beds with a thickness of about 30 cm, showing thin concentrations of mollusc-shells in their lowermost part. Larger foraminifera are less abundant than in the underlying lithologic unit IIIa.

c. Well- to wavy-bedded limestones, alternating with thin silty marl layers and a thickness of about 3.7 m. This unit shows a decrease of marly intercalations in its upper part. Larger foraminifera were not found.

The strata of the same lithology, exposed near the church and behind the school/rectory of Priabona, are partly the same as those described above. The overlying strata are again characterized by the abundance of larger foraminifera, in particular *Asterocyclina* and *Discocyclina,* on which characteristic the correlation between this outcrop III and outcrop IV is based.

Outcrop IV: motor-cross circuit

These highest outcrop series are mainly composed of several successive small exposures along the motor-cross circuit of Priabona. They extend from

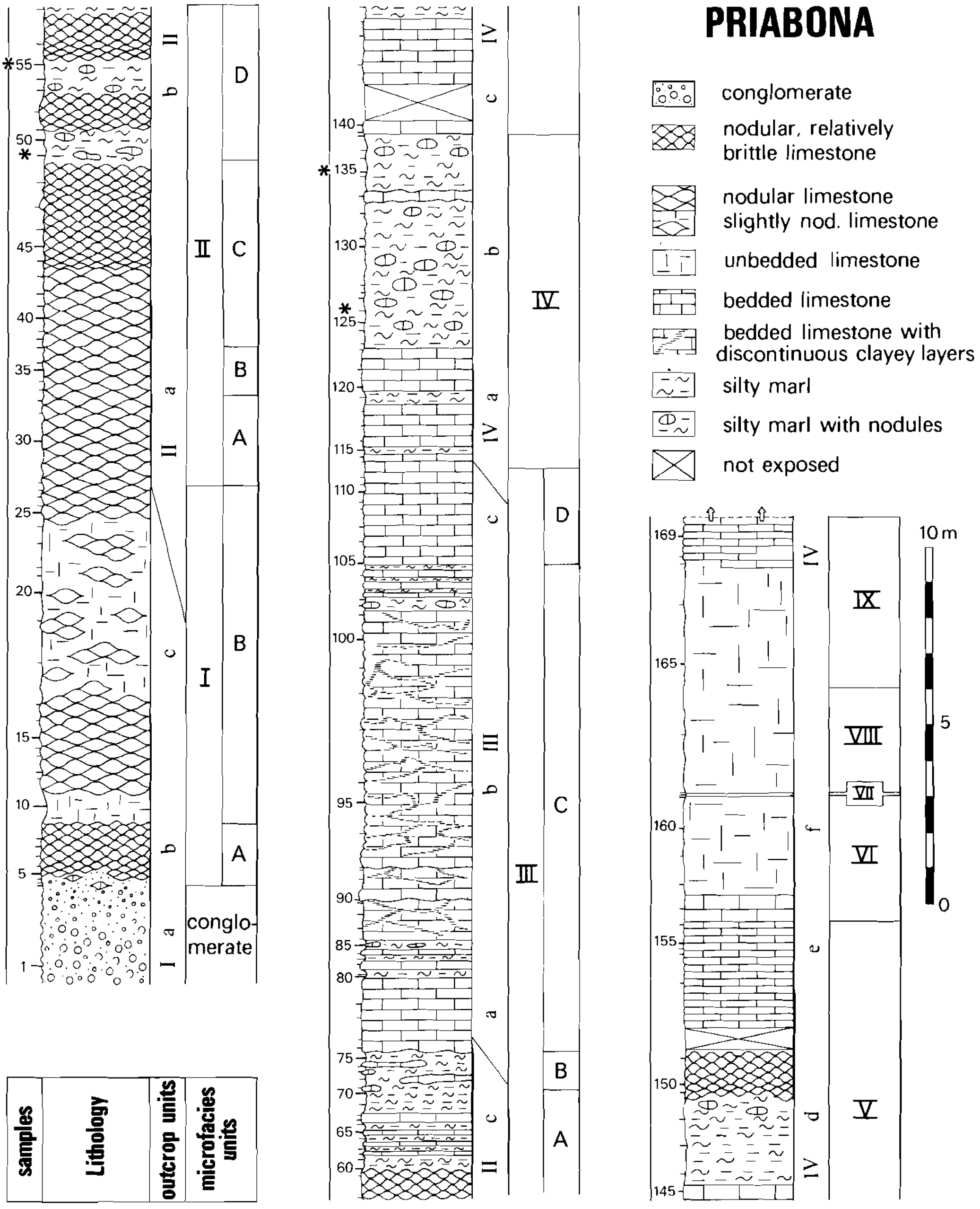


Fig. 5 Composite lithostratigraphic column of section Priabona.

the motor-cross bridge located behind the rectory upward to the foot of Monte Grande (figs. 3 and 4). The following lithostratigraphic units are recognized from bottom to top.

a. Wavy-bedded to somewhat nodular limestones, containing intercalations of silty marl layers (thickness about 4.5 m). Most thinner layers are irregular and discontinuous; the thicker ones (30–40 cm) are more continuous.

b. Silty marl layers over about 6 m, rich in isolated, partly weathered tests of larger foraminifera, especially of *Asterocyclina, Discocyclina* and *Actinocyclina.* Nodular indurations are widespread in this unit. In the upper part, some calcisponge-nodules were found.

c. Wavy-bedded to somewhat nodular limestone, containing a marl layer in its uppermost part (total thickness about 4.3 m). A small number of larger foraminifera occur only in the basal part, below an unexposed interval.

d. Soft, greyish marls, becoming indurate in the upper part (thickness about 2.7 m). These marls are very rich in bryozoa, which tend to weather out in the lower part.

e. Wavy-bedded to nodular limestones with a thickness of about 5.6 m. In the upper part the strata show relatively thick bedding.

f. About 11 m of unbedded limestones; at about 3 metres from the base there is a single thin, but continuous layer of about 3–4 cm thickness. Under this layer, a large number of *Nummulites* were found, whereas above it algal rhodoliths are frequent. The massive and indurate limestones of this unit form the terrace above the motor-cross circuit.

The lithostratigraphic units IVa, b and c are also characterized by rather common *Pecten*-like pelecypods. The discontinuously exposed limestones on the higher, vegetated slope of Monte Grande have not been taken into consideration for our study.

II.2. MICROFACIES ANALYSES

II.2.1. **Introduction**

As a result of our investigation of thin sections of the limestones of the Priabona section we were able to distinguish nine microfacies-units; these will be discussed in stratigraphical order. For the description we used the carbonate rock classifications of Dunham (1962) and Embry and Klovan (1972).

The distinction of successive microfacies-units is based on the following criteria:

– the content and nature of bioclasts (the presence or absence of particular smaller and larger foraminifera, the presence or absence of certain groups such as algae and bryozoa),

- the occurrence of lithoclasts as well as their preservation, and
- textural and structural features: such as carbonate rock type, grain sorting, grain roundness, and particular sedimentary structures.

A slight, vertical variation in the three lowest units permitted a further subdivision into subunits.

The conglomerate at the base of section Priabona, which shows well-rounded, rather tightly packed basaltic pebbles, suggests deposition in a high energy environment. The decrease in grain size in the upward sense points to a gradual diminution of energy during deposition.

The conglomerate may have originated in a coastal environment, as was suggested by Piccoli and Massari Degasperi (1968) for the nearby section Boro/Granella. A transgressive position with respect to the underlying unexposed basalts can be concluded.

II.2.2. Microfacies-units

II.2.2.1. Microfacies-subunit I A: *algal miliolid packstone*

Outcrop Ib; samples 3–9; thickness 1.75 m; pl. I, fig. 1.

Algae, in particular branching forms, and small well-preserved miliolids are frequent in the entire subunit, especially in the lower portion. *Orbitolites, Chapmanina, Rotalia, Halkyardia* and agglutinated foraminifera are present in small numbers. In the lower part some *Nummulites* were observed; only small and/or broken specimens occur. They increase in number and size and are better preserved in the upper part, where echinoderm fragments are also common.

In the upward direction the grains show a decrease in degree of sorting and roundness. Together with this phenomenon micritized grains and small aggregates appear, and the micrite content increases.

Rounded basaltic lithoclasts (0.3 to 0.5 mm in diameter) are rather frequent in the lowermost part and only rare in the remaining part.

The upper boundary is characterized by:

- the increase in number and diversity of the larger foraminifera
- a change in grain sorting from good to moderate-poor
- the appearance of abundant minute quartz grains.

Interpretation: The occurrence of *Orbitolites*, abundant miliolids and gastropods (see outcrop Ib) implies a somewhat restricted, sheltered and shallow environment (Henson, 1950; Arni, 1965; Hottinger, 1973) during deposition.

Branching and articulated red algae abound in the basal part. Their preference for a turbulent shallow environment is mentioned by Wray (1977).

Judging from the increase in micrite content and the decrease in grain sorting and roundness, a decrease in energy took place in the course of the deposition. Slowing down of the rate of sedimentation is expressed by aggregates and micritized grains in the upper part (Kendall, 1969; Flügel, 1978: p. 362, 363).

The distinctly abraded *Nummulites* are considered to be of allochthonous origin. Their upward increase in number, in size and in degree of preservation probably reflects the gradual approach of their original habitat to the Priabona site.

II.2.2.2. Microfacies-subunit I B: *larger foraminiferal-algal packstone*

Outcrops Ic and below IIa; samples 10–28; thickness 9.5 m; pl. I, figs. 2, 3, 4, 5.

An abundance of *Nummulites* and encrusting algae with other less frequent larger foraminifera such as *Baculogypsinoides, Rotalia, Orbitolites,* alveolinids, *Chapmanina* and *Fabiania* characterize this subunit. Pelecypod fragments are also present. The upper part contains a considerable number of *Gypsina linearis* (Hanzawa) (see Hagn and Wellnhofer, 1967), agglutinated foraminifera and *Victoriella,* associated with fragments of hydrozoa and calcisponges. Here, encrusting algae, *Baculogypsinoides, Rotalia,* alveolinids, *Chapmanina* and rounded basaltic lithoclasts (up to 3 mm in diameter) occur more frequently than in the lower part of the subunit.

Recrystallized grains, probably of skeletal origin and recognizable only by their remaining micrite-envelopes, are occasionally frequent in this subunit.

Minute, angular quartz grains (0.05 to 0.10 mm in diameter) occur rather frequently in the lower reaches and in the uppermost part.

Boundary criteria characterizing the overlying subunit are:

– the disappearance or strong decrease of *Baculogypsinoides, Gypsina, Chapmanina, Orbitolites, Fabiania,* alveolinids, larger agglutinated foraminifera, fragments of hydrozoa and calcisponges, micritized grains and basaltic lithoclasts

– the increasing abundance of minute quartz grains.

Interpretation: The lower part shows a continued trend of decrease in degree of grain sorting and grain roundness with respect to the upper part of the underlying subunit. The presence of well-preserved *Nummulites* and the diminution of smaller miliolids are evidence of increasing open marine influence.

Encrusting algae, which prefer solid substrate (Johnson, 1961; Wilson, 1975; Wray, 1977) abound in the upper part. Together with other sessile and/

or encrusting faunal elements such as *Gypsina linearis*, *Victoriella*, hydrozoa, calcisponges and corals they probably formed the framework of mound-like structures, which were situated along the seaward limit of a platform lagoon. Seagrasses probably gave additional coherence to the mound (Davies, 1970). Such algal "reefs" are well-known in ancient and recent carbonates (Wray, 1964; Davies, 1970; Bosence, 1977; Ghose, 1977). *Baculogypsinoides*, *Orbitolites*, alveolinids, *Chapmanina* and to a lesser extent *Rotalia* apparently preferred such a "reefal" habitat. The displaced products of such organic structures are found in this subunit.

As suggested by its textural characteristics, this subunit represents a somewhat sheltered, low energy environment with a low rate of deposition. This assumption is corroborated by the common presence of micritized grains and micrite envelopes.

A direct or indirect terrigenous influence is represented by abundant quartz grains in the lower and upper reaches and by minute, well-rounded basaltic lithoclasts in the upper portion.

With regard to the underlying, restricted deposits of subunit I A, a gradual transgressive migration of material displaced from the "barrier" can be concluded. This material must have gradually encroached upon the open lagoonal or "back-reef" environment.

II.2.2.3. Microfacies-subunit II A: *Nummulites-Rotalia packstone to grainstone*

Outcrops upper Ic and lower IIa; samples 29–32; thickness 2.5 m; pl. II, fig. 1.

Black-pigmented *Nummulites* and *Rotalia* are frequent, together with blackened and abraded debris of algae and echinoderms. In places, annelid tubes are common. Sorting is moderate because of the admixture of fine quartz grain.

Boundary criteria in the upward sense are:

- the appearance of *Operculina* and Discocyclinidae
- more intensive bioturbation
- a strong decrease of quartz grains and algal debris
- a change from packstone and grainstone to packstone only.

Interpretation: Judging from the disappearance of most of those larger foraminifera that prefer restricted, sheltered environments, an open marine realm may be inferred. With respect to the postulated, landwards migrating "reef/barrier", the deposits of this subunit originated on its seaward margin or even on its fore-slope, representing slow accumulation of resistant material in a zone of moderate winnowing.

II.2.2.4. Microfacies-subunit II B: *Nummulites-Operculina packstone*

Outcrop IIa; samples 33–37; thickness 1.5 m; pl. II, fig. 2.

In addition to entire specimens of *Nummulites* and *Operculina*, this highly micritic subunit contains small and angular debris of these forms. Stouter and larger *Nummulites* show borings. Broken and rounded *Discocyclina* and *Asterocyclina* are present throughout.

The upper boundary is characterized by:

- the increase in abundance of *Discocyclina*
- the appearance of *Pellatispira*
- a change from packstone to rudstone.

Interpretation: The richness of angular debris of *Nummulites* and *Operculina* showing indications of boring gives evidence of intensive biological breakdown. These phenomena reflect a low rate of deposition and low energy conditions (Swinchatt, 1965), which are confirmed by the relatively high quantities of fine matrix. It seems probable that this subunit had a position further off-shore and was deposited at relatively greater depth than subunit II A.

The autochthonous position of *Nummulites*, represented by relatively large and stout specimens, and *Operculina* in this facies is concluded from their abundance and the angularity of their fragments. Rare and abraded fragments of Discocyclinidae may have been displaced from nearby environments.

II.2.2.5. Microfacies-subunit II C: *Discocyclina-Nummulites rudstone*

Outcrops IIa, b; samples 38–48, thickness 5.25 m; pl. II, fig. 3.

In addition to abundant *Discocyclina* and *Nummulites*, there are other larger foraminifera such as *Pellatispira, Actinocyclina,* and *Spiroclypeus.* There is commonly an admixture of bryozoa. Stouter and larger *Nummulites* are present exclusively in the basal part.

The dark-coloured matrix is made up of cryptocrystalline micrite mixed with material of probably pelletal origin. Pyritized bioclasts and unrecognizable pyritizied bodies are common, especially in the upper part. A small number of bioclasts show infilling of glauconite.

Microstylolithic intergrain penetrations exist in some levels which contain less micrite matrix.

At the upper boundary we noticed:

- a conspicuous decrease of *Nummulites* and a strong decrease of *Discocyclina*
- a change in macrolithology from nodular limestone to silty marl alternating with nodular to bedded limestone.

Interpretation: The complete tests of larger foraminifera of especially *Discocyclina* and *Nummulites*, accompanied by less frequent *Pellatispira, Actinocyclina* and *Spiroclypeus*, do not show any orientation. These features together with the presence of angular and bored bioclasts in micrite matrix all indicate a modest rate of sedimentation in a tranquil environment. The faunal association may be regarded as being of autochthonous origin.

Pellatispira, recorded as being typical in fore-slope areas (Schlanger, 1963; Ghose, 1977), occurs nearly throughout, but it is more frequent in the lower part of this subunit, where large and stout forms of *Nummulites* are present.

As suggested by the frequent presence of pyrite and the subordinate presence of bioclasts with glauconite infilling, anaerobic conditions somehow played a part. These must have developed below the sediment-water interface as a result of bacterial decay of organic and pelletal matter derived from the abundant bottom dwelling organisms.

II.2.2.6. Microfacies-subunit II D: *Discocyclina-Nummulites rudstone to packstone*

Outcrop IIb; samples 49–57; thickness 4.7 m; pl. II, fig. 4.

Larger foraminifera, in particular *Nummulites* and *Discocyclina*, are the main recognizable components of this microfacies-subunit. They are sometimes fragmented and abraded. Fine bioclastic hash increases in quantity upwards, whereas the admixture of pelletal matter in the matrix diminishes. Distinct pyrite concretions were not recognized.

Two silty marl layers rich in isolated specimens of larger foraminifera are intercalated in this subunit.

The upper boundary is marked by:

– a change in macrolithology from nodular limestone to thin and wavy bedded limestones with silty marl intercalations

– a distinct decrease in degree of preservation of larger foraminifera

– a continuous presence of planktonic foraminifera and increasing numbers of smaller benthonic foraminifera.

Interpretation: Two silty marl layers, rich in larger foraminifera, express fine sediment settling under tranquil conditions. These observations also hold true for the intercalated and overlying limestones, as is indicated by their high micrite content and the grains that show poor sorting and poor roundness. The very abundant and complete specimens of larger foraminifera probably lived in this habitat. On the other hand, at least part of the fine bioclastic hash might be of allochthonous origin. A relative increase in the number of smaller benthonic foraminifera in the upper part is accompanied by a disappearance of pelletal material and a conspicuous decrease of pyrite.

In summary, relatively open marine, quiet and aerobic conditions may be concluded. A slightly greater depth and a decreasing density of subaquatic vegetation may have been responsible for these features.

II.2.2.7. Microfacies-subunit III A: *fine bioclastic foraminiferal packstone*

Outcrops IIb, c; samples 58–70; thickness 2.7 m; pl. III, fig. 2.

Bioclastic hash is the most important volumetric contributor to this subunit, which shows intercalations of silty marl layers. In some levels the hash is associated with rather frequent, but altered, recrystallized and/or black-pigmented, larger foraminifera. Frequent smaller benthonic foraminifera are another characteristic throughout.

In the lowermost part of the subunit there is a distinct level rich in *Turritella*-like gastropods, and to a lesser degree, in echinoderms.

Boundary criteria in the upward direction are:

- a change from packstone to rudstone-packstone
- the increase in abundance of larger foraminifera.

Interpretation: A continuation of the upward trend of decreasing grain size goes together with increasing numbers of planktonic and smaller benthonic foraminifera. A further increase in depth and a position relatively further off-shore can thus be postulated. The greater part of the bioclastic hash in this subunit, as well as of the black-pigmented larger foraminifera, gastropods and echinoderms was presumably displaced from neighbouring, shallower regions. The stained aspects of the larger foraminifera probably developed in an environment with anaerobic bottom conditions (Maiklem, 1967; Davies, 1970; Logan, 1974).

II.2.2.8. Microfacies-subunit III B: *Discocyclina-Operculina rudstone to packstone*

Outcrops IIc and IIIa; samples 71–75, thickness 1.1 m; pl. III, fig. 1.

This subunit is very rich in larger foraminifera. In continuous beds they are oriented parallel to the bedding. When concentrated in nodules with a dark-coloured, pelletal matrix they show an orientation parallel to the nodule-outlines. *Discocyclina* and *Operculina* predominate; *Actinocyclina* and *Spiroclypeus* also occur.

Only small numbers of planktonic and smaller benthonic foraminifera were found in the indurate parts of this subunit.

At the upper boundary we noticed:

- a decrease of larger foraminifera
- a change in macrolithology from silty marl with nodular indurations to well-bedded limestones with silty marl intercalations.

Interpretation: The reappearance of a larger foraminiferal fauna of high diversity, and of pelletal material seems to be in contradiction with the continued presence of fine material and of planktonic and smaller benthonic foraminifera. The orientation of the larger foraminifera, either parallel to bedding in continuous beds, or parallel to the periphery of pseudo-nodules, indicates discontinuous phases of rapid deposition of allochthonous material in an off-shore environment. The internal structure of the skeletal pseudo-nodules is comparable to that of the pseudo-nodules of Macar (1948), which can be explained as advanced stages of load-casting, leading to disruption of beds during episodes of rapid deposition (Kuenen, 1958).

II.2.2.9. Microfacies-subunit III C: *fine bioclastic foraminiferal packstone*
Outcrop IIIa, b; samples 76–104; thickness 14.45 m.

Characterized by an abundance of bioclastic hash, this subunit is similar to subunit III A. Larger foraminifera, mostly recrystallized and/or black-pigmented, occur rather frequently in the lower part. In some levels foraminiferal debris, often abraded, but partly also angular, is present.

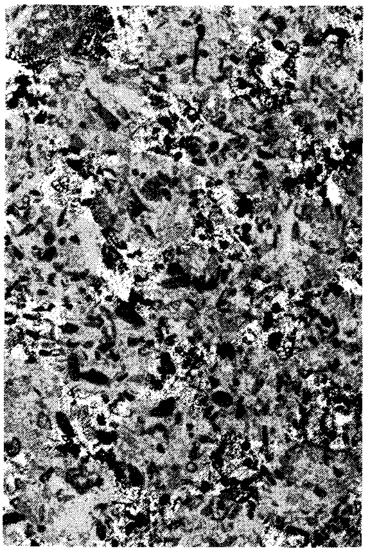
In addition, a large number of smaller benthonic foraminifera (especially taxa of the suborder Rotaliina) and a smaller number of planktonic foraminifera have been found throughout this subunit. The middle part, which is rich in annelid tubes and bryozoa, shows intensive burrowing.

In the disrupted beds, which often occur at this level, most of the matrix is composed of rather coarse pseudospar (average crystal size about 10 μ), which is probably a product of recrystallization.

The upper boundary shows:

- a change in macrolithology from bedded rocks with irregular, discontinuous intercalations of clayey layers to regularly bedded limestones
- the appearance of abundant rounded algal debris and questionable filaments.

Interpretation: A distinct drop in the supply of non-indigenous larger foraminifera reflects the return to conditions of sedimentation comparable to those of subunit III A. The limestone-beds resulted from phases of rapid supply and deposition, leading to load-casting. The settling of the fine silty marls on the other hand must have been very slow, promoting an early diagenetic cementation of the limestones (Purser, 1969; Shinn, 1969; Bathurst, 1975). This process and its consequences during compaction explain the disruption of these beds (McCrossan, 1958; Pettijohn and Potter, 1964). These features might express an environment position further off-shore with respect to subunit III A.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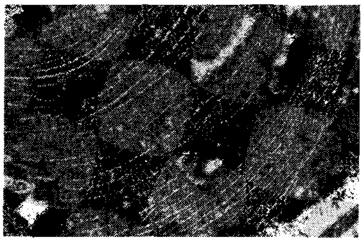
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Fig. 1 Well sorted algal miliolid packstone in lower part of subunit I A (sample Pr. 5). Additional echinid fragments and rare basaltic lithoclasts in a prevalently micritic matrix. Top of layer left of photo, 20 X.

Fig. 2 Larger foraminiferal-algal packstone in lower part of subunit I B (sample Pr. 13). *Orbitolites* sp., small *Nummulites* sp., algal fragments, echinid- and pelecypod bioclasts. Top of layer left of photo, 8 X.

Fig. 3 Larger foraminiferal-algal packstone in upper part of subunit I B (sample Pr. 25). *Baculogypsinoides* sp., *Nummulites* sp., alveolinids, *Gypsina linearis* and *Fabiania* sp. associated with algal fragments. Top of layer left of photo, 6 X.

Figs. 4, 5 Sections of *Gypsina linearis*. Subunit I B (sample Pr. 25). Top of layer above top of photo. Fig. 4: 30 X, fig. 5: 60 X.

II.2.2.10. Microfacies-subunit III D: *rounded algal debris packstone*

Outcrops IIIc and IVa; samples 105–112; thickness 2.95 m; pl. III, figs. 3, 4, 5.

Rounded and usually micritized algal debris (average diameter about 0.2 mm) is very abundant in this subunit. Intensive micritization produced unidentifiable pelletoids in some places.

Another feature of this subunit is the occurrence of frequent, questionable filaments of variable, irregular shape, having a thin wrapping (thickness about 0.1 mm) of prismatic crystals perpendicular to their outlines (see pl. III, figs. 4, 5). This coating thickens in marginal areas. We are presumably dealing with carapaces of brachyuran crabs (Hagn, personal communication 1981).

Smaller benthonic and planktonic foraminifera are common elements in this subunit. A thin accumulation of small gastropods is discernible in the upper part.

The upper boundary is marked by:

- the reappearance of Discocyclinidae and of abundant bryozoa
- the disappearance of the filaments and a decrease of algae.

Interpretation: The exact nature of the deposition is difficult to evaluate. The sediments may represent the framework of a lime-mound, where micrite was trapped by algae. Such features often occur on shelves or gentle slopes along shelf-margins (Wilson, 1975). Or else the deposits might have been formed as a result of a relatively high supply of carbonate particles derived from relatively shallow environments. The original position of the carapaces of brachyuridae is doubtful. Given the sequential position of this facies above carbonates of inferred off-shore origin, a shallowing trend might be concluded.

II.2.2.11. Microfacies-unit IV: *Discocyclinid-bryozoan rudstone to floatstone*

Outcrop IVa, b; samples 113–138; thickness 9.2 m; pl. IV, fig. 1.

This unit resembles subunit II B in being rich in larger foraminifera and in having an admixture of pelletal material in its micrite matrix. Another characteristic is a considerable amount of clayey material.

Asterocyclina and *Actinocyclina* are prevalent, except in the lower-most part. *Discocyclina* and agglutinated foraminifera are present in relatively large numbers in the entire unit, *Operculina* is less frequent. Bryozoa and bioclastic hash are abundant.

Micro-lamination is a typical structure in this unit. As in subunit II B, microstyloliths and intergrain penetrations have been noticed in levels relatively poor in micrite matrix.

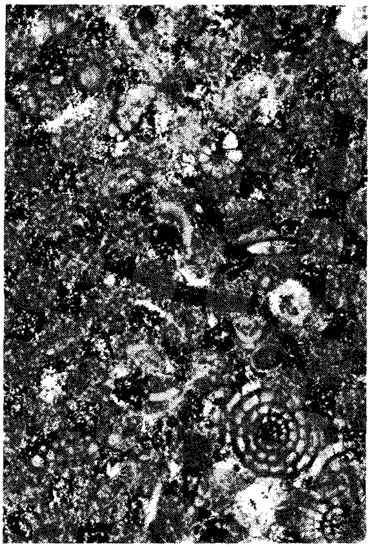

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Fig. 1 *Nummulites-Rotalia* packstone in middle part of subunit II A (sample Pr. 30). Algal fragments, sections of annelid tubes and quartz grains. Top of layer left of photo, 12 X.

Fig. 2 Complete specimens and fragments of relatively large *Nummulites* sp. and *Operculina* sp. in packstone of subunit II B (sample Pr. 37). The large *Nummulites* specimen shows traces of boring. Top of layer above top of photo, 5 X.

Fig. 3 *Discocyclina-Nummulites* rudstone in subunit II C (sample Pr. 44). Top of layer left of photo, 5 X.

Fig. 4 *Discocyclina-Nummulites* packstone with fragmented *Discocyclina* sp. and abundant bioclastic hash in subunit II D (sample Pr. 56). Top of layer above top of photo, 5 X.

A section through a calcisponge-nodule, which was found in the uppermost portion, shows an encrustation by red algae.

Criteria by which the upper boundary can be recognized:

- the disappearance of *Asterocyclina, Actinocyclina* and *Discocyclina*
- a change in macrolithology from silty marl to bedded limestone.

Interpretation: The postulated regressive development shown from III C to III D is confirmed by the reappearance of a microfacies that strongly resembles that of subunit II B, lower down in the section. Characteristic is the rich fauna of larger foraminifera, as well as the admixture of pelletal material in the matrix.

The presence of fine lamination and the abundance of bioclastic hash, and of oriented Discocyclinidae suggests the influence of bottom currents. A partly non-indigenous position of faunal elements such as the bryozoans can therefore not be ruled out.

The high content of fine terrigenous material in this and the following unit may be explained by the ability of abundant bryozoa to trap, baffle and stabilize sediments (Wilson, 1975). An additional and effective support may have been provided by submarine vegetation; this assumption is supported by the abundance of epiphytic benthonic foraminifera in the intercalated marls (see V.1.4.1.).

II.2.2.12. Microfacies-unit V: *bryozoan packstone*

Outcrop IVc, d, e; samples 139–156; thickness 12 m; pl. IV, figs. 2, 3.

Bryozoa are the most important faunal elements in this unit. In some levels they constitute nearly 100% of the bioclasts. Marl layers are intercalated in the middle part of the unit. *Operculina, Heterostegina* and flat *Nummulites* are frequent in the lowermost part (plate IV, fig. 2); they vanish in the middle reaches and are common again in the uppermost portion. Lenticular *Nummulites* occur very rarely, but they display a conspicuous augmentation in number in the upper reaches. Here, planktonic foraminifera disappear. Rounded debris of Discocyclinidae were found near the lower boundary of the unit.

The degree of sorting and to a lesser extent also the degree of grain roundness tend to increase in an upward sense, while micrite and bioclastic hash diminish. In some levels the grains tend to be oriented parallel to the bedding planes.

Boundary criteria in the upward sense are:

- a change in macrolithology from bedded to unbedded limestone
- a change from packstone to grainstone
- the increasing numbers of *Nummulites, Rotalia* and encrusting algae
- a decrease of bryozoa.


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Fig. 1 Vertical section of pseudo-nodule in subunit III B (sample Pr. 73), showing orientation of *Discocyclina* sp. and *Operculina* sp. Top of layer above top of photo, 1,7 X.

Fig. 2 Stained specimens of *Nummulites* sp. and *Discocyclina* sp. with abundant bioclastic hash in packstone of subunit III A (sample PR. 68). Top of layer left of photo, 6 X.

Fig. 3 Sections of gastropods, annelid tubes, algal fragments and brachyuran carapaces in algal debris packstone in upper part of subunit III D (sample Pr. 110). Top of layer left of photo, 7 X.

Figs. 4, 5 Sections of possible brachyuran carapaces in upper part of subunit III D (sample Pr. 110). Top of layer above top of photos. Fig. 4: 22 X, fig. 5: 52 X.

Interpretation: All the textural and faunistic features displayed by the upper part of this unit give evidence of a shallowing trend. The sorting and orientation of grains reflects an – at least episodical – influence of high energy during deposition. Nevertheless, the faunal elements are considered to be essentially of autochthonous origin.

II.2.2.13. Microfacies-unit VI: *Nummulites algal grainstone*

Outcrop IVe; samples 157–161; thickness 3.6 m; pl. IV, fig. 4.

In addition to predominating *Nummulites* and encrusting algae, this unit contains frequent *Rotalia, Chapmanina,* echinoderms and bryozoa. Minute, angular debris of *Nummulites* constitutes a considerable portion of the grains in the lower part. Micritization and black-pigmentation of bioclasts are widespread throughout this unit. There is a slight increase of the micrite content in the uppermost levels.

The upper boundary is characterized by:

- a change from grainstone to packstone
- the disappearance of *Nummulites, Rotalia* and bryozoa.

Interpretation: The gradual decrease in depth may have led to the well-washed grainstone-texture of these sediments. Winnowing, in a very shallow environment promoted slow deposition and caused an intensive pigmentation of the grains. The concentration of echinoderms may be connected with a base of wave action (Seibold *et al.,* 1973).

The association of *Nummulites, Rotalia* and algae is to a certain extent comparable to that of subunits I B and I C, in the lower part of the section.

II.2.2.14. Microfacies-unit VII: *algal faecal pellet packstone*

Outcrop IVf; sample 162; thickness 3–4 cm.

Encrusting algae and well-preserved faecal pellets are prevalent components of this very thin microfacies-unit. Echinoderm fragments and smaller benthonic foraminifera (miliolids and spiral forms) were found as well. Some grains, probably of skeletal origin, show micrite envelopes. The micrite content is remarkably high. *Nummulites* are absent.

At the upper boundary we recognize:

- the return in macrolithology from bedded to unbedded
- a change in the faunal contents.

Interpretation: The high energy facies of unit VI is succeeded by this subunit, showing indications of a return to more quiet conditions. The total faunal assemblage does not show the same distinctly marine character as the underlying units do. A protected, back-barrier realm may be inferred.

Plate IV

Section Priabona

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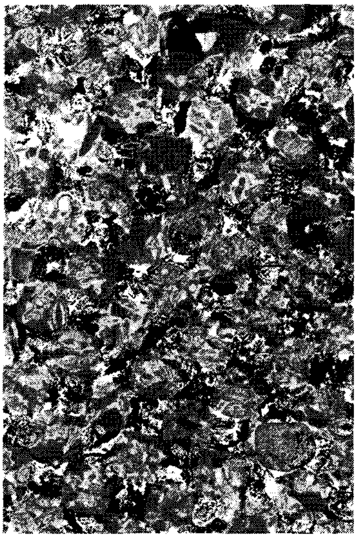

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Fig. 1 Discocyclinid-bryozoan rudstone to floatstone of unit IV (sample Pr. 122) showing sections of *Asterocyclina* sp., *Discocyclina* sp. and *Actinocyclina* sp. in micritic matrix. Top of layer left of photo, 6 X.

Fig. 2 Sections of *Nummulites* sp., *Operculina* sp. and *Heterostegina* sp. in Bryozoan packstone of lower part of unit V (sample (Pr. 139). Top of layer left of photo, 10 X.

Fig. 3 Agglutinated foraminifera in Bryozoan packstone in middle part of unit V (sample Pr. 152). Top of layer left of photo, 5 X.

Fig. 4 *Nummulites* algal grainstone of unit VI (sample Pr. 158), containing echinid-bryozoa fragments and showing pigmentation of larger foraminifera and bioclasts. Top of layer left of photo, 6 X.

II.2.2.15. Microfacies-unit VIII: *rhodolith floatstone*

Outcrop IVf; samples 163–164; thickness 2.9 m; pl. V, fig. 1.

The skeletal grains of this unit consist mainly of rhodoliths (diameter up to 3 cm), which may include the encrusting foraminifera *Nubecularia.* They encrust debris of calcisponges, hydrozoa and corals. Larger agglutinated and smaller rotaliid foraminifera are rare. The micrite content of this unit is considerable.

The upper boundary is placed at:

– the disappearance of rhodoliths containing calcisponges, hydrozoa and corals as nucleus

– the reappearance of planktonic foraminifera and miliolids.

Interpretation: Highly micritic carbonates persist from this unit to higher up in the section. Such sediments do not represent the original environment of rhodoliths; rhodoliths need to have moving water turning them over periodically (Logan *et al.,* 1969; Adey & Macintyre, 1973; Wilson, 1975). Wilson (1975) considers such microfacies to be characteristic for protected, shallow environments.

II.2.2.16. Microfacies-unit IX: *encrusting algal foraminiferal packstone*

Outcrop IVf; samples 165–169; thickness > 4.2 m; pl. V, fig. 2.

This uppermost unit is rich in encrusting algae, which form rhodoliths with a diameter up to 1 cm. It is characterized by the presence of planktonic and smaller benthonic foraminifera. Miliolids and spiral forms occur frequently, especially in the upper part. Micritized grains, presumably of skeletal origin, show micrite-envelopes. A high micrite content is to be noted throughout this unit.

Interpretation: No fundamental changes in environmental conditions can be concluded from the attributes of this facies, which evidently came into being in a back-barrier, lagoonal environment of low energy and slow deposition.

The local abundance of smaller miliolids is in accordance with such circumstances. Planktonic foraminifera found in this upper part of the investigated section must have been introduced from near-by open marine waters.

II.2.3. Synthesis of depositional history

The succession of microfacies-units in the section Priabona came into being as a result of a gradual transgression succeeded by a slow shallowing (see fig. 6).

The sequence of micro-facies-subunits I A up to III C comprises the de-

Section Priabona


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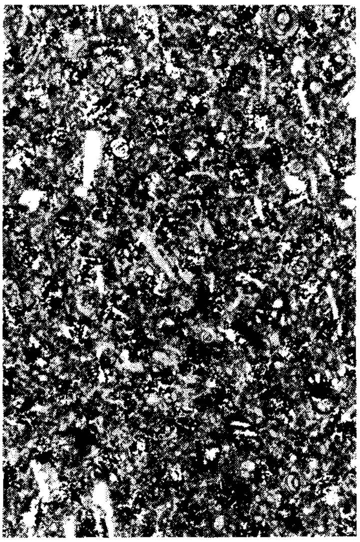
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Fig. 1 Rhodolith floatstone of unit VIII (sample Pr. 163). Top of layer left of photo, 7 X.

Fig. 2 Algal foraminiferal packstone with abundant miliolids in upper part of unit IX (sample Pr. 169). Top of layer above top of photo, 9 X.

Section Buco della Rana

Fig. 3 Encrusting algae, bryozoa fragments and *Asterocyclina* sp. in rudstone to boundstone of unit XI (sample BdR. 49). Top of layer above top of photo, 4 X.

positional record of the slow landward passage of a number of juxtaposed environments in a subsiding basin. The initial lagoonal conditions, represented by subunits I A and I B, were replaced by the open marine sediments of subunits II A–III C. In between these two major groups of environments, morphological structures of largely organic origin acted as the protecting barrier. The proximity of such structures was inferred from the upper part of subunit I B.

From subunit III C up to unit IX the evolution of the Priabona-area showed essentially the same picture but in reverse order. A slow shallowing possibly only due to a slowing down of subsidence, created a superposition of sediment types, which then gradually migrated in a seaward direction. The offshore facies of subunits II A–III C were succeeded by a shallowing sequence, culminating in unit VI in high energy deposits of inferred littoral barrier origin. Continuation of this trend ultimately led to the return of quiet protected, back-barrier conditions near the top of the investigated section (units VII–IX).

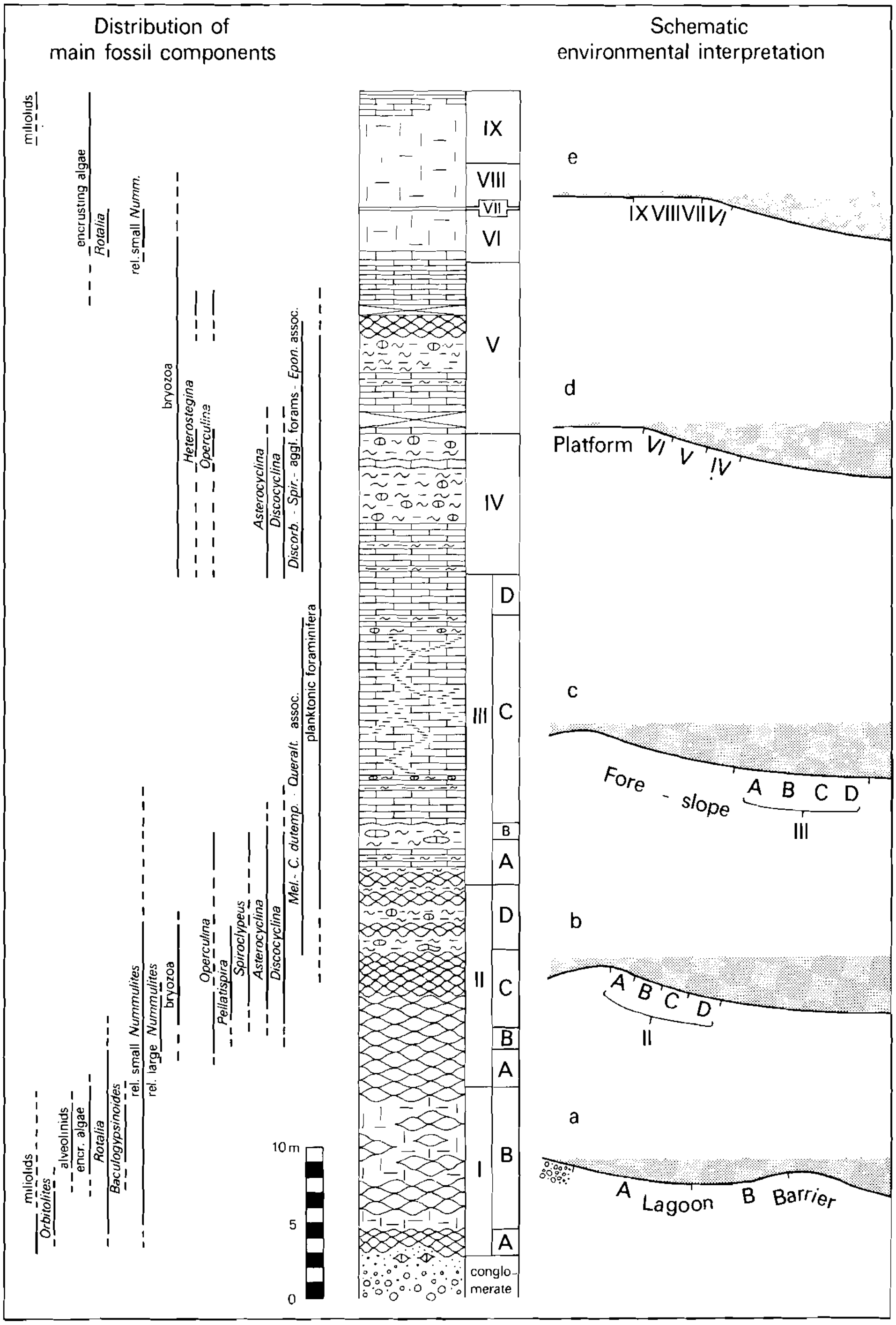


Fig. 6 Vertical sequence of microfacies-units of section Priabona, showing the distribution of main fossil components and a schematic environmental interpretation.

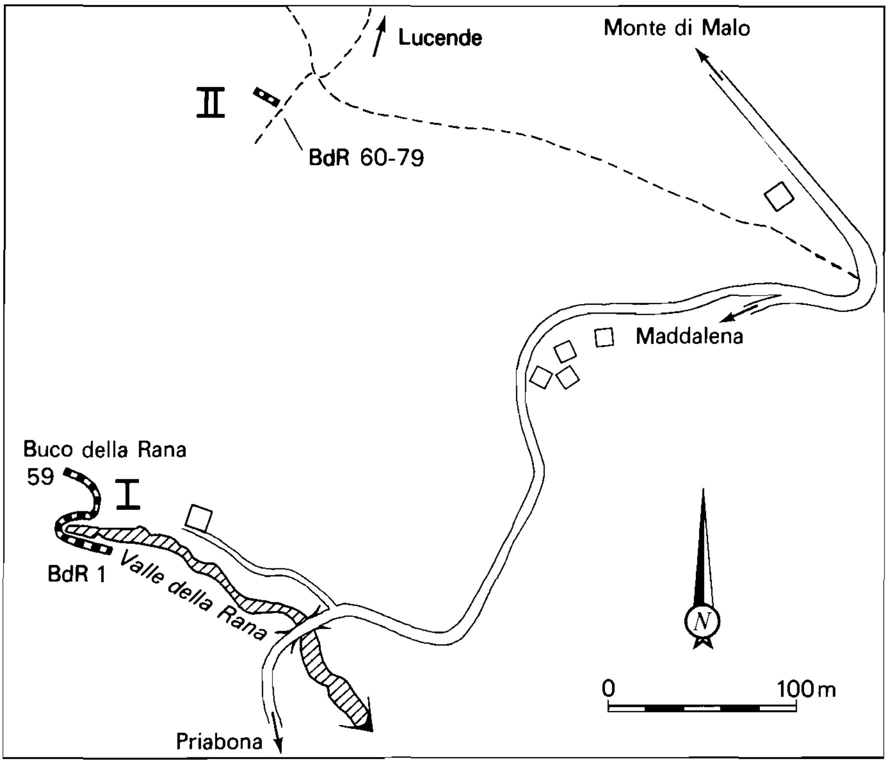


Fig. 7 Location of outcrops and samples at Buco della Rana.

Chapter III

SECTION BUCO DELLA RANA

III.1. GENERAL DESCRIPTION

The total thickness of this section, which consists of two outcrop units at about 2 km NNW of Priabona, is about 62 m. The position of the exposures is shown in figure 7 and a composite lithostratigraphic column is depicted in figure 8.

Outcrop I

This outcrop unit is located west of the road to Monte di Malo, in the immediate neighbourhood of the cave Buco della Rana. The following lithostratigraphic units are exposed from bottom to top.

a. Strongly weathered basalt; visible thickness about 3 m

b. Irregularly stratified to somewhat nodular limestones (thickness about 2.9 m); rather light in colour. A direct contact with the underlying basalt can only be seen at low water level of the river Rana. A bed rich in oysters is present in the upper part. The basalt-limestone contact is also visible in a nearby exposure along the road Priabona-Monte di Malo. Here, the carbonate seems to have penetrated into fissures in the upper part of the basalt.

c. Irregularly stratified to somewhat nodular silty limestones (thickness about 2.7 m); this lithological unit differs from the previous one in being dark-grey in colour. Part of it is somewhat brittle owing to clay admixture. At some levels the nodular appearance is due to large horizontal burrows.

d. Nodular to rather well-bedded limestones (thickness: 3.65 m); this unit is exposed at the entrance of the cave.

e. Bedded limestones (thickness: 2.9 m); this unit is exposed in the cave itself. The succeeding lithological units were sampled on the slope outside.

f. Stratified to massive limestone (thickness: 9.5 m); approximately half way there are beds rich in larger foraminifera, in particular *Discocyclina* and *Nummulites*. The degree of the stratification decreases in an upward sense.

g. An alternation of massive and somewhat bedded limestones (total thickness about 25 m).

The measuring, description, and sampling of the section were hampered by vegetation and the steepness of the slope.

The higher strata are also exposed and more easily accessible about 200 m to the north (outcrop II). The relative position of these two sections is based on the correlation of levels I g (top) and II a.

Outcrop II

This outcrop can be reached by way of a footpath from the hairpin curve or from the hamlet of Lucende (see fig. 7). The following lithostratigraphic units are exposed from bottom to top:

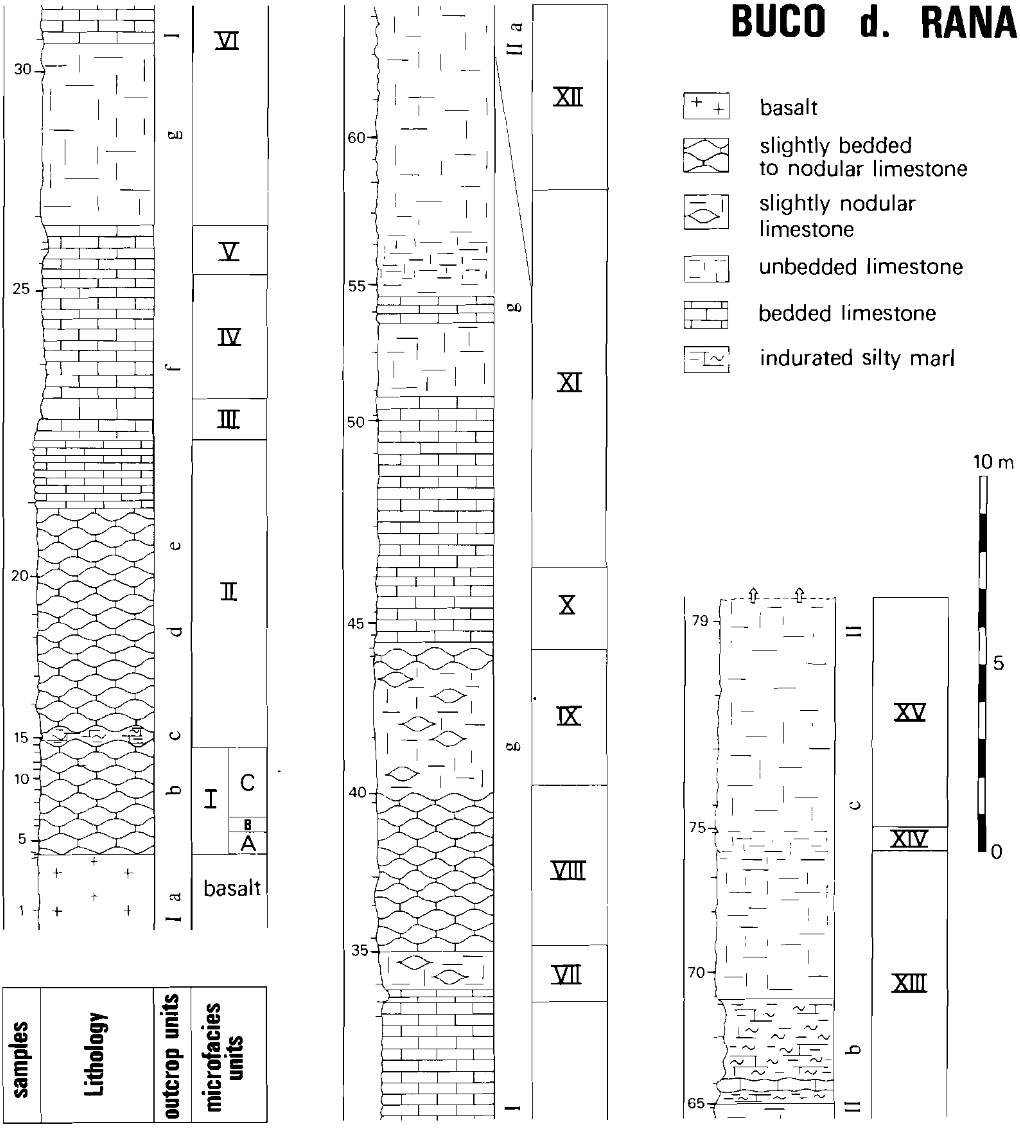


Fig. 8 Composite lithostratigraphic column of section Buco della Rana.

a. relatively massive limestone, somewhat stratified in the lower two metres (total thickness: 8.2 m)

b. poorly-cemented brittle limestones to silty marls (thickness: 2.8 m)

c. relatively massive, partly stratified limestones resembling those of unit a (total thickness about 18 m–20 m). Only the lower part was taken into account in our investigation.

III.2. MICROFACIES-UNITS

Fifteen microfacies-units distinguished at Buco della Rana will be treated in stratigraphical order.

III.2.1. Microfacies-subunit I A: *algal Nummulites packstone I*

Outcrop Ib; samples 3–5; thickness 60 cm.

Encrusting and branching algae are important elements in this subunit. *Nummulites, Baculogypsinoides,* smaller miliolids, agglutinated foraminifera (with some larger specimens) and echinoderms are common. Alveolinids are rare and *Orbitolites* is sporadically present only.

The micrite content is low in the lower 7 to 9 cm, where *Nummulites* are small and often abraded. Further upwards a decrease in degree of sorting and roundness of the grains is accompanied by an increasing quantity of micrite and increasing size and better preservation of the *Nummulites.*

Rounded, basaltic lithoclasts (0.3 to 0.5 mm in diameter) and minute, angular quartz grains (0.05 to 0.10 mm in diameter) occur rather frequently throughout.

The upper boundary is marked by:

– the appearance of abundant *Rotalia,* hydrozoa, calcisponges and corals

– an increase in degree of micritization and in micrite content.

III.2.2. Microfacies-subunit I B: *Nummulites-Rotalia algal packstone I*

Outcrop Ib: samples 6–7; thickness about 40 cm.

This microfacies-subunit is characterized by a remarkably large quantity of *Rotalia,* calcisponges, hydrozoa and corals, associated with abundant *Nummulites, Baculogypsinoides* and algae. Alveolinid foraminifera, *Fabiania, Orbitolites* and *Chapmanina* occur in small numbers. Thin, but well-preserved pelecypods and gastropods are also frequent.

Recrystallized particles, probably of skeletal origin, recognizable only from their remaining micrite envelopes occur in remarkably high numbers.

At the upper boundary we found:

– a conspicuous decrease in *Rotalia,* hydrozoa, calcisponges, corals, micrite content and in degree of micritization

– a strong increase of quartz grains.

III.2.3. Microfacies-unit I C: *algal-Nummulites packstone II*

Outcrop Ib; samples 8–13; thickness 1.9 m.

The basal part of this subunit resembles subunit I A in its grain content and sedimentary attributes. A bed rich in oysters in situ (thickness about 90 cm) is present in the middle part. *Baculogypsinoides* occur frequently immediately below and above the oyster bed; above this bed, aggregates are present, while alveolinids, *Orbitolites* and smaller miliolids reappear or become more abundant.

At the upper boundary we noted:

- the disappearance of alveolinids, *Orbitolites*, *Baculogypsinoides*, larger agglutinated foraminifera, hydrozoa, calcisponges and corals
- the appearance of *Operculina* and indications of an intensive skeletal breakdown
- an increase in the micrite content.

III.2.4. Microfacies-unit II: *Nummulites-Operculina packstone*

Outcrop Ic, d, e, f; samples 14–22; thickness 8.4 m.

In addition to entire specimens of *Nummulites* and *Operculina*, this unit also contains numerous small, angular fragments of these forms. *Nummulites* become more abundant and larger in the upper part. Rounded debris of algae and bioclastic hash are frequent. Smaller miliolids tend to decrease in the upward direction. Small aggregates are present in small numbers throughout, while abraded *Discocyclina* occur only locally.

The upper boundary shows:

- the reappearance of alveolinids, hydrozoa, and calcisponges
- the introduction of frequent *Eorupertia/Victoriella*
- the increase in miliolids, agglutinated foraminifera, encrusting algae and *Rotalia*.

III.2.5. Microfacies-unit III: *Nummulites-Rotalia algal packstone II*

Outcrop If; sample 23, thickness 90 cm.

The absence of *Baculogypsinoides*, quartz grains and basaltic lithoclasts, as well as the greater frequency of *Eorupertia/Victoriella* are the main differences between this unit and subunit I B.

Boundary criteria in upward sense are:

- the reappearance of *Operculina* and of angular debris of Nummulitidae
- the appearance of *Spiroclypeus*
- the strong decrease or disappearance of miliolids, agglutinated foraminifera, alveolinids, hydrozoa, calcisponges and corals.

III.2.6. Microfacies-unit IV: *Nummulites-Rotalia-Operculina packstone to rudstone*

Outcrop If; samples 24–25; thickness 3.20 m.

To a large extent this unit is comparable to unit II. It differs, in that it contains more *Rotalia* and *Spiroclypeus;* on the other hand algae are less frequent. In the upper part, *Pellatispira,* larger specimens of *Nummulites* and planktonic foraminifera appear, while *Discocyclina* increase in number.

At the upper boundary we noted:

- the appearance of *Asterocyclina* and *Actinocyclina*
- the appearance of abundant *Discocyclina*
- a change from packstone-rudstone to rudstone.

III.2.7. Microfacies-unit V: *Discocyclina-Nummulites-Operculina rudstone*

Outcrop If; samples 26–28; thickness 1.30 m.

The majority of the grains in this unit consists of larger foraminifera. *Discocyclina, Operculina, Spiroclypeus, Asterocyclina, Actinocyclina* and *Pellatispira* are present in large numbers. *Nummulites* are represented by small specimens only. Planktonic foraminifera occur rarely.

Boundary criteria in upward sense are:

- the disappearance or strong decrease of Discocyclinidae, *Spiroclypeus, Operculina, Pellatispira* and planktonic foraminifera
- the increase of *Rotalia,* bryozoa, algae and agglutinated foraminifera.

III.2.8. Microfacies-unit VI: *Nummulites-Rotalia packstone to rudstone*

Outcrop Ig; samples 29–33; thickness 8.80 m.

This unit resembles units II and IV in the frequent occurrence of *Nummulites* and their angular fragments. It differs from unit II in containing more *Rotalia* than *Operculina,* and from unit IV in a higher content of algae, while *Spiroclypeus* is completely lacking here. Debris of Discocyclinidae is rare.

The upper boundary is characterized by:

- the reappearance of *Pellatispira,* and the conspicuous increase of *Discocyclina*
- the near-absence of *Rotalia*
- a change from packstone-rudstone to rudstone.

III.2.9. Microfacies-unit VII: *Discocyclina-Nummulites-Pellatispira algal rudstone*

Outcrop Ig; samples 34–35; thickness 1.4 m.

Characterized by the abundance of larger foraminifera, this unit bears a resemblance to unit V, but the fauna shows less diversity; *Asterocyclina* and *Actinocyclina* are very rare to absent. Algae and bioclasts encrusted by algae are frequent.

Admixture of some pelletal material in the matrix is restricted to the basal part. An increase in the number of angular debris occurs in the upper part, where larger specimens of *Nummulites* appear. Planktonic foraminifera are present throughout in small numbers.

The upper boundary is marked by:

– a decrease of *Discocyclina* and the disappearance of *Pellatispira.*

III.2.10. Microfacies-unit VIII: *Nummulites-algal-Rotalia packstone to rudstone*

Outcrop Ig; samples: 36–40; thickness 4.8 m.

This unit again strongly resembles unit VI. Planktonic foraminifera occur more continuously, but in small numbers. *Operculina* are frequent. Remarkable is a tendency to a negative correlation of the frequencies of *Discocyclina* and *Rotalia* within this unit. *Discocyclina* become more abundant in the upper portion, which contains more angular bioclasts.

At the upper boundary we noticed:

– the increase of *Discocyclina* and the decrease of algae.

III.2.11. Microfacies-unit IX: *Discocyclina-Nummulites rudstone*

Outcrop Ig; samples 41–42; thickness 3.70 m.

The absence of *Pellatispira, Asterocyclina and Actinocyclina* distinguishes this unit from units V and VII lower in the section. *Discocyclina* locally are poorly preserved. Planktonic foraminifera are rare. Angular bioclasts are common.

Boundary critaeria in the upward sense are:

– the appearance of (probably) carapaces of brachuyridae
– a decrease of *Discocyclina* and to a lesser extent of *Nummulites*
– the increase of algae and a change from rudstone to packstone.

III.2.12. Microfacies-unit X: *algal foraminiferal packstone*

Outcrop Ig; samples 43–47; thickness 2.1 m.

Grains consist mainly of algal fragments and smaller benthonic foraminifera. *Nummulites, Rotalia, Sphaerogypsina* and abraded debris of *Discocyclina* are also frequent. There are rather frequent carapaces of brachuyridae comparable to those recorded from Priabona (see II.2.2.10).

In the upper part, *Rotalia* and *Discocyclina* are more frequent than lower down; there is no indication of a negative correlation of their frequencies.

The upper boundary is to be found at:
- the increase of algae, especially encrusting forms and of bryozoa
- the appearance of *Asterocyclina*
- a change from packstone to rudstone-boundstone.

III.2.13. Microfacies-unit XI: *algal bryozoan Asterocyclina rudstone to boundstone*

Outcrops Ig and IIa; samples 48–57; thickness: 9.9 m; pl. V, fig. 3.

A large quantity of the skeletal components consists of encrusting algae; a large number of the bryozoa and *Asterocyclina* are coated by algae. *Asterocyclina* decrease in number in the upper reaches, where *Nummulites* reappear. *Operculina*, *Heterostegina* and agglutinated foraminifera are present in the entire unit.

The upper boundary shows:
- the disappearance of *Asterocyclina*
- an increase of *Nummulites* and to a lesser degree also of *Operculina* and *Heterostegina*.

III.2.14. Microfacies-unit XII: *algal bryozoan foraminiferal rudstone to boundstone*

Outcrops Ig and IIa; samples 58–63, thickness 4.9 m.

In addition to abundant algae and bryozoa, this unit contains rather frequent *Operculina*, *Heterostegina*, *Nummulites*, *Eorupertia*/*Victoriella*, agglutinated foraminifera and fine bioclastic hash. In some layers, encrusting algae show a boundstone structure; they decrease in number in the upper part, where they are represented only by their debris. Brachiopods and ostracods are discernible in some intervals.

At the upper boundary we recognized:
- the disappearance or strong decrease of algae and bioclastic hash
- the increase of bryozoa
- the disappearance of *Operculina* and *Heterostegina*.

III.2.15. Microfacies-unit XIII: *bryozoan packstone-grainstone*

Outcrop IIb; samples 64–73; thickness 7.20 m.

This microfacies-unit is characterized by the abundance of bryozoa, which make up nearly 100% of the bioclasts. The middle part contains *Operculina* and *Heterostegina*; these vanish in the upper portion, where *Nummulites*, *Rotalia*, algae and echinoderms become abundant.

A high micrite content occurs in the basal part. Here, planktonic foraminifera are frequent. In the upper part, a gradual decrease of micrite takes place in upward direction leading to a grainstone texture in the uppermost part of this unit.

The upper boundary is marked by:

- a decrease of bryozoa
- the increase of *Nummulites, Rotalia* and algae
- a change from packstone-grainstone to grainstone.

III.2.16. Microfacies-unit XIV: *Nummulites algal grainstone*

Outcrop IIb; sample 74; thickness 70 cm.

Nummulites, algae, and *Rotalia* associated with echinoderms and *Chapmanina,* are the dominant components of these well-washed limestones. Most of the bioclasts are worn and black-pigmented.

The upper boundary criteria are:

- the strong decrease of *Nummulites, Rotalia* and *Chapmanina*
- the appearance of fragments of hydrozoa, calcisponges and corals
- a change from grainstone to packstone-wackestone.

III.2.17. Microfacies-unit XV: *algal packstone-wackestone*

Outcrop IIc; samples 75–79; thickness > 5.60 m.

This uppermost unit is rich in encrusting algae and rather poor in foraminifera. *Nummulites* and *Rotalia* occur rarely in the lower part; miliolids and agglutinated foraminifera are present in small numbers throughout. Fragments of hydrozoa, calcisponges and corals, in part algally coated, are rather frequent. In addition, some gastropods have been recognized associated with less frequent pelecypods.

III.3. INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS

As in section Priabona, a gradual marine transgression over basaltic rocks initially produced a shallow, somewhat restricted environment of carbonate deposition at Buco della Rana (microfacies-unit I). These conditions are shown by the presence of smaller miliolids, alveolinids and *Orbitolites.* In comparison to section Priabona, the influence of open lagoonal conditions was apparent from the base upwards in this section as shown by the presence of *Nummulites.* The oysters *in situ* in subunit I C may indicate a relatively low salinity (Shepard and Moore, 1960; Wiedemann, 1972) possibly due to a local and temporary influence of a fresh water supply, which also caused the contamination by terrigenous quartz grains.

The abundance of sessile elements of mound-like organic structures in subunit I B and unit III might express the proximity, migration and reworking of such structures, situated along the seaward limits of the lagoon.

In microfacies-unit II, the *Nummulites-Operculina* association in carbonates of substantial thickness, witness to intensive skeletal breakdown, which is characteristic for open marine, fore-slope environments with a low rate of sedimentation. Further upwards, in units IV to XI, such fore-slope conditions are reflected in various diverse associations of larger foraminifera. *Nummulites-Rotalia-Operculina* associations reflect an upper open marine fore-slope, while *Discocyclina-Nummulites-Pellatispira-Spiroclypeus-Asterocyclina-Actinocyclina* associations suggest a lower open marine fore-slope.

Towards the top of the investigated section, a shallowing trend is indicated by the increasing importance of encrusting algae and bryozoa in units XI to XV. The presence of abundant *Asterocyclina* in deposits rich in algae suggests a favourable condition for this genus. This habitat differs from the habitat of the lower fore-slope associations. The upward change of *Operculina-Heterostegina*-flat *Nummulites* assemblages to lenticular *Nummulites-Rotalia-Chapmanina* associations reflects a continuation of the shallowing trend, culminating in the appearance of well-washed grainstones in unit XIV. These presumably high energy deposits of barrier or shoal were succeeded upwards by a shallow but relatively sheltered environment, containing abundant (probably allochthonous) rhodolith and other algal remains. The constant nature of the organic content and sedimentary structure of these strata of considerable thickness (more than 13 m) points to an equilibrium of carbonate accumulation and rate of subsidence over a relatively long period at Buco della Rana.

Apart from minor deviations, the depositional history of section Buco della Rana is comparable to that of section Priabona. The main differences are

1. the prevalence of carbonates at Buco della Rana; marly intervals such as occur halfway in the section Priabona are lacking here. This feature is accompanied with a subordinate role of planktonic foraminifera and of bioclastic hash in the open marine facies, while algal fragments occur continuously in these deposits at Buco della Rana
2. the considerable thickness of rhodolith-bearing limestones in the upper part of the section at Buco della Rana.

These differences are best explained by assuming a more proximal position of Buco della Rana relative to the shallow platform habitat.

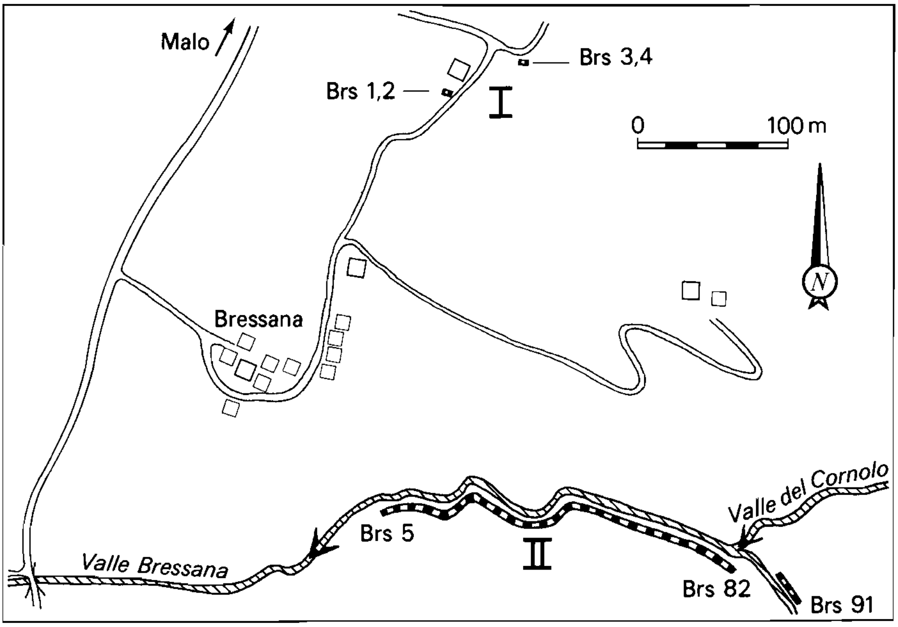


Fig. 9 Location of outcrops and samples at Bressana.

Chapter IV

SECTION BRESSANA

IV.1. GENERAL DESCRIPTION

The section Bressana has a total thickness of about 75 m and consists of two outcrop units. Their position is depicted in figure 9 and a composite lithostratigraphic column is given in figure 10. Our Bressana section is, at least partly, identical to section Ghenderle of Hardenbol (1968).

Outcrop I

This unit consists of two smaller exposures along the country road north of the Bressana hamlet (see fig. 9). The following beds are exposed from bottom to top.

a. Nodular, rather indurate limestone (thickness about 1.5 m), containing abundant *Discocyclina* and *Nummulites*. This level seems to become more clayey in an upward direction. No direct contact has been found with b.

b. Greyish silty marl (thickness 90–100 cm) without visible faunal content; larger foraminifera (Discocyclinidae and *Nummulites*) and bryozoa have been found washed out on the overlying cultivated field.

Outcrop II

The continuously exposed outcrop is located along the Valle Bressana, a small river about 350 m to the south of outcrop I (see fig. 9). The lowest exposed strata have been found at approximately the level of the highest house of Bressana (June 1981). The exposures show greyish silty marls (partly indurated) with incidental intercalations of carbonate beds and of alternating, thinner silty marl-carbonate layers. In general, the indurate beds have a distinct lower contact and show a more gradual transition to the overlying silty marls.

The lithological description of this outcrop concerns mainly the carbonate-bearing levels and their position in the section:

a. Somewhat indurated parts (5.7 to 7.7 m), containing common *Discocyclina, Nummulites* and *Operculina*

b. Thin silty marl layers alternating with carbonate beds (14.5 to 15.7 m)

c. Somewhat indurate carbonates (16.5 to 23 m); very rich in larger foraminifera such as *Asterocyclina, Actinocyclina* and *Discocyclina*. Some pseudonodules consisting of larger foraminifera were found.

d. Indurate carbonate bed (26.7 to 27.4 m).

e. Alternating thin silty marl layers and carbonate beds (31.9 to 43.2 m).

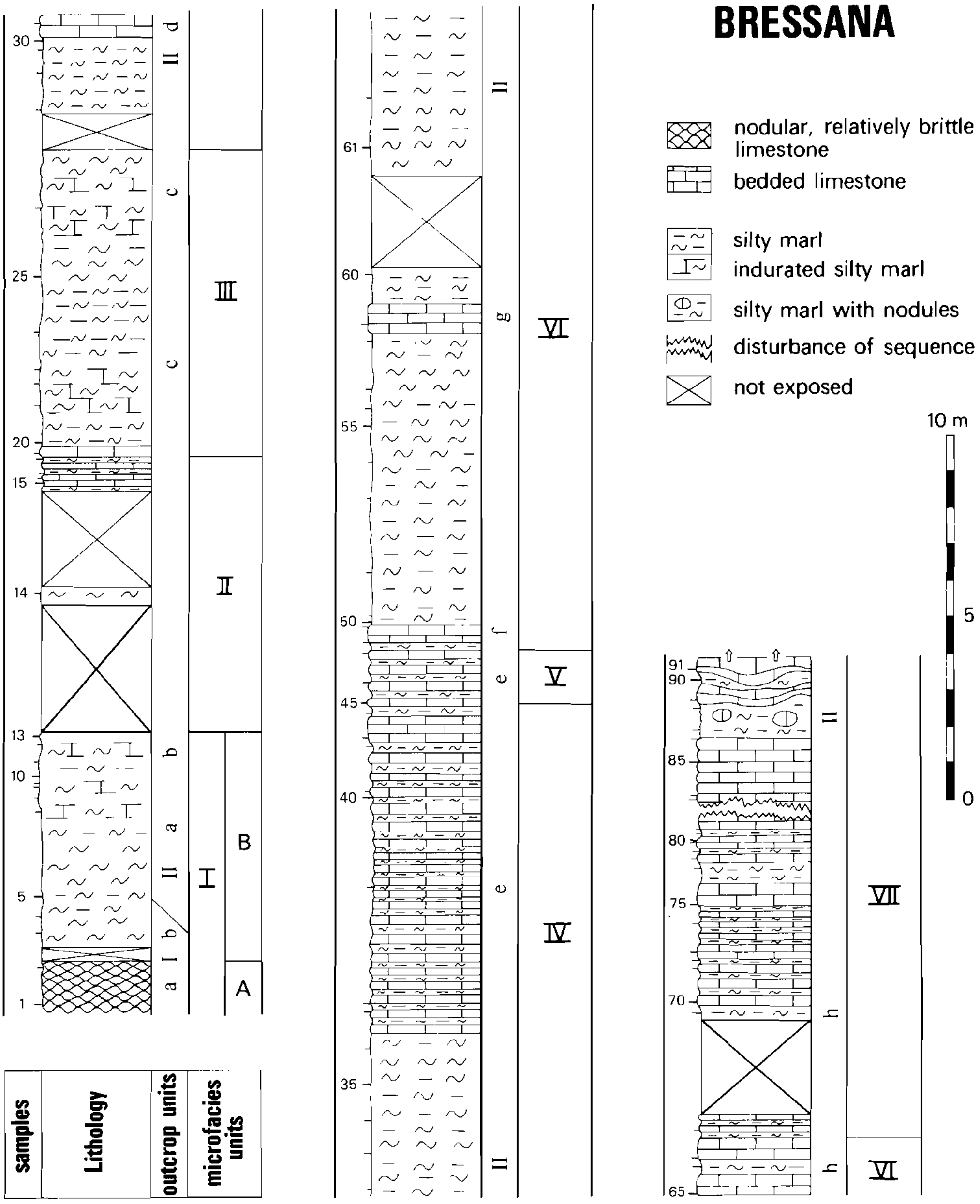


Fig. 10 Composite lithostratigraphic column of section Bressana.

The carbonate beds show a gradual upward increase in thickness from about 10 cm to 80 cm. The thickness of the highest five beds, which are of light colour, ranges from 20 cm to 50 cm.

f. Yellow silty marl (thickness about 25 cm), directly above unit e, very rich in *Operculina.*

g. Indurate carbonate bed (51.2 to 52 m)

h. Alternating silty marls and carbonate beds (60.2 to 70.5 m). The indurated levels as well as the softer layers do not show any trend in thickness, which ranges from 3–4 cm to about 70 cm. In the upper part of this unit, we recognized pinching out of a carbonate bed, containing numerous larger fragments of hydrozoa.

Further upwards the succession of the strata seems to be disturbed. An interesting phenomenon can be observed above the junction with the Valle del Cornolo (see fig. 9), where the strata occur on both sides of the valley. Lithologically they are still comparable with those of unit h but due to the nature of the exposure, at least three channel fills can be distinguished. All channels show an axial direction of about 60 to 70 degrees NE. The strata still higher up are not taken into account.

IV.2. MICROFACIES-UNITS

Seven microfacies-units distinguished in section Bressana will be treated in stratigraphical order. The description mainly pertains to the indurate beds, which in this section are intercalated in marls.

IV.2.1. Microfacies-subunit I A: *Discocyclina-Nummulites rudstone*

Outcrop Ia; samples 1–2; thickness 1.5 m; pl. VI, fig. 1.

Larger foraminifera, especially *Discocyclina* and *Nummulites* associated with *Operculina, Asterocyclina, Actinocyclina* and *Pellatispira,* are abundant. Bioclastic hash and bryozoa occur rather frequently.

The micrite content is high and more or less mixed with dark pelletal material. In the lower part there are microstylolithic contacts or even interpretations of the rather tightly packed grains. This phenomenon was not observed in the more loosely packed upper part.

The next higher subunit shows:

- a change in macrolithology from nodular limestone to silty marl
- a decrease in the quantity of the larger foraminifera and in the quality of their preservation
- a change from rudstone to wackestone.

IV.2.2. Microfacies-subunit I B: *fine bioclastic larger foraminiferal wackestone*

Outcrops Ib and IIa; samples 3–13; thickness 6.3 m.

Blackened and/or badly preserved larger foraminifera occur floating in this highly micritic subunit with a faunal composition that is approximately the same as in the previous subunit. The wackestones also contain a considerable amount of fine bioclastic hash. In some levels gastropods are present.

Boundary criteria in an upward sense are:

- a distinct decrease or even disappearance of larger foraminifera
- a decrease of bioclastic hash
- the appearance of frequent planktonic foraminifera.

IV.2.3. Microfacies-unit II: *foraminiferal wackestone*

Outcrop II; samples 14–18; thickness 7.5 m; pl. VI, fig. 2.

Planktonic and smaller benthonic foraminifera are frequent in this highly micritic to clayey unit. In some levels debris of larger foraminifera occurs.

The upper boundary shows:

- the appearance of bryozoa, *Asterocyclina, Actinocyclina* and *Discocyclina,* and agglutinated foraminifera
- a change from wackestone to packstone-floatstone.

IV.2.4. Microfacies-unit III: *Asterocyclina-Discocyclina bryozoan packstone-floatstone*

Outcrop IIc; samples 19–26; thickness 8.4 m; pl. VI, fig. 3.

Larger foraminifera, such as *Asterocyclina, Discocyclina, Actinocyclina* and *Operculina,* are associated with abundant bryozoa. They are partly concentrated in levels, showing orientation parallel to the bedding and a floating texture. Some pseudo-nodules similar to those found in Priabona are present. Agglutinated foraminifera and spiral forms as well as planktonic foraminifera are common.

The upper boundary is characterized by:

- the disappearance of all larger foraminifera except *Operculina*
- an increase of bryozoa.

IV.2.5. Microfacies-unit IV: *bryozoan foraminiferal packstone*

Outcrop IId–e; samples 27–44; thickness 17.3 m.

In addition to numerous bryozoa, this unit contains smaller benthonic foraminifera, in particular agglutinated forms, and planktonic foraminifera. At certain levels *Eorupertia/Victoriella* occurs rather frequently. *Operculina,* often broken, is common in the lower and uppermost part. Algae and rare *Nummulites* appear in the uppermost reaches.

The upper boundary is to be found at:
- a decrease of bryozoa
- an increase of algae, especially encrusting forms.

IV.2.6. Microfacies-unit V: *algal foraminiferal packstone*

Outcrop IIe; samples 45–47; thickness 1.5 m.

Encrusting algae are the predominant element in this unit. In the lower reaches, long algal filaments tend to show a boundstone-texture. They become less abundant and are smaller in the upper part, where they reveal an orientation parallel to bedding.

Smaller benthonic foraminifera are common, especially agglutinated forms. Planktonic foraminifera are also rather frequent. In bedded intervals, algal-encrusted coral fragments were recognized together with fragments of hydrozoa, gastropoda and ostracoda. Bryozoa are rare.

At the upper boundary we noted:
- a conspicuous decrease of algae
- an increase of bryozoa.

IV.2.7. Microfacies-unit VI: *foraminiferal bryozoan packstone*

Outcrop IIg–h; samples 48–67; thickness 19.3 m.

This unit is very rich in smaller benthonic foraminifera associated with bryozoa. An increase in the number of smaller miliolids takes place in the middle part. Planktonic foraminifera are rather frequent. *Operculina* and *Nummulites* occur in small numbers in the entire unit but become more abundant in the uppermost levels. Fragments of hydrozoa are present in some beds.

Boundary criteria in an upward direction are:
- the re-appearance of abundant algae, particularly of rhodoliths
- a decrease of bryozoa
- a change from packstone to rudstone.

IV.2.8. Microfacies-unit VII: *algal/rhodolith foraminiferal rudstone*

Outcrop IIh; samples 68–91; thickness > 13.0 m; pl. VI, fig. 4.

This highest unit is characterized by the abundance of encrusting algae and algally coated particles of hydrozoa, corals, bryozoa, sponges, oysters and echinoderms. Large debris of hydrozoa is numerous. Entire tests and debris of *Operculina*, associated with *Nummulites* and *Chapmanina* occur at some levels.

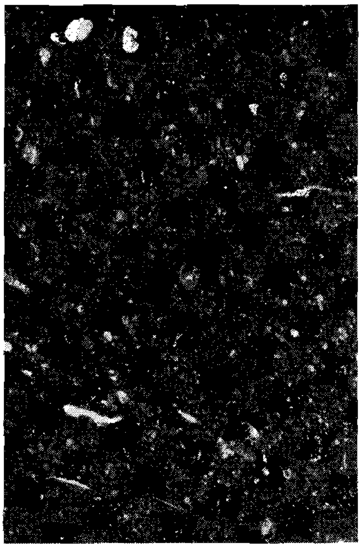
The matrix hardly differs from that of unit VI; it contains frequent smaller benthonic and planktonic foraminifera. The micrite content is higher in this unit.

IV.3. INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS

With its assemblages of abundant and typical larger foraminifera the section Bressana reveals the initial presence of carbonate facies, comparable to those of units II C and II D of section Priabona. Hence, these deposits are equally regarded as open marine fore-slope sediments. As in Priabona there is a trend to a greater depth and lower energy conditions from the basal deposits upwards. From subunit I B up to the highest unit the sedimentary conditions remained essentially constant. Low energy conditions dominated, permitting the settling of silty and clayey material. The frequent planktonic foraminifera point to a persisting open marine, off-shore position. Phases of rapid deposition of carbonate particles, derived from shallower environments, caused the intercalation of carbonate beds. Three channel fills rich in rhodoliths at the top of the section point to a transport direction to the north-east.

Summarizing, the Bressana locality was situated on the north-east slope, away from the shallow, platform-like area of Buco della Rana – Priabona. The upper part of the succession of depositional environments in the latter region may be considered responsible for the succession of microfacies and displaced faunal associations in the limestone intercalations of the Bressana section.

1



2

3

4

Fig. 1 Loosely packed *Discocyclina* sp. and *Nummulites* sp. in rudstone in upper part of subunit I A (sample Brs. 2). Top of layer above top of photo, 4 X.

Fig. 2 Foraminiferal wackestone containing planktonic specimens of unit II (sample Brs. 15). Top of layer left of photo, 12 X.

Fig. 3 Section showing orientation of *Asterocyclina* sp., *Actinocyclina* sp. and *Discocyclina* sp. in pseudo-nodule of unit III (sample Brs. 21). Top of layer above top of photo, 3 X.

Fig. 4 Rhodoliths and miliolid foraminifera in rudstone of unit VII (sample Brs. 91). Top of layer above top of photo, 4 X.

samples	total specimens counted	Textularia spp.	Spiroplectammina spp.	Valvulina triangularis	Clavulina parisiensis	Gaudryina rugosa	miscel. agglut. foraminifera	Quinqueloculina spp.	Pyrgo bulloides	Miliolidae	Lagena spp.	Nodosaria/Dentalina spp.	Lentic./Astac./Marginulina spp.	Polymorphinidae	Bolivinella spp.	Fissurina spp.	Buliminella pulchra	Buliminella turbinata	Buliminella spp.	Sphaeroidina bulloides	Bulimina spp.	Bolivina nobilis	Bolivina spp.	Reussella recurvata	Reussella spinulosa	Reussella spp.	Uvigerina eocaena	Trifarina spp.	Discorbis spp.	Rosalina douvillei	Rosalina limbata	Rosalina obvoluta	Discorbinae	Laticarinina altocamerata	Baggina dentata	Cancris primitivus	Cancris subconicus	Glabratella spp.	Siphonina reticulata	Asterigerina brencei	Asterigerina aberystwythi	Asterigerina spp.	Spirillinidae	Ammonia spp.	Pararotalia spp.	Protelphidium sp.	Elphidium latidorsatum	Eponides spp.	Neoeponides schreibersii	Cibicides lobatulus	Cibicides carinatus/westi	Cibicides tenellus	Cibicides sulzensis	Cibicides dutemplei	Maslinella chapmani	Fursenkoina schreibersiana	Globocassidulina globosa	Nonionidae	Alabamina perlata	Alabamina obtusa	Gyroidina spp.	Anomalina acuta/alazanensis	Anomalina grosserugosa	Boldia lobata	Melonis affinis	Queraltina epistominoides	Schlosserina asterites	larger foraminifera	miscellaneous	indeterminable	total specimens counted	samples
90	258	6	7	8		2	5		12	28		1	2										2	3	7			1	11	13		2	26		2								23				3			31	16	24					2	1			1		4			1				16	259	90
88	235	12	7			3	4	16	8		1						2				2		2		7			2	7	19		2	32		3						1	2	28				1	4		27	1	18					3	1			7		7	2		1			1	2	235	88
81	271	14	6	2		3	29						4				2				2		2	1	12			7	2	5		6	18									10	12		17	5	5			11		40		3			5	5			7	1		4	6	18				9	271	81
78	226	10	2			6	29	1			1		4				1				3				14			2		9		2	15			1		2				4	27		16		3			7		34		1			1	1		3	6				1	17			1	5	226	78
76	242	18	8	1		5	13	1			1	1	5			1	1				3		5		12			2		10			10					3				3	12		10		4			20		42				1	5	3		6	7			2	4	14				9	242	76
72	199	5	1	3			12	1			5	3	2				3					1	4	1	6			3	4	1	2		7				1				3	4	3			3		2		22		47		2			8	1	1	2	8	3	4		6	7				8	199	72
69	211	10	8	8		9	2	1			2		1									2	3	1	6			3		8			20			2	1	2				18	12		5		2			38		16								7	11		7			4				2	211	69
66	201	9	3	5		4	15			4	2	1	4	1			4					1	3	3	8			7	1	1	1		4		2	1	3	1			5		3			4		1		19		39	1	4		3	2	2			7	4	1			3		2		13	201	66
63	267	7					18			5		1	2		5		12	12			4		6	1				6	6	6	3		48					3			7		6	25	5	22	7			16	2	4		7		2	3			1	4	8				3					267	63
62	237	2				1	8			29	1		1	1	1	4	8	11	1		4	1	4	5	27			1	9	4		3			1			9			7		2	21	1	10	7		2	16		3		3		2		3			1	1		6		4			2	10	237	62
61	307	10	2				29		2	54	2	2	1	2	1	6	2	3			4	2	6	3	34			6	8		1	1			1	1					13		4	13	1	3	9	2		21		11	1	2		2	11	3			7	4		11		4				2	307	61
60	304	35	8				15			59	9	3	4	4		3					3		1	3	1					6			1				1	3			13		1	1	1		1	3		25		22		27		5		17			10				2	9				8	304	60
58	479	6	3	5			4			80		2	1		18		34	6	5		21		3	16	49	1		2	14		7	3	16			1		25			12	4	6	43	3	9	11	2		14		7		2		2	1	7	4		1			8	4	1			2	4	479	58
57	524	1	1			2	3			164	1		3	1	10	1	33	14	5		21	1	4	13	60			3	18	1	10	2	11		1			16			11		3	24	1	14	4	6		14	2	13		2		2	2	6			1			5	4	1				7	524	57
55	376	10	7	3			3			68	1	1			3	3	15	4			24	3	3	14	45			2	10	8	9	3	3		1			6			7		5	16		5	6	1		29	2	18		5		2	5	6	2		8			8		1			1	1	376	55
54	476	12	5	6			6			102	1	2	1	1	5	1	25	10	1		8	3	6	11	40			3	12	12	11	4	8		3		1	14	1		7	2	12	14	4	7	8	3		36	1	20				1	4	10	3	1	2	1	2	11		1			1	10	476	54
53	458	2	8	4			7			98	4	2	4		7	3	25	11	2		8	1	8	14	46	8		5			8	5	7		8	2	1	8			7	3	10	4	1	15	4	1	1	29	2	27	1	2		1	8	7	5		7		4	5	2				3	3	458	53
52	446		28	7		2	12			35	6	4	6	1		4	1				3	2	8	17	9			18		4	16	4	5		17			1					6	3	3		2	6		46	1	64	4	1		3	38	7	7	2	28	3	4							8	446	52
51	295	3	10				16			4	6		3	1					1		2	3	7	3	6			23			8	15	2		12							1	1	2	1	2		3		43	3	54	2	2		3	26	6		2	13		2	1	2					7	295	51
50	290	6	10	1		5	8			7	4	1	2	3		1					5	4	7		4			14			6	9	3		3	2						5				2				38	3	78		1		2	13	4		5	19	2			2	2		3		6	290	50
42	253	1	8			1	5				3	2				1									3			22		6	6	11			2						1	2	20		3					40		78		1		1	1	3		4	10	1	5		6					6	253	42
40	268	1	3				2									5							6		3			11		3		11	18		3				1		1	2	16		4	3		3		49		80		4		1	7	2	2		8	2	6							11	268	40
37	217	1	2	1	2	2	2				3												3		5			7		4	3	12	18						4		3		7					6		35		62		3			2	2	1	2	6	1	6		2					10	217	37
36	231		2	2			3	1			1		2			1				1			11					11		2	4	3	26		1						3	1	2		2	1		8		49	1	56		3			5	2	3		9	3	3		1					8	231	36
35	227	1	1		1		6				2	1	1	3							3		14		2			7	1		8	9	12						2	2	1		2					11		59	2	47					5	1	4	2	6		3		3					5	227	35
34	269	2	4	1	2		10				5	3	1	2		3					1	1	15					16		1	4	12	2						3		6	2	9					8		52		53					15	4	3	2	12	6	3		3					3	269	34
33	231	2	8	6	4		4	1			3	2	7	2		1							11		1			14		3	6	3							2				4		1			17		34		60				2	2	4	4	5	7	3	4		4					5	231	33
32	338		21	1	4		3				3	3	1	1							1		10		1		5	30			5	5	7		2				4		6		1				1	8		32		120		2		2	3		2	5	17	5	6		4	1				13	338	32
30	360	4	6			8	31				1	5	8	4		2				2	2	2	5	1	6			21			5	10	9		7	1					4							17		60		63		8			4	4	9		12	2	10					13	1	10	360	30
29	353	7	13	2		1	31	4			5	2	7	2		1					2	1	1					15		4	18	9	21		2	1			4		2	3	10					17		51	4	51		5		5	3	4		1	12	4	3		4			7	2	12	353	29
28	266	9	5	1		1	7	5			1	3	3	1						1		2	4	5	1		1	17		7	15	21	7		4	1			2		8	1	3		1	1		9		29	3	42		3			1	2	3	2	16	2	7		3				1	5	266	28
27	336	7	1			7	4	4			6	2	7			1					10	1	7	1	1	1		37			6	14	25		3	1					8		2		3	2		15		36	9	67		4		2	4	3	4		10	1	5		3				5	7	336	27
25	255		3	2		1	7				2	1	3			1						1	5		2			23		2	9	17	2		5						3		5		1			16		38		58					13	3	3	4	5	3	6					4		7	255	25
24	216	1	3					2			6		3			3						2	4		2	3				8	2	17	12		5							2	6					5		53	4	46	2			1	2	4	2		6		2	2	4					2	216	24
23	264	4	1	1		2		1			5		2			1				1	1	2	7		1			25		6	3	17	5		8				1		4		3					8		45	5	58		5		1	5	3	6		11		2		4					10	264	23
20	225	5				1	3	2			1		3	1		1					4	1	4					10		3	11	13	6		7						5					1		4	1	53		43	8	2		2		1	4		10	1	1		5			1		7	225	20
18	341		18				3				2		2								4	4	8				10	39				2	2		9						3		1		1	1		2	1	31		133	12	4				1	1		10	8	3	1	11	1		1	1	11	341	18
16	618		14				7	2			5	4	5	3		1					5	20	12	2	1	1	8	55		2		5			3	3			2		16				1			8	3	99	5	120	32			1	2	5	8		58	7	15		4	49		6	6	13	618	16
14	283	5					1	6			2		4	1		2				2	3	1	15	2			9	8	2	2		1	2		4				1	4	9		2					1	2	22		57		9			15		1	3	20	11	1	1	12	12		12		16	283	14
13	240	3	3	2			7	6			2		2	2		10					12	1	9				19	10				1			4	3				1	6					2		2	2	10	1	43		6		3	8	1	3		14	11	2		11	5		9		4	240	13
12	258	1	3				1	6			3	1	1	2		7					2	1	13				30	6				1	2		1				2		14							2	1	12	2	49		3		2	32	4	1		28	4			9	2			2	8	258	12
9	225	2	2	1							1	2				2					1	2	8	4	1				1				6			2	4			1	4		2		2			2		14	4	55		5		2		5			13	26			41		1	7		2	225	9
7	382		4	3			4	2			2	1	1	6		6				7	11	4	20	1	6			5	1		1	4			3	4	1		2	7	5				1	1		5		33	5	102		15		3	12	3	5	3	21	10			24	7		13	3	6	382	7
6	221	7	5				1	2			2		2			2				2	4	2	17		8			6				1	3		1				1		2	2	2				1	2		15		50				5	1	5	1		21	6			19	16		9		3	221	6
5	332		7				4	30			6		6	4		9				10	6	2	9		1			7					2	1							10	10								13	1	54		32		5	4	6	1		14	15			36	7	1	9		10	332	5
4	244							6				1	4								3		16		4		1	4				4	2	10	4						5		11				1			11		54		18		5		1	1		23	13			13	24		2	1		244	4
3	209						4	3			1					2					1	1	15	1			2	2	1					2	3						2		2				1	2		9		34		15	3	6	6	4		1	36	13			9	8	11	3		4	209	3

TABLE I: Distribution chart of the benthonic foraminifera of section Bressana (fraction $< 600\ \mu$).

Chapter V

BENTHONIC FORAMINIFERA

Eighty-one samples from (silty) marls intercalated between the limestones were used for our quantitative faunal analyses. From the Priabona section we collected 34 samples, derived from the interval corresponding to the microfacies-(sub)units II D to V (total thickness about 42 m). From the Bressana section we used 47 samples, ranging through the microfacies-(sub)units I B to VII (total thickness 73 m). The position and the spacing of the samples is shown in figures 11 and 17. All these samples contained rich faunas of smaller foraminifera and some of them also contained larger foraminifera. These two groups will be treated separately.

V.I. SMALLER BENTHONIC FORAMINIFERA

V.1.1. Introduction

Many elements of the foraminiferal associations have been recorded from the Eocene of the Paris Basin (Le Calvez, 1970; Murray & Wright, 1974), from the Hampshire Basin and the English Channel (Murray & Wright, 1974) and from the Eocene-Oligocene of Belgium (Batjes, 1958; Kaasschieter, 1961). Others are mainly known from more southern areas.

For our counting procedures we used the 125 μ to 600 μ fraction of each sample. Between 200 and 400 specimens per sample were identified and counted. Preservation was so bad in some samples that determination of the specimens had to be limited to the generic or even to subfamily level.

Throughout both sections the P/B-ratio remains persistently low; commonly it is below 0.1. Range charts of all taxa are given in tables I and II. The frequency patterns of the most common species or taxa groups are shown in figures 11 and 17.

V.1.2. Quantitative analyses

Statistical analyses of the counting data were carried out on the Cyber computer of the Academic Computer Centre of the University. For our R-mode analyses we used the DISTUR and BALANC computer programs of M. M. Drooger. We refer to the paper of M. M. Drooger (1982) for the theoretical considerations concerning the resulting correlations and trends based on proportions. Our results are presented in correlation matrices (figs. 12, 13, 18 and 19) and for the Bressana data in spider-web diagrams (figs. 14 and 15) and one dendrogram (fig. 16). The latter was based on the DENDRO program of M. M. Drooger.

We selected 20 categories for the statistical analyses of the benthonic foraminiferal frequency data for both the Priabona and Bressana sections. These categories are either the most frequent taxa (groups) or they are combinations of less numerous taxa which were thought to have had comparable habitats. They are:

1. *Melonis affinis*;
2. *Queraltina epistominoides*;
3. *Anomalina* spp. (excluding *A. grosserugosa*);
4. *Gyroidina* spp.;
5. *Fursenkoina schreibersiana*;
6. *Cibicides dutemplei*;
7. *Cibicides tenellus* (*C. sulzensis* included);
8. *Cibicides lobatulus* (*C. westi* and *C. carinatus* included);
9. all agglutinated foraminifera;
10. *Trifarina* spp.;
11. Discorbinae;
12. Spirillinidae;
13. *Eponides* spp.;
14. *Reussella* spp.;
15. *Asterigerina* spp.;
16. Miliolidae;
17. *Bolivina* spp.;
18. *Globocassidulina globosa*;
19. all larger foraminifera found in the < 600 μ residues and
20. the group of remaining taxa called Miscellaneous.

The groups Miscellaneous of Bressana and Priabona are markedly different. In Bressana the group is dominated by species of *Elphidium, Pararotalia, Ammonia, Boldia, Bolivinella* and *Buliminella* which are very frequent in only a part of the section. These taxa probably had very similar habitats in shallow water. In section Priabona the Miscellaneous category is less diverse and of a different composition; *Laticarinina altocamerata, Schlosserina asterites, Cancris subconicus* and *Maslinella chapmani* are the main components of this category. The frequencies of some elements of the Miscellaneous group are shown in figures 11 and 17.

After the computer analyses had been carried out there was some doubt about the homogeneity of some of our categories with regard to the habitat of their components. For instance we feel less certain now that our groupings of *Cibicides lobatulus* and *Cibicides tenellus* give a distinct habitat separation. For the *Bolivina* spp. a mixture is more acceptable, while it is reasonable to suppose that the categories Miliolidae and agglutinated foraminifera are too broad to indicate a limited habitat. The group of larger foraminiferal juveniles may not have much ecological significance either.

Because the frequency patterns are more regular throughout section Bressana than in Priabona, we assumed that the analyses of the data from the former section would give a better grouping as to environment, i.e. with less influence of time-bound stratigraphic distribution.

V.1.3. Section Bressana

The application of the DISTUR program to our data (figs. 12 and 14) results in a rather clear-cut taxa grouping. There are two main groups (I and II), the second of which shows three subgroups (IIa, b and c).

Group I is composed of the categories: *Melonis affinis, Anomalina* spp., *Cibicides dutemplei, Fursenkoina schreibersiana, Gyroidina* spp., *Bolivina* spp., larger foraminifera and *Queraltina epistominoides.* They show a variable number of mutually positive correlations. Most taxa of this group have negative correlations with the category Discorbinae of group IIb and with two of the taxa of group IIc, but none have negative correlations at 1% level with the elements of group IIa. In contrast we see some positive correlations between *Bolivina* spp. and *Gyroidina* spp. of group I with *C. tenellus* of group IIa.

Group II seems to consist of three subgroups.

Group IIa comprises *C. lobatulus, C. tenellus, Trifarina* spp. and *Eponides* spp. The three first-mentioned taxa show several negative correlations at 1% level with the elements of group IIc. A positive link is present between *C. tenellus* and the categories *Gyroidina* spp. and *Bolivina* spp. belonging to group I, and between *C. lobatulus* and the Discorbinae of group IIb.

The agglutinated foraminifera, Spirillinidae and Discorbinae constitute group IIb. Especially the Discorbinae have negative correlations with the majority of the species of group I, and the positive correlation between the Discorbinae and *C. lobatulus* is the only positive link between groups IIa and IIb. There is no significant correlation either way between elements of IIb and IIc.

Finally, *Reussella* spp., the Miliolidae and the Miscellaneous category form group IIc; this subgroup shows negative links with group IIa as well as with group I, but no positive correlation in any direction.

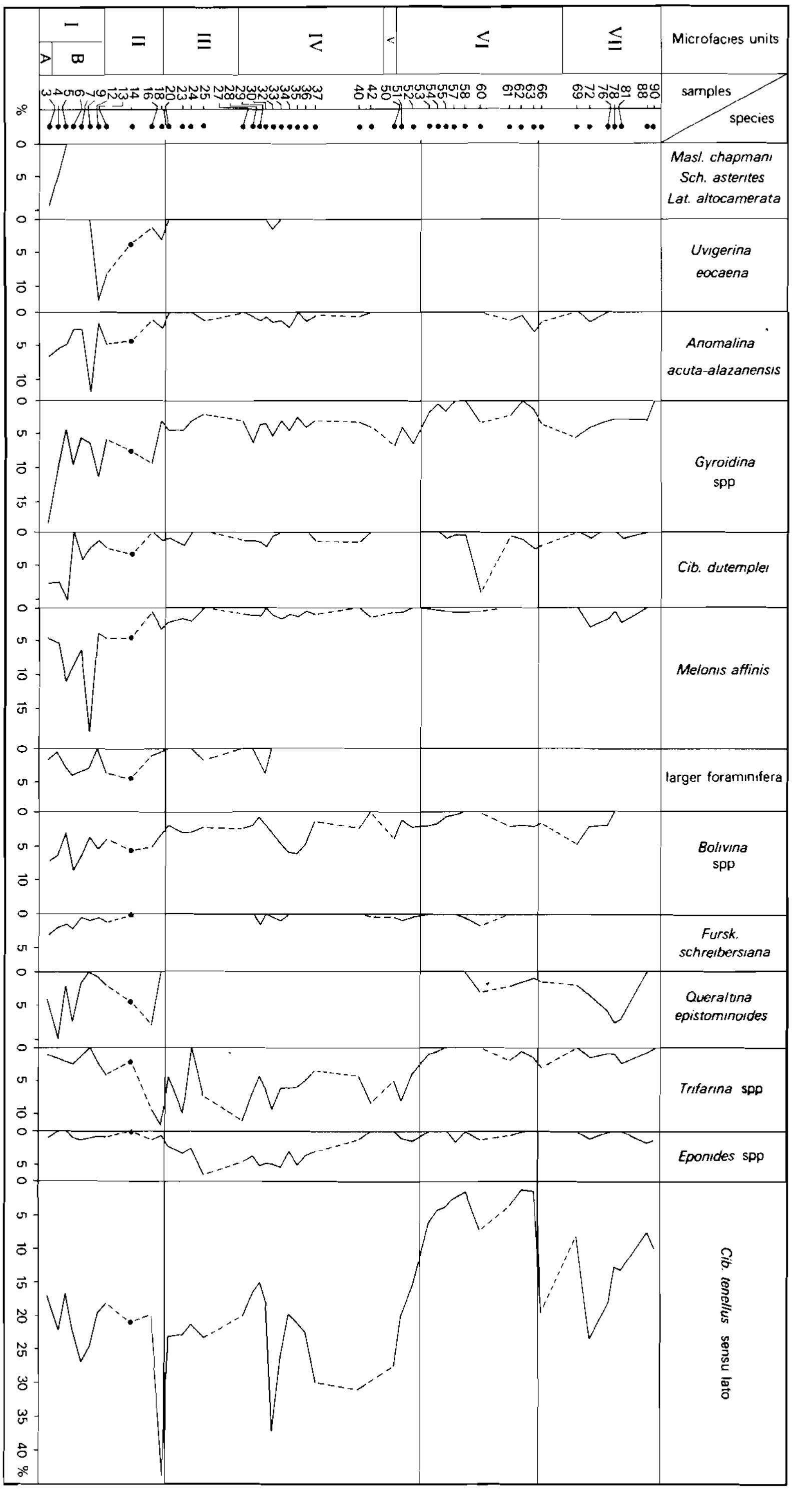
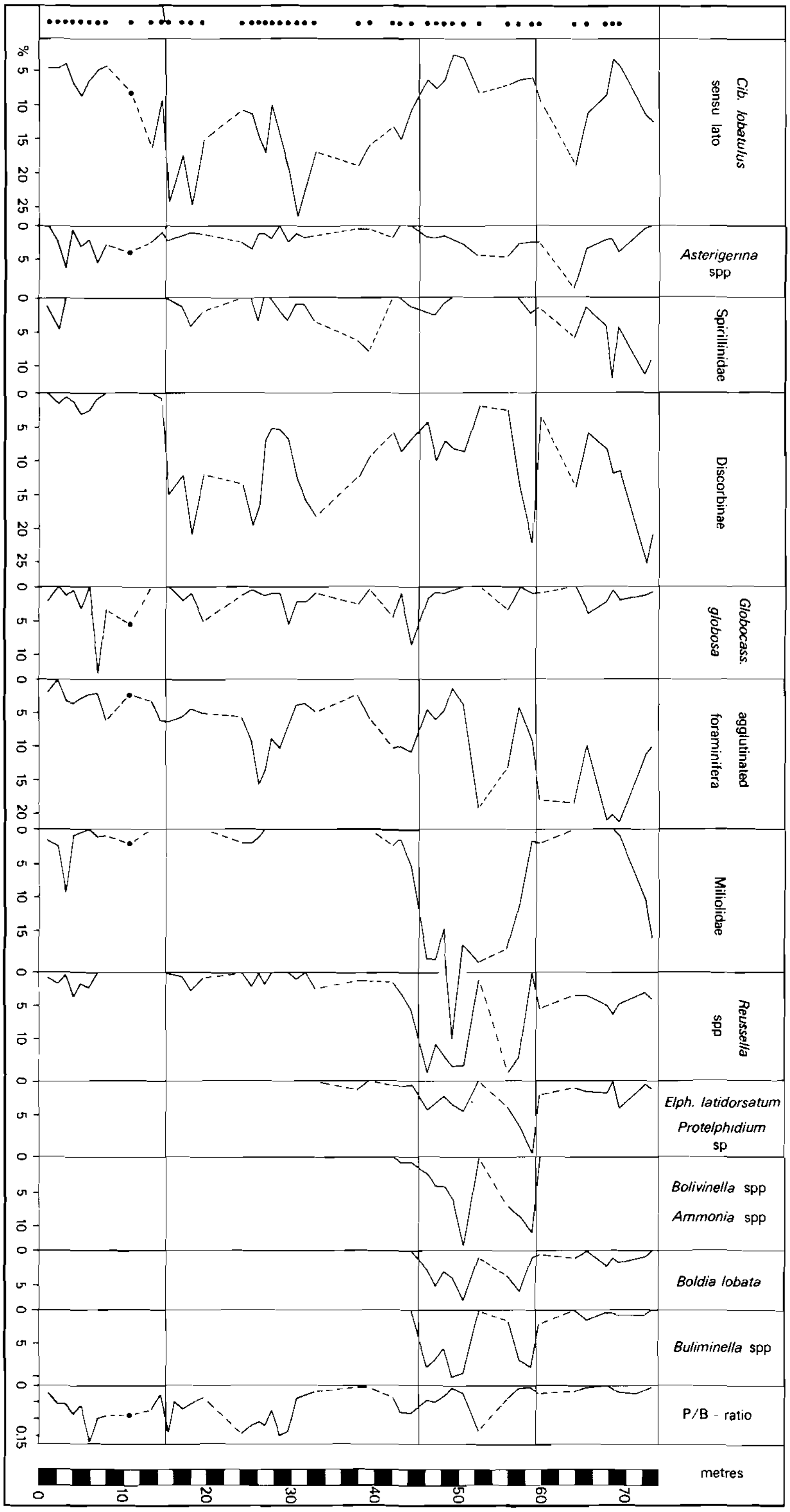
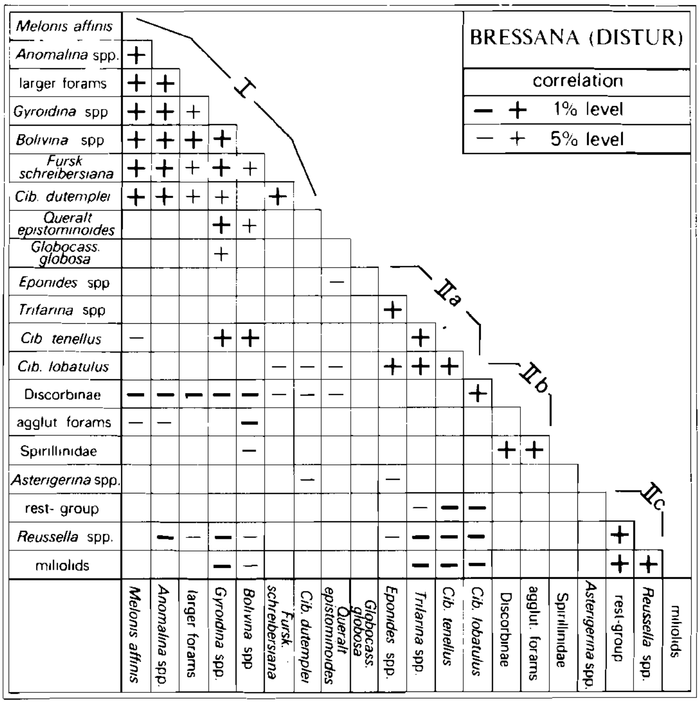


Fig. 11 Relative frequencies of benthonic foraminifera of section Bressana. Horizontal lines indicate the subdivision of the section into foraminiferal zones.


%
0
5
10
15
20
25
Cib. lobatulus sensu lato
Asterigerina spp
Spirillinidae
Discorbinae
Globocass. globosa
agglutinated foraminifera
Miliolidae
Reussella spp
Elph. latidorsatum
Protelphidium sp
Bolivinella spp
Ammonia spp
Boldia lobata
Buliminella spp
P/B - ratio
0.15
metres
0
10
20
30
40
50
60
70

A comparable grouping of the taxa appears from the BALANC output (figures 13 and 15). The application of this program resulted in the disappearance of nearly all negative correlations produced by the DISTUR program. Actually the sums of all negative and all positive correlations remain of the same order of magnitude, but the negative correlations become of more equal value, although they do not reach the 5% significance limit. This phenomenon is difficult to explain but we suppose that there is a ground-mass of random numerical contributions of most categories caused by sedimentary mixing, above which the most autochthonous elements stand out owing to their positive correlations. The results of a cluster analysis (unweighted pair group method; program DENDRO) are visualized in the dendrogram of fig. 16. The dendrogram clearly shows group I and the three subgroups of group II. Only the Discorbinae now figure in group IIa with which they already had a link in the DISTUR output.



BRESSANA (DISTUR)

correlation

— **+** 1% level

— + 5% level

	Melonis affinis	*Anomalina* spp.	larger forams	*Gyroidina* spp.	*Bolivina* spp	*Fursk. schreibersiana*	*Cib. dutemplei*	*Queralt epistominoides*	*Globocass. globosa*	*Eponides* spp.	*Trifarina* spp.	*Cib. tenellus*	*Cib. lobatulus*	Discorbinae	agglut. forams	Spirillinidae	*Asterigerina* spp.	rest-group	*Reussella* spp.	miliolids
Melonis affinis																				
Anomalina spp.	**+**																			
larger forams	**+**	**+**																		
Gyroidina spp	**+**	**+**	+																	
Bolivina spp	**+**	**+**	**+**	**+**																
Fursk schreibersiana	**+**	**+**	+	**+**	+															
Cib. dutemplei	**+**	**+**	+	+		**+**														
Queralt epistominoides				**+**	+															
Globocass. globosa				+																
Eponides spp								—												
Trifarina spp										**+**										
Cib tenellus	—			**+**	**+**						**+**									
Cib. lobatulus						—	—	—		**+**	**+**	**+**								
Discorbinae	**—**	**—**	**—**	**—**	**—**	—	—	—					**+**							
agglut forams	—	—			**—**															
Spirillinidae					—									**+**	**+**					
Asterigerina spp.							—			—										
rest- group											—	**—**	**—**							
Reussella spp.		**—**	—	**—**	—					—	**—**	**—**	**—**					**+**		
miliolids				**—**	—						**—**	**—**	**—**					**+**	**+**	

Fig. 12 Matrix of correlation coefficients of the benthonic foraminiferal frequency data from section Bressana derived from the DISTUR output.

Group I contains the same categories as in the DISTUR output. Now the larger foraminifera join *Queraltina epistominoides* in being more loosely attached to group I and these taxa are responsible for most of the negative correlations with group II.

Group II appears from the BALANC matrix as well, as do the subgroups IIa, IIb and IIc. The positive correlation between group IIa (*C. tenellus*) and group I (*Bolivina* spp.) still exists. Only one negative correlation between the taxa of the three subgroups was found, that between the Miliolidae (group IIc) and *C. tenellus* (group IIa). *Asterigerina* spp. (mainly *A. aberystwythi*) now shows positive links with subgroups IIb and IIc.

V.1.3.1. *Presumed environmental significance of the four taxa groups*

Although the DISTUR and BALANC outputs of the Bressana frequency data give a consistent pattern, the interpretation in terms of environment is rather difficult. This is due to the fact that most of the taxa are extinct and that some of the taxa groups may be too heterogeneous.

BRESSANA (BALANC)

correlation

– **+** 1% level

– + 5% level

	Melonis affinis	*Anomalina* spp.	larger forams	*Gyroidina* spp.	*Bolivina* spp.	*Fursk. schreibersiana*	*Cib. dutemplei*	*Queralt. epistominoides*	*Globocass. globosa*	*Eponides* spp.	*Trifarina* spp.	*Cib. tenellus*	*Cib. lobatulus*	Discorbinae	agglut. forams	Spirillinidae	*Asterigerina* spp.	rest-group	*Reussella* spp.	miliolids
Melonis affinis																				
Anomalina spp.	**+**																			
larger forams	**+**	**+**																		
Gyroidina spp.	+	**+**																		
Bolivina spp.	**+**	**+**	+	**+**																
Fursk. schreibersiana	+	**+**		**+**	+															
Cib. dutemplei	+	**+**		+		**+**														
Queralt. epistominoides				+																
Globocass. globosa																				
Eponides spp.								–												
Trifarina spp.										**+**										
Cib. tenellus					+					+	**+**									
Cib. lobatulus								–		**+**	**+**	**+**								
Discorbinae			–							**+**			**+**							
agglut. forams					–									**+**						
Spirillinidae														**+**	**+**					
Asterigerina spp.															+					
rest- group														**+**	+		**+**			
Reussella spp.														+	+			**+**		
miliolids												–					+	**+**	**+**	

Fig. 13 Matrix of correlation coefficients of the benthonic foraminiferal frequency data from section Bressana derived from the BALANC output.

Considering the components of groups I and II, the general opposition seems to be understandable. As far as we can estimate the habitat of these components it seems safe to conclude that group II is vegetation-bound, whereas the *Melonis* group I contains a combination of mud-dwellers in a low-energy environment.

However, in both groups we find elements whose position is remarkable. For one thing we would not have expected that the larger foraminifera would join the mud-dwellers group; for *Discocyclina* this is still understandable but not for *Asterocyclina*, which is thought to have preferred vegetated habitats (see V.2.4.). These conclusions were also drawn by Fermont (1982). The fact that we are dealing with juveniles (< 600 μ) and with undifferentiated heterogeneous larger foraminiferal associations, may be held responsible for the remarkable position in the spider-webs.

For another thing we might have expected the rest-group Miscellaneous to have been associated with the mud-dwellers, as it commonly is in this type of analysis (M. M. Drooger & Hageman, 1979); it is in our Priabona section

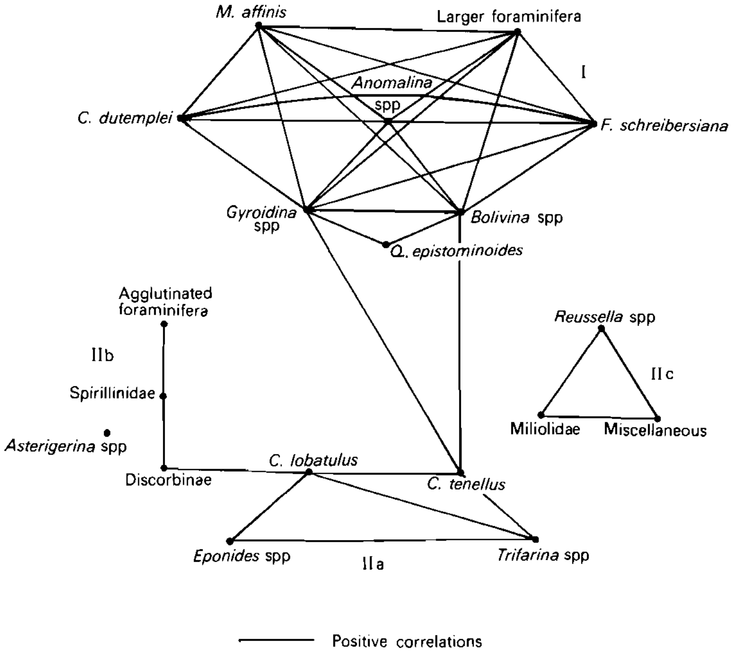


Fig. 14 Spider-web diagram of the benthonic foraminiferal frequency data from section Bressana according to the DISTUR output. The negative correlations have not been entered.

(V.1.4.). For Bressana the composition of this rest-group, mentioned already above, makes the link to the vegetation-bound group easy to understand.

It is much more difficult to give an interpretation of the three subgroups of the vegetation-linked fauna. Especially the computer output of BALANC suggests a serial arrangement from the *Melonis* group I, via the *C. lobatulus* subgroup IIa and the Spirillinidae subgroup IIb to the Miliolidae subgroup IIc. One might suppose that this order corresponds to an increase in environmental energy, which for the three associations IIa–c that lived on and be-

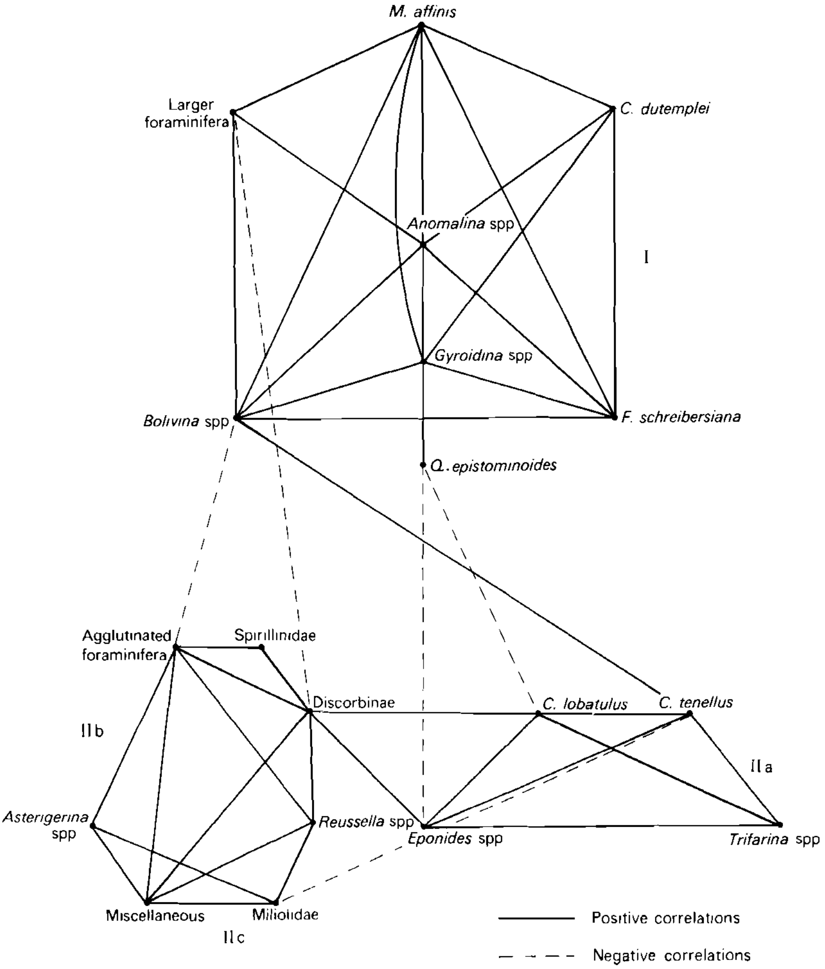


Fig. 15 Spider-web diagram of the benthonic foraminiferal frequency data from section Bressana according to the BALANC output

tween the vegetation, was not necessarily caused by a decrease in water depth. Unknown differences in the plant-associations may have been another factor and finally it cannot be ruled out that some kind of restriction of the habitat (salinity increase?) favoured the group of the Miliolidae, *Reussella, Elphidium* and other rotaliids, *Boldia, Bolivinella* and *Buliminella.* The subgroup IIb with the Spirillinidae and various agglutinated species is understood least of all; maybe we are dealing with yet another mode of habitat restriction.

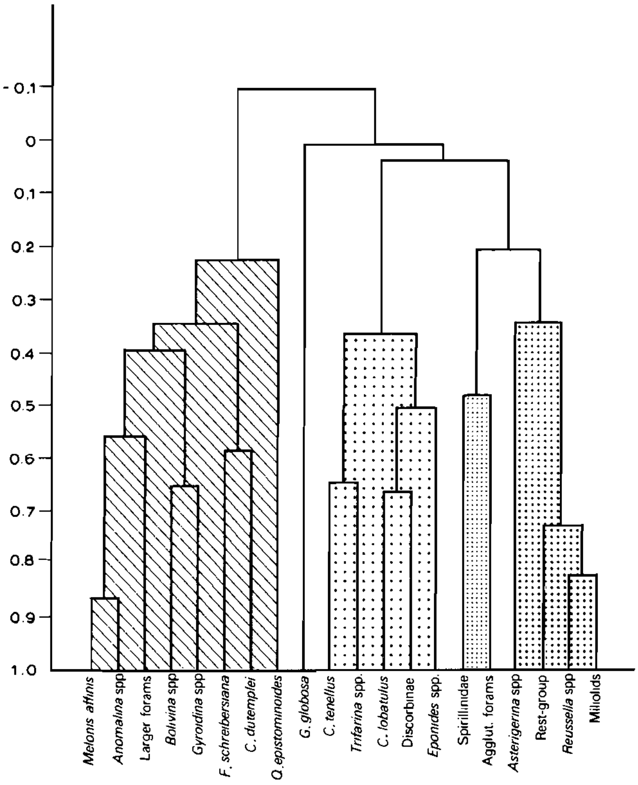


Fig. 16 Dendrogram of the Bressana taxa based on the unweighted pair group method of the BALANC correlation matrix.

V.1.3.2. *Zonation of the Bressana section*

A visual inspection of the frequency distribution (fig. 11) of the faunal associations permits a rough subdivision of section Bressana into four zones, each one characterized by its own, though strongly variable faunal composition. The characteristic elements of these faunas are considered to be (par)-autochthonous because of their frequency dominance.

The lowermost zone, designated as *Melonis* Zone corresponds with microfacies-units I and II. In this interval we found a high number of taxa of the *Melonis* group, but the faunal composition differs from sample to sample. *Uvigerina eocaena*, species of *Schlosserina, Laticarinina* and *Maslinella*, and large typical specimens of *Bolivina nobilis* and *Spiroplectammina carinata* are restricted to this interval. It also contains large specimens of the *Globigerina eocaena*-group. The faunas point to an off-shore position and a muddy environment.

The overlying *Cibicides lobatulus*-Discorbinae Zone, which corresponds to microfacies-units III, IV, V and the lower part of unit VI, shows a frequency drop for the *Melonis* group and the frequent occurrence of the taxa of the *C. lobatulus* group IIa and the Discorbinae of group IIb. This faunal difference relative to the lowermost zone may point to a shallowing, and certainly indicates a strong increase in bottom vegetation.

The Miliolidae Zone in the middle part of microfacies-unit VI is very distinct owing to the strong increase in taxa belonging to the Miliolid group IIc. In addition to *Reussella* species the group Miscellaneous is particularly frequent and it is dominated by species of *Bolivinella, Buliminella, Ammonia, Elphidium* and *Protelphidium*, and by *Boldia lobata* and *Glabratella* spp. We might conclude that this fauna reflects an increase of energy due to a continued shallowing and/or a change in vegetation type. The large numbers of miliolids and rotaliids may even point to some kind of restriction of the area, for instance caused by a salinity increase behind a carbonate build-up, situated further off-shore.

In the uppermost zone, named as agglutinant Zone (upper part of microfacies-unit VI and unit VII) there is not such a clear faunal characterization. There are strongly variable mixtures of elements of all three vegetation-bound subgroups. The taxa of subgroup IIb, especially the agglutinated foraminifera predominate slightly. Some elements of group I (e.g. *Queraltina epistominoides* and *Melonis affinis*) re-appear or become more frequent again. The faunal composition of this zone is hard to interpret; anyway the peculiar habitat of the underlying Miliolidae zone seems to have disappeared from the Bressana location. The decrease of environmental energy does not necessarily mean that we have to conclude that there was a renewed depth increase; quieter conditions could have been brought about at constant shallow depth as well.

V.1.4. Section Priabona

The analyses of the species frequency patterns of the Priabona section by the computer programs DISTUR and BALANC clearly indicate the existence

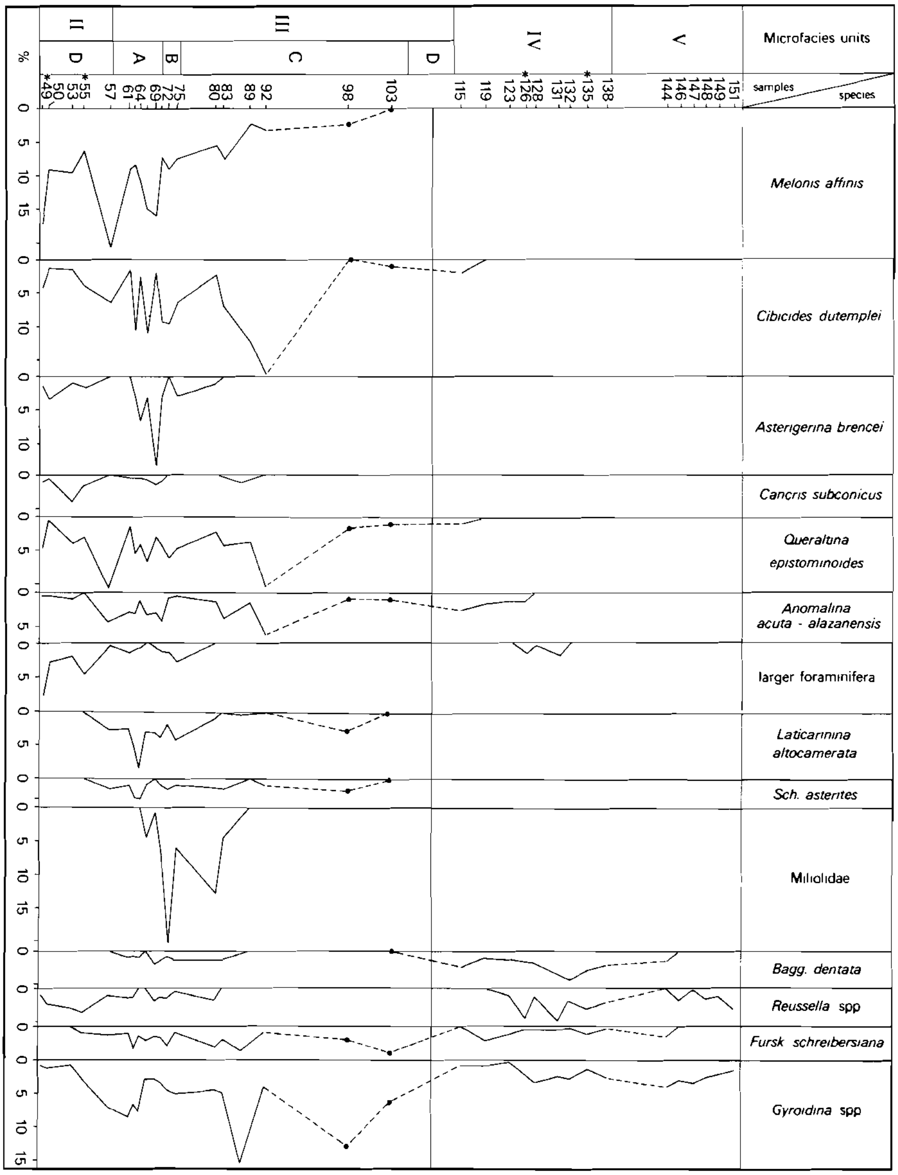
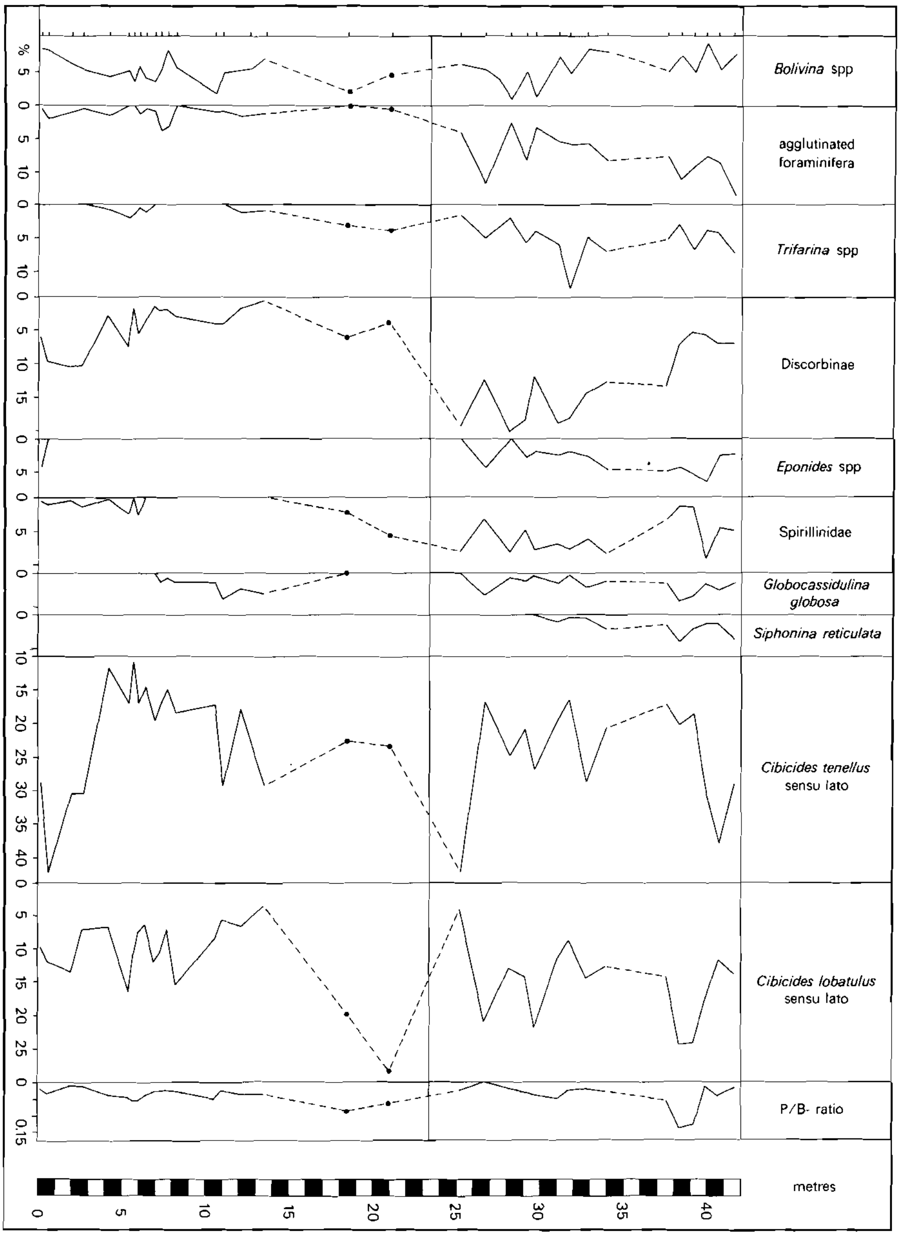


Fig. 17 Relative frequencies of benthonic foraminifera in section Priabona. The horizontal line indicates the subdivision of the section into two foraminiferal zones.


%
Bolivina spp
agglutinated foraminifera
Trifarina spp
Discorbinae
Eponides spp
Spirillinidae
Globocassidulina globosa
Siphonina reticulata
Cibicides tenellus sensu lato
Cibicides lobatulus sensu lato
P/B- ratio
0.15
metres
0
5
10
15
20
25
30
35
40

of two groups of taxa (figs. 18 and 19). These two clusters are comparable to groups I and II recognized in the Bressana section.

The mud-dwellers group I contains with many mutual positive correlations *Queraltina epistominoides*, *Cibicides dutemplei*, *Anomalina* spp., *Melonis affinis*, *Fursenkoina* spp. and *Gyroidina* spp. The vegetation-group II comprises the Discorbinae, Spirillinidae, agglutinated foraminifera, *Eponides* spp., *Trifarina* spp. and *Cibicides lobatulus*. The remaining eight taxa (groups) are connected with rather few ties with one or the other of these two groups.

The miliolids and the group Miscellaneous which belonged to group II of the Bressana section now have positive correlations with group II. However, the composition of the group Miscellaneous is different from that of the Bressana section. The peculiar position of the Miliolidae may have been caused by its stratigraphic distribution in the Priabona section (see fig. 17) where its isolated peak may indicate an environmental spell which is not recognized otherwise by our analyses. The single positive link of *Asterigerina* spp. with group I may be explained in a similar way. The larger foraminifera of Pria-

PRIABONA (DISTUR)

correlation	
— **+**	1% level
— +	5% level

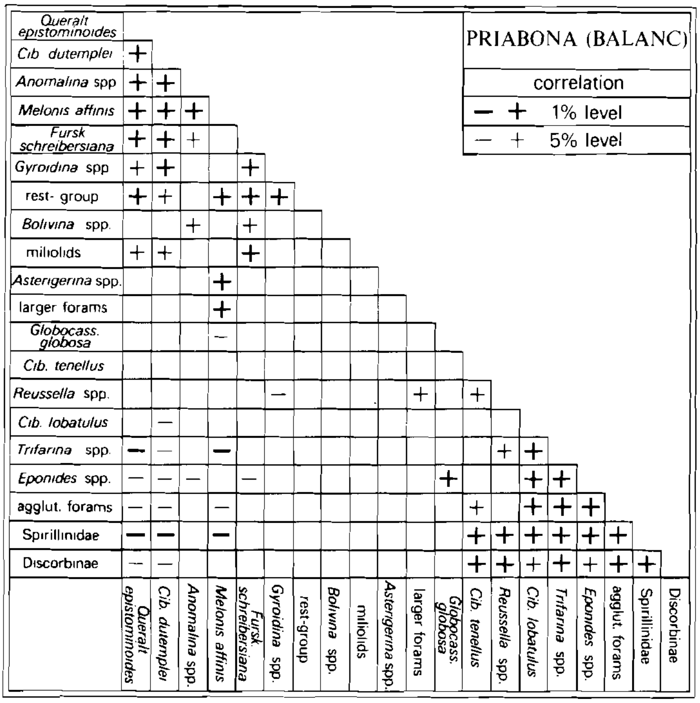
	Queralt. epistominoides	*Cib. dutemplei*	*Anomalina* spp.	*Melonis affinis*	*Fursk. schreibersiana*	*Gyroidina* spp.	rest-group	*Bolivina* spp.	miliolids	*Asterigerina* spp.	larger forams	*Globocass. globosa*	*Cib. tenellus*	*Reussella* spp.	*Cib. lobatulus*	*Trifarina* spp.	*Eponides* spp.	agglut. forams	Spirillinidae	Discorbinae
Queralt. epistominoides																				
Cib. dutemplei	**+**																			
Anomalina spp.	**+**	**+**																		
Melonis affinis	**+**	**+**	**+**																	
Fursk. schreibersiana	+	**+**																		
Gyroidina spp.	+	**+**			**+**															
rest- group	+			+	**+**	**+**														
Bolivina spp.					+		+													
miliolids		+			**+**															
Asterigerina spp.				**+**																
larger forams				**+**																
Globocass. globosa				**—**						—	—									
Cib. tenellus					**—**	—														
Reussella spp.		—	—		—	**—**	**—**													
Cib. lobatulus	**—**	**—**	**—**	—																
Trifarina spp.	**—**	**—**	**—**	**—**	—					—	—				**+**					
Eponides spp.	**—**	**—**	**—**	**—**	**—**							**+**			**+**	**+**				
agglut. forams	**—**	**—**	**—**	**—**	**—**	—				—	—	**+**			**+**	**+**	**+**			
Spirillinidae	**—**	**—**	**—**	**—**	**—**	—	—						+	+		**+**	+	**+**		
Discorbinae	**—**	**—**	**—**	**—**	**—**	**—**							**+**	**+**		**+**		**+**	**+**	

Fig. 18 Matrix of correlation coefficients of the benthonic foraminiferal frequency data from section Priabona derived from the DISTUR output.

bona have an ambiguous position in the computer outputs in that they show single positive ties to both groups I and II.

As in Bressana *Reussella* spp. and *C. tenellus* are linked to group II and now *Globocassidulina globosa* too joins this vegetation-bound association.

On the basis of the Priabona data little needs to be added to the environmental explanation given for the Bressana faunas. Both main associations are recognized again, but there are two major differences. Firstly, it is impossible to separate the three subgroups in the vegetation realm. The combination of Miliolids and the peculiarly constituted Miscellaneous taxa group of Bressana is not clearly represented in Priabona. The vegetation-bound faunas are more homogeneous here, possibly pointing to fewer differences in plant associations or to their more varied composition. However, we may be dealing with an artefact of the computer analyses arising from the more restricted number of sampled units (see V.1.5.). Secondly, the BALANC output does not give the extreme reduction in the number of significant negative correlations, although it remains true that the DISTUR output gives more. This might



PRIABONA (BALANC)

correlation

− + 1% level

− + 5% level

	Queralt epistominoides	*Cib. dutemplei*	*Anomalina* spp.	*Melonis affinis*	*Fursk. schreibersiana*	*Gyroidina* spp.	rest-group	*Bolivina* spp.	miliolids	*Asterigerina* spp.	larger forams	*Globocass. globosa*	*Cib. tenellus*	*Reussella* spp.	*Cib. lobatulus*	*Trifarina* spp.	*Eponides* spp.	agglut. forams	Spirillinidae	Discorbinae
Queralt epistominoides																				
Cib dutemplei	**+**																			
Anomalina spp	**+**	**+**																		
Melonis affinis	**+**	**+**	**+**																	
Fursk schreibersiana	**+**	**+**	+																	
Gyroidina spp	+	**+**			**+**															
rest- group	**+**	+		**+**	**+**	**+**														
Bolivina spp.			+		+															
miliolids	+	+			**+**															
Asterigerina spp.				**+**																
larger forams				**+**																
Globocass. globosa				−																
Cib. tenellus																				
Reussella spp.						−					+		+							
Cib. lobatulus		−																		
Trifarina spp.	**−**	−		**−**										+	**+**					
Eponides spp.	−	−	−		−							**+**			**+**	**+**				
agglut. forams	−	−		−									+		**+**	**+**	**+**			
Spirillinidae	**−**	**−**		**−**									**+**	**+**	**+**	**+**	**+**	**+**		
Discorbinae	−	−											**+**	**+**	+	**+**	+	**+**	**+**	

Fig. 19 Matrix of correlation coefficients of the benthonic foraminiferal frequency data from section Priabona derived from the BALANC output.

49	50	53	55	57	61	63	64	66	69	70	72	75	80	83	89	92	98	103	115	119	123	126	128	131	132	135	138	144	146	147	148	149	151	samples
234	216	209	303	267	206	371	419	267	336	242	267	221	226	244	262	347	247	197	210	193	254	244	216	205	255	272	230	275	232	347	240	243	283	total specimens counted
	1	1	1					1			1							1	5	9		4			1	5	9	1	2		3	1	4	*Textularia* spp.
1	1			4			2			3	2				2					6	1	6	3	5	7	4	2	13	2	2	3	9	12	*Spiroplectammina* spp.
	1						1														1	5	2	1				4	1	3	4	4	8	*Valvulina triangularis*
																													3	11	4	2	5	*Clavulina parisiensis*
		1						1		1	2								1	3									4	1			3	*Gaudryina rugosa*
	1		1			1	2	1	3	5	4		2	2	2			1	5	5	5	5	2	5	8	6	8	3	16	15	4	6	6	miscel. agglut. foraminifera
	1	1				1	2								1	4								2		1	1		1			1		*Quinqueloculina* spp.
								17	2	16	53	13	28	11																				Miliolidae
1	1	1	5	2	1	8	5	2	1	2	2		4	3	3	1	2	2		2	2	1			4	2	1	3	4	5	1		6	*Lagena* spp.
		1	3	6	1	1	3	3	2			2			5	1			1					1		1	1	3		4		1	3	*Nodosaria/Dentalina* spp.
2	1	1		3	2		3	3		2			9	4	3	7	2			2	3				1	2	3	4	3	6	8	5	1	*Lentic./Astac./Marginulina* spp.
1	2			3		6	6	4	5	2		3	3	2	2		3	1										2	4	2		1		Polymorphinidae
																										2					1			*Buliminella* spp.
3	3				2				3	3	2	1	4	2	4			5			1		1	1			1		3	7		2		*Bulimina* spp.
		4		2	1	5		3	3	1	2		3	1	1	3	2		1	2	2		1		2			1	1					*Bolivina nobilis*
4	4	4	14	13	9	19	18	13	19	10	3	10	15	12	11	9	16	10	7	7	20	12	17	6	12	5	5	13	8	18	2	9	7	*Bolivina* spp.
2	5	6	11	3	3	5		1	7	3	4	1	4					1	1		4	9	3	10	5	8	5		4	1	4	3	9	*Reussella* spp.
								3							2		1											1						*Uvigerina eocaena*
			1	2	4	5	2	3	1		1	1	2		3	3	7	9	3	9	5	14	8	12	31	13	16	14	7	23	9	10	20	*Trifarina* spp.
1	1	6	4	2	1		13	2	1			2			3	1	1	2	10	3		2	2	7		4	6	4				2	4	*Discorbis* spp.
1	2	5	3			1	4								2		6	2	2	1	8		1		1		2				1	3		*Rosalina douvillei*
2	1	2	9	1	9	2	3	1		2	2	2	7				3	3	20	4	9	12		5	19	17	3	12	9	10	3	3	5	*Rosalina limbata*
3	16	5	11	5	4	3	2	4	1	3	3	2	2	8		2			3	8	8	21	15	16	22	11	3	16	6	6	7	10	4	*Rosalina obvoluta*
5		3	4		1				5	2							4	2	2	7	25	10	7	10	4	6	15	5	2	2	3	4	6	Discorbinae
1		1		7	5	18	34	1	2	3	5	9	2		1		6																	*Laticarinina altocamerata*
		1			2	1	4		7	3	2	3	3	3					5		3	4	4	7	11	8	5	7						*Baggina dentata*
2	2	1	3							1			2		1		1											3						*Cancris primitivus*
2	1	8	5			3	3	2		1					3																			*Cancris subconicus*
								2		1			1			2				1		1		2	1	1	5	4	9	7	3	4	10	*Siphonina reticulata*
3	7	2	5			11	26	8	45	7		6	2			3																		*Asterigerina brencei*
1		2	1	1	1	13	4						4		1			1		4	2				2		6				3	1		*Asterigerina* spp.
1	2	3	4	1	5		10			3	2		1	1			5	11	16	6	20	12	16	16	19	15	19	8	3	5	21	11	14	Spirillinidae
						1																							2	1	2			*Ammonia* spp.
				2			3								1			1			1			1		1	1	1				2	1	*Pararotalia* spp.
					2		1				2	2							1		4	2	1			2	1						1	*Protelphidium* sp.
		1	1						2	3	1			3	5																			*Elphidium latidorsatum*
9		1			1	3	2						2				3			8		7	4	5	5	7	11	13	10	19	15	6	7	*Eponides* spp.
						3									7	15									1									*Neoeponides schreibersii*
15	13	14	9	16	33	35	16	14	29	21	14	24	15	12	16	10	37	39	6	35	31	27	33	14	21	33	26	36	47	61	30	21	34	*Cibicides lobatulus*
6	12	13	15	2	1	5	14	3	9	4	5	9	4	2	2	2	8	11	2	4	1	8	7	9	1	6	3	3	3	13	5	7	4	*Cibicides carinatus/westi*
62	88	61	90	31	35	39	71	39	57	37	39	39	36	70	46	95	50	41	79	28	61	51	55	37	42	69	44	39	42	47	62	85	76	*Cibicides tenellus*
									9	3			2		3	4	1			3			1	3		2	3	8	4	17	8	4	4	*Cibicides sulzensis*
9	3	5	12	17	3	38	10	29	7	22	25	14	5	17	33	58		2	4		1			1										*Cibicides dutemplei*
1			1	4																														*Maslinella chapmani*
1		2	3	3	2	12	6	6	5	4	8	2	7	5	10	3	4	7		4	3	1	1	1	1	3	1	4						*Fursenkoina schreibersiana*
										3	2	3	3	9	6	11				6	2	3	1	3	1	6	3	4	9	12	4	6	4	*Globocassidulina globosa*
6	6	9	15	5	8	13	12	6	12	8	7	8	5	5	4	1	11	10		7	4	4	1	4	7	4	1	3	4	2		2		Nonionidae
	3		3	5	3	1	7	11	5	3		2	1		12	12		1	3	2	1	1	9	3		3	3	20	1	12	4	1	6	*Alabamina perlata*
3					1			3		1	2			9		6			1	2	2	4	1		2	2		2	7	6	4	1		*Alabamina obtusa*
2	3	1	9	19	17	24	32	8	10	8	12	13	10	12	41	14	29	11	2	2	1	6	7	5	7	4	6	11	7	12	6	5	4	*Gyroidina* spp.
1	1	2		12	6	12	5	9	10	10	2	1	3	9	4	21	2	2	5	3	3	3	1	1	1	1	1			3				*Anomalina acuta/alazanensis*
						2	2		1			3	1		4		6		2	2	5	1		1	4		3	6	1	5	4	1	2	*Anomalina grosserugosa*
					2		2										1		1		1						1							*Boldia lobata*
37	19	19	19	54	18	30	45	40	54	17	24	16	12	18	2	11	5		1				1	2		1	1		1	3	1			*Melonis affinis*
10	1	8	9	28	5	20	17	18	10	10	16	10	5	10	10	35	4	7	2			1												*Queraltina epistominoides*
			1	4	2	10	12	5	1	2	4	2	3	4		3	4							2										*Schlosserina asterites*
16	6	4	14	1	3	4	3		4	3	4	6			1						1	4	1	4			1							larger foraminifera
1					1																													*Victoriella abnormis*
17	12	8	9	8	9	10	5	3		9	7	8	7	7		9	22	17	21	8	9	2	10	3	5	13	3		2	3	11	9	9	indeterminable
		4	6	1	5	4	7	3	4		3	4	8	3	8	1	1	2		1	4	1			7	4			2	3		3	4	miscellaneous
234	216	209	303	267	206	371	419	267	336	242	267	221	226	244	262	347	247	197	210	193	254	244	216	205	255	272	230	273	232	347	240	243	283	total specimens counted
49	50	53	55	57	61	63	64	66	69	70	72	75	80	83	89	92	98	103	115	119	123	126	128	131	132	135	138	144	146	147	148	149	151	samples

TABLE II: Distribution chart of the benthonic foraminifera of section Priabona (fraction < 600 μ).

mean that the Priabona area received fewer random contributions of allochthonous elements than the Bressana location.

V.1.4.1. *Ecological interpretation*

As a whole, a normal marine, sparsely vegetated, mainly muddy and low-energy environment may be regarded as the habitat of the foraminiferal associations in our lower zone (see below). Submarine vegetation may have been present in the lower part (microfacies-subunit II D), but it diminished or disappeared in an upward sense probably as a result of increasing water depth, leaving a muddy environment. The occasional high frequencies of the miliolids in the upper part of the lower zone and to a lesser extent of *Asterigerina brencei* seem to be in contradiction with such a muddy, low-energy environment. However, the bad preservation may point to an allochthonous origin. This assumption is corroborated by the occurrence of skeletal pseudonodules of inferred allochthonous origin at the same level (see II.2.2.8.).

As in the Bressana section, the great increase in relative frequencies of the vegetation-bound faunal elements in our upper zone may be explained by a strongly increased density of submarine vegetation. The typical mud-dwellers association of the lower zone has vanished, much more completely than in the Bressana section. Yet, there remain various low-energy forms (*Fursenkoina, Gyroidina*) and elements of the IIa association of Bressana which probably thrived in muddy subenvironments under and in between the vegetation. Assisted by abundant bryozoa (see. II.2.12.) the suggested dense submarine vegetation probably was an important factor in stabilizing the fine sediments. A well vegetated platform-like area seems to correspond with our upper Priabona zone.

V.1.4.2. *Zonation of the Priabona section*

On the basis of the frequency pattern (fig. 17) the Priabona section can be subdivided visually into two distinct stratigraphic parts, each with a typical benthonic foraminiferal association.

The lower *Melonis* Zone corresponding to our microfacies-units II D, III A, III B and III C/III D, is characterized by a predominance of taxa belonging to the *Melonis* group. The group Miscellaneous of this section which shows a distinct presence in this lower zone only consists mainly of *Laticarinina altocamerata, Schlosserina asterites, Cancris subconicus* and *Maslinella chapmani.* Elements of group II are regularly present in the lower zone, but their relative numbers are fairly low. However, in some samples of the microfacies-unit II D (*Discocyclina* beds) at the bottom of the chart, *Cibicides tenellus* and the Discorbinae are very well represented.

Miliolids are very common in microfacies-unit III B and in the lower part of unit III C. Most of them are badly preserved. Although less distinct, *Asterigerina* spp. (mainly *A. brencei*) tend to show the same distribution pattern and they are also badly preserved.

Taxa of group II are the prevalent benthonic foraminiferal components in the upper *Cibicides lobatulus*-Discorbinae Zone from which several taxa of group I have completely disappeared. Only *Gyroidina* spp. and *Fursenkoina* spp. are persistently present, although in relatively low frequencies. *Siphonina reticulata*, which is counted under the group Miscellaneous, shows an increase in relative frequency, especially in microfacies-unit V.

V.1.5. Correlation of both sections

The zones recognized in both sections do not permit an easy correlation of chronostratigraphic value. Before we can establish a satisfactory best fit we need two extra assumptions.

1. Our associations I and II of the computer analyses could be translated into terms of deeper and shallower.

2. During the Priabonian the area considered here had a habitat gradient and depth gradient (slope) on which the Bressana location was further offshore than that of Priabona.

On the basis of the first assumption we can recognize a shallowing trend in both sections, at Bressana between microfacies-units II and III and in the Priabona section somewhere between III C and III D. Below this vague datum line the faunas of both localities are dominated by similar mud-dwellers associations. Above it there are vegetation-bound associations which at Bressana seem to contain more elements of the earlier mud-controlled fauna than at Priabona. If there is time equivalence this seems to be logical against the background of the second assumption about the environmental gradient.

In the Priabona section the lower fauna is preceded by a fauna with vegetation elements (II D). This points to a transgressive phase between II D and III A, which fits in with the idea of a transgression corresponding to the lower part of the Priabonian. If this conclusion is correct, the transgressive phase cannot be recognized in the Bressana data. Unit II D of Priabona would correlate with some part of the Bressana section below the interval from which we analysed the marl samples.

In the top part of the Bressana section we find the Miliolidae zone, which contains a more specialized vegetation-fauna (higher energy and/or salinity increase) which need not necessarily reflect a further regression. This fauna cannot be recognized in any association of our Priabona suite of samples. We have to conclude that the Miliolidae zone of Bressana, and as a consequence the topmost zone of this section as well, have no counterpart in the sample series of Priabona (up to microfacies-unit V). If the second assumption of the local gradient or slope is correct we can expect the strata of both upper Bressana zones (from the upper part of microfacies-unit VI and higher) and the limestones of microfacies-unit V and higher in the Priabona section to be time-equivalent.

V.2. LARGER FORAMINIFERA

V.2.1. Introduction

The classical deposits of the Priabonian are known to contain a diverse fauna of larger foraminifera. The larger foraminifera are not evenly distributed over the entire section; they are abundant in some parts and totally absent in others. Many authors have provided lists of names of species accompanied by some paleontological documentation (Gümbel, 1868; Oppenheim, 1901; Douvillé, 1922; Schweighäuser, 1954; Roveda, 1961; Sirotti, 1978). The main groups in the faunas are the Nummulitidae and Discocyclinidae.

The larger-than-600 μ fraction was used for our counting. We selected samples containing fairly large numbers of larger foraminifera. Fifteen samples from section Priabona and eighteen samples from Bressana section appeared suitable for our purpose. Between 200 and 300 specimens per sample – apart from a few exceptions – were identified and counted. The resulting distribution charts of the taxa are given in table III for section Bressana, and in table IV for section Priabona.

Because of the relatively small number of samples and their relatively wide and irregular spacing in both sections, our counting data should be regarded as an approximation of the vertical distribution of the larger foraminifera.

V.2.2. The taxa or groups recognized

The family Discocyclinidae is represented by three genera: *Discocyclina, Asterocyclina* and *Actinocyclina.* In some cases the juvenile individuals of these taxa were hard to separate. In many such cases we had to restrict our determination to the family level.

Three morphological groups could be distinguished among the specimens of *Discocyclina:* the *dispansa, papyracea* and *sella* groups (see V.2.5.7.). In several samples we also found relatively frequent indeterminable juveniles of *Discocyclina.*

microfacies-units	samples	total specimens counted	*Discocyclina* (*papyracea*-group)	*Discocyclina* (*dispansa*-group)	indeterminable *Discocyclina*	*Asterocyclina* (*stellaris*-group)	*Asterocyclina* (*stellata*/*stella*-group)	indeterminable *Asterocyclina*	*Actinocyclina radians*	indeterminable Discocyclinidae	lenticular *Nummulites*	flat *Nummulites*	*Operculina alpina*	*Heterostegina heterostegina*	*Spiroclypeus granulosus*	*Sphaerogypsina globulus*	Miscellaneous
VII	81	226									13	181	7	4			21
	76	218									25	165	9	6			13
	72	58										50					8
VI	66	215									45	151				12	7
	61	222									15	185	4				18
	60	142									3	129	2	3			5
	58	241									24	97	48	49			23
	53	201									7	49	42	78		3	22
	50	199									9	34	49	74		23	10
IV	27	252		19						11			27	165		6	24
III	25	203		65	2	30	15	44	4	19			4	4		4	12
	20	216	7	56	6	14	1	70	2	37			5	2		3	13
II	16	215	2	152				3		7			2	17	7	13	19
	14	195	67	15				4		7	56		26				13
I B	13	216	51	47						27	56		26				9
	9	205	45	30				5	4	15	48		32		25		1
	4	199	6	25						70	87						11
	3	244	8	23	7			5		102	83		1				15

TABLE III: Distribution chart of the benthonic larger foraminifera of section Bressana (fraction > 600 μ).

microfacies-units	samples	total specimens counted	*Discocyclina* (*papyracea*-group)	*Discocyclina* (*dispansa*-group)	*Discocyclina* (*sella*-group)	indeterminable *Discocyclina*	*Asterocyclina* (*stellaris*-group)	*Asterocyclina* (*stellata*/*stella*-group)	indeterminable *Asterocyclina*	*Actinocyclina radians*	indeterminable Discocyclinidae	lenticular *Nummulites*	*Operculina alpina*	*Heterostegina heterostegina*	*Spiroclypeus granulosus*	*Pellatispira madaraszi*	*Sphaerogypsina globulus*	Miscellaneous
V	146	117		22								1						94
IV	135	213	1	18		3	56	24	14	11	6		16	35			3	26
	132	145		19		6	42	22	10	2	8	1	2	7			5	21
	128	219		39	2	19	33	17	5	8	18	7	16	27			5	23
	126	304	3	80		8	82	13	44	8	11	3	14	32			1	5
	123	209	9	37		4	42	20	30	5	4		11	22			2	26
	115	196		27		4	60		4	3	66		12	4				16
III B	75	278	8	21	2	39			3	3	20	111	40		6			25
III A	70	220	4	8		46	1		3		32	76	28		12			10
	69	276		25		75	2	1			15	88	50		6			14
	64	345	6	26		95			1		17	100	22		10			68
II D	55	467	52	81	13	18	30		12	2	56	105	29	5	56	3	2	3
	53	347	63	33	39	39	8		16	3	24	97	7		14			4
	50	353	91	31	42	55	18	2	11	17	17	26	5		10	2		2
	49	473	77	34	22	4	44	4	54	18	61	64	35	2	40	12	2	

TABLE IV: Distribution chart of the benthonic larger foraminifera of section Priabona (fraction > 600 μ).

Asterocyclina shows two major external groups: the *stellaris* and *stellata/stella* groups (see V.2.5.3.). Juvenile and broken specimens are rather frequent in some samples; they were counted under the genus name.

The third genus, *Actinocyclina,* is of low frequency. The specimens fit in with the typological description of *Actinocyclina radians* (d'Archiac).

Nummulites is the most abundant genus of the Nummulitidae in our material. The specimens represent a variable group often with vague boundaries between "species". Three major groups were distinguished on the basis of the ornamentation pattern and the shape of the test.

1. *fabianii*-group: The distinct reticulate pattern on both sides of the test made us refer three specimens found in section Priabona (a single specimen in sample Pr. 70 and two in sample Pr. 55) to *N. fabianii* (Prever). They are relatively small (diameter about 3 mm; thickness about 1.3 mm) with a blunt periphery. It is remarkable that we found so few of these index fossils for the Priabonian in the sequence of marl samples.

2. *incrassatus*-group: In this group we united individuals with a diameter of about 2 to 4 mm having the following characteristics in common. Mostly they have distinct radiate patterns; in fairly well preserved specimens a vague granulation was observed as additional ornamentation in the central part of the test. In other specimens the radiate pattern becomes indistinct towards the central part, which seems to have a knob-like structure. This feature might be due to abrasion during or after deposition, however. The periphery varies from thin to thick and blunt. The specimens of this external group could be assigned to a variety of species (names): *N. incrassatus* de La Harpe, *N. chavannesi* de la Harpe, *N. garnieri* de la Harpe, *N. budensis* Hantken and *N. stellatus* Roveda. Rather flat specimens with a vague radiate pattern occur in the upper part of section Bressana; in some cases they were difficult to separate from our *bouillei*-group (see below).

3. *bouillei*-group: This group contains relatively small specimens (diameter 1.5–2 mm). The most characteristic feature is the flatness of the test, which causes a resemblance with *Operculina.* However, the involute coiling and the gradual increase in height of the chambers made us assign these specimens to *Nummulites.* Radiate patterns are not always easy to recognize. The names *N. bouillei* de la Harpe and *N. budensis* Hantken may be applied to our individuals.

Operculina, Heterostegina, and *Spiroclypeus* are the remaining genera of the family Nummulitidae. *Pellatispira* is also present. Except for the specimens of *Spiroclypeus,* which vary in the degree of development of lateral chambers, these taxa do not show a wide variation in their external morphology. *Operculina alpina* Douvillé, *Heterostegina heterostegina* Silvestri, *Spiroclypeus granulosus* (Boussac) and *Pellatispira madaraszi* (Hantken) are considered to be present in our material.

In the group Miscellaneous we united specimens larger than 600 μ of various smaller foraminifera and of some low-frequent larger foraminifera such as *Chapmanina*. In the frequency distribution specimens assigned to *Sphaerogypsina globulus* (Reuss) were mentioned separately.

The composition of the Miscellaneous group is variable and often differs from sample to sample. In the middle part of section Priabona (samples Pr. 64–Pr. 75) we noted *Maslinella chapmani, Schlosserina asterites, Neoeponides schreibersii* and *Victoriella abnormis,* whereas in the upper part (samples Pr. 115–Pr. 146) *Textularia agglutinans, Eponides ocalana, Lenticulina* sp., *Victoriella abnormis* and *Lingulina glabra* are the major elements. In the lower part of section Bressana (Brs. 3–Brs. 16) the group Miscellaneous contains *Neoeponides schreibersii, Lenticulina* sp., *Quinqueloculina* sp., and *Queraltina epistominoides.* From the sample Brs. 20 upwards we found *Textularia agglutinans, Eponides ocalana, Victoriella abnormis* and *Chapmanina* spp., *Sphaerogypsina* sp. is more or less restricted to the middle part of the section (samples Brs. 16–Brs. 50) while *Victoriella* and *Chapmanina* are more frequent in the upper part.

V.2.3. **Zonation of the sections**

Although our counting data represent a scattered record of the larger foraminifera associations, their patterns allow a rough subdivision into zones for both sections.

Section Bressana

We recognize three zones:

1. *Discocyclina-Nummulites* Zone, which corresponds to the samples of microfacies-units I B and II, and to the *Melonis* Zone of the smaller foraminifera (see V.1.3.2.). It is characterized by frequent *Discocyclina* (*papyracea-* and *dispansa-*groups) and *Nummulites* of the *incrassatus-*group.
2. *Asterocyclina* Zone, which corresponds to the samples from microfacies-unit III, and with the lower part of the *Cibicides lobatulus-*Discorbinae Zone (see V.1.3.2.). It contains frequent specimens of both *Asterocyclina* groups and of the *dispansa-*group of *Discocyclina.*
3. *Nummulites* Zone, which extends from the base of microfacies-unit VI into unit VII, is characterized by abundant individuals of the *Nummulites bouillei-*group associated with specimens of the *incrassatus-*group, and of *Operculina* and *Heterostegina.*

Section Priabona

Two zones can be distinguished here:

1. *Discocyclina-Nummulites* Zone, which corresponds to microfacies units II D, III A and III B, and to the lower part of the *Melonis* Zone (see V.1.4.2.). The elements of this zone are very similar to those of the corresponding zone in section Bressana. However, in subunit II D we observed the additional presence of specimens of *Pellatispira* and of the *Discocyclina sella*-group.

2. *Asterocyclina* Zone; this zone, corresponding to microfacies-unit IV, and to the lower part of the *Cibicides lobatulus*-Discorbinae Zone, shows approximately the same elements and frequency distribution as the corresponding zone in section Bressana.

V.2.4. Larger foraminiferal assemblages and their presumed ecological significance

The "regular" vertical distribution of facies and the approximately symmetrical nature of the sequence of initially transgressive and later regressive origin permits the recognition of a sequence of larger foraminiferal assemblages (see fig. 6). The data were derived mainly from our thin-section analysis and completed in some cases by the counting results.

I. *Orbitolites – Chapmanina,* often associated with smaller miliolids, *Rotalia* and in some instances with *Halkyardia:* relatively restricted lagoonal
II. *Nummulites – Orbitolites* – alveolinids: relatively open lagoonal
III. *Nummulites – Baculogypsinoides – Rotalia – Chapmanina – Fabiana* – alveolinids, associated with larger sessile foraminifera such as *Victoriella/Eorupertia* and with larger agglutinated forms: organic mound (barrier)
IV. *Nummulites – Rotalia:* high energy upper open marine fore-slope
V. *Nummulites* (with diversity in size and shape) – *Operculina:* upper open marine fore-slope
VI. *Discocyclina – Nummulites,* associated with *Asterocyclina, Operculina, Actinocyclina* and *Spiroclypeus:* open marine fore-slope, relatively off-shore, some vegetation
VII. *Discocyclina – Nummulites,* associated with *Operculina* and *Actinocyclina:* lower open marine fore-slope with a little vegetation
VIII. *Asterocyclina – Discocyclina – Actinocyclina,* associated with *Operculina, Heterostegina, Sphaerogypsina* and smaller agglutinated foraminifera: open marine fore-slope, relatively off-shore, habitat with vegetation

IX. *Operculina – Heterostegina* – flat *Nummulites:* upper open marine fore-slope

X. lenticular *Nummulites – Rotalia – Chapmanina:* shallow high energy barrier/shoal

XI. flat and lenticular *Nummulites – Heterostegina – Operculina:* shallow high energy, probably somewhat restricted environment because of the combination with frequent Miliolidae.

The assemblages VI, VII and VIII probably represent subtle variants on a general open marine, fore-slope environment, as is shown by the similarity of their microfacies.

The assemblage VI was found at Priabona in microfacies-subunit II D but it could not be recognized in section Bressana. We noted that all morphological groups of *Discocyclina* are present in this assemblage. The ecological evaluation of the accompanying smaller benthonic foraminifera indicates that during the deposition of subunit II D submarine vegetation was probably present in a mainly muddy, low-energy environment (V.1.4.1.). The change in foraminiferal composition, leading to our assemblage VII containing *Discocyclina* specimens of the *dispansa-* and *papyracea*-groups only, might be explained by a decreased density of the submarine vegetation.

The frequency distribution of the assemblage VIII corresponds to that of vegetation-bound, smaller foraminiferal associations in both sections. Assemblage VIII was probably also vegetation-bound.

The assemblage XI, which is clearly present in section Bressana only, shows a distribution pattern similar to that of the Miliolidae group (see V.1.3.).

V.2.5. **Biometrical analyses of Asterocyclina and Discocyclina**

V.2.5.1. *Introduction*

Because of the time-consuming preparation procedures for the median sections we were unable to make a biometerical investigation of all larger foraminifera. We refrained from making a detailed analysis of the Nummulitidae because the preservation of external features in our material was usually rather poor. Since there are good reviews of the internal morphology of the Upper Eocene nummulitid assemblages of Northern Italy by Lanterno and Roveda (1957), Roveda (1961) and Herb and Hekel (1973, 1975) we had the feeling that biometrical data on a few samples only would add little to our knowledge.

Although evolutionary patterns in the Discocyclinidae still remain largely enigmatic, we considered it worthwhile to establish biometrical data on the internal morphology of the Priabonian *Discocyclina* and *Asterocyclina*, following the recent investigations of Fermont (1982) on Lower and Middle Eocene forms of these genera in Israel.

Material from four samples of the section Priabona appeared suitable for our purpose, but the samples belong to only two of the microfacies-units distinguished above. The lower two samples (Pr. 49 and Pr. 55) were derived from the so-called *Discocyclina*-beds (Hardenbol, 1968; Sirotti, 1978) (our subunit II D) at the Via Centro, the upper two (Pr. 126 and Pr. 135) are from our unit IV immediately below the Bryozoa-beds of the motor-cross circuit (see figs. 3, 4 and 5).

All *Asterocyclina* specimens show the presence of mostly five, rarely six rays in the median layer; these are the characteristics that distinguish *Asterocyclina* from *Discocyclina*. In the literature species designations for both genera are commonly based on external features (size, shape, ornamentation). So first of all we tried to group our individuals from each sample on the basis of external characteristics, notwithstanding the fact that it is very likely that the external appearance of the tests is largely controlled by ontogeny and environment. We were fairly successful in our grouping for each of the two genera, although several specimens were hard to place because of intermediate characteristics and/or poor preservation. Most specimens of *Asterocyclina* belong to one of two external type-groups. In *Discocyclina* there are three such groupings. These five groups were given names of comparable "species" from the literature and each specimen was determined on the basis of its external features before we started the sectioning for the establishment of the internal features.

After sectioning a large number of individuals from all four samples, we found that the biometrical data for the embryonic-nepionic stage (shown in histograms and scatter diagrams) necessitated another grouping of the individuals which did not correspond exactly to the subdivision based on outer features.

The contents of the lower two samples appeared to be highly similar in that they both contain two *Discocyclina* clusters and one *Asterocyclina* cluster. Also the two upper samples contain near-identical biometrical groups, but in these there are two *Asterocyclina* clusters and there is only one *Discocyclina* cluster.

In addition, it appears impossible to make definite links between the groups of the lower two samples and those of the upper samples. The combinations of internal and external characteristics in both *Asterocyclina* and *Discocyclina* seem to give an unsystematic pattern when placed along the time scale.

As a consequence we must conclude that our data are too scanty to give an outline of evolution and/or ecological control for either of the two genera in the course of the Priabonian of its type section. Our data should be regarded as a primary inventory which has to be "explained" by further research on more samples.

V.2.5.2. *Parameters of the embryonic-nepionic stage*

For both *Asterocyclina* and *Discocyclina* we ascertained values for the following parameters in median sections (with slight modifications after Brolsma, 1973). The parameters are shown in figure 20.

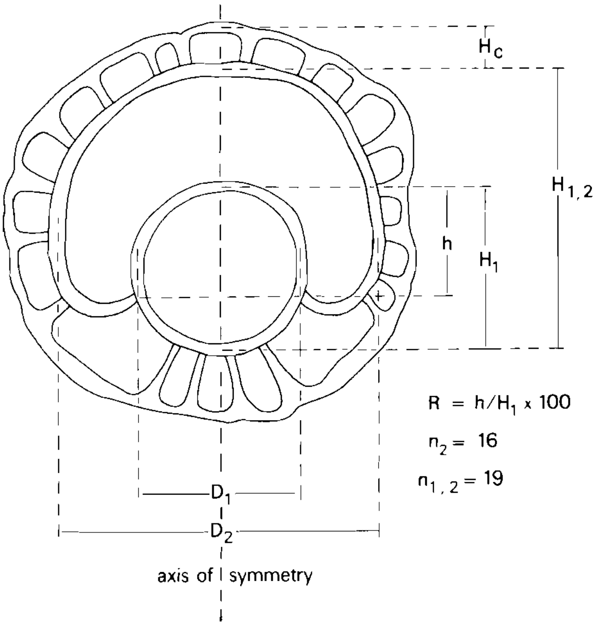


Fig. 20 Internal parameters of the Discocyclinidae.

– H_1 = the height of the protoconch, measured along the axis of symmetry through the embryon.

– $H_{1,2}$ = the height of the protoconch and the deuteroconch along the same line as H_1.

– H_c = the height of the peri-embryonic chamber on the deuteroconch along the same line as H_1.

– h = the height of the protoconch along the same line as H_1 from the the top of the chamber to the point of intersection with the line that connects the points of attachment of the deuteroconch wall.

– R = the degree of embracing, which is calculated from: $R = h/H_1 \times 100$.

– D_1 = the greatest width of the protoconch, measured along a line perpendicular to the axis of symmetry of the embryon.

– D_2 = the greatest width of the deuteroconch along a line perpendicular to the axis of symmetry of the embryon.

– n_2 = the number of the peri-embryonic chambers in direct contact with the deuteroconch, including both principal auxiliary chambers.

– $n_{1,2}$ = the total number of peri-embryonic chambers.

All size measurements are given in microns. They include half of the thickness of the walls. Ranges, means and standard errors are given in table V.

Since all size parameters are well correlated, we shall use only two of them (D_1 and D_2) in our discussion. R is used as a measure of embryonic configuration and $n_{1,2}$ as a measure pertaining to the nepionic stage.

V.2.5.3. *External characteristics of Asterocyclina*

Two morphological groups could be distinguished for nearly all specimens. Their distribution is shown in table IV.

stellaris-group (pl. XVI, figs. 1, 2)

Outline of the test more or less pentagonal to roughly stellate; there is a well-defined umbo. Five, occasionally six conspicuous ribs radiate from the umbo. The umbo and the ribs are ornamented with prominent pustules. Some specimens show additional ribs in the inter-ray areas at the margin. Such specimens become somewhat circular in outline. The diameter of the test varies from 5 mm to 9 mm; the average thickness across the umbo is about 1.2 mm, across the ribs 0.8 mm and across the inter-ray areas 0.6 mm.

stellata/stella-group (pl. XVI, figs. 3, 4)

This group contains individuals, which have the following characteristics in common. The test is more or less distinctly stellate in outline. The central part is very thick, but without a clear umbo. The inter-ray areas are less pronounced than those from the specimens of the *stellaris*-group. The entire surface is covered with big pustules, which are often connected by delicate ridges forming a reticulate pattern. The diameter of the test ranges from 2 mm to 4 mm; the average thickness varies from 1.0 mm in the median part to 0.4 mm in the marginal area.

Both groups were found in all samples. Since they are clearly different in size, we need not be amazed that their separation on the basis of internal features is not perfect.

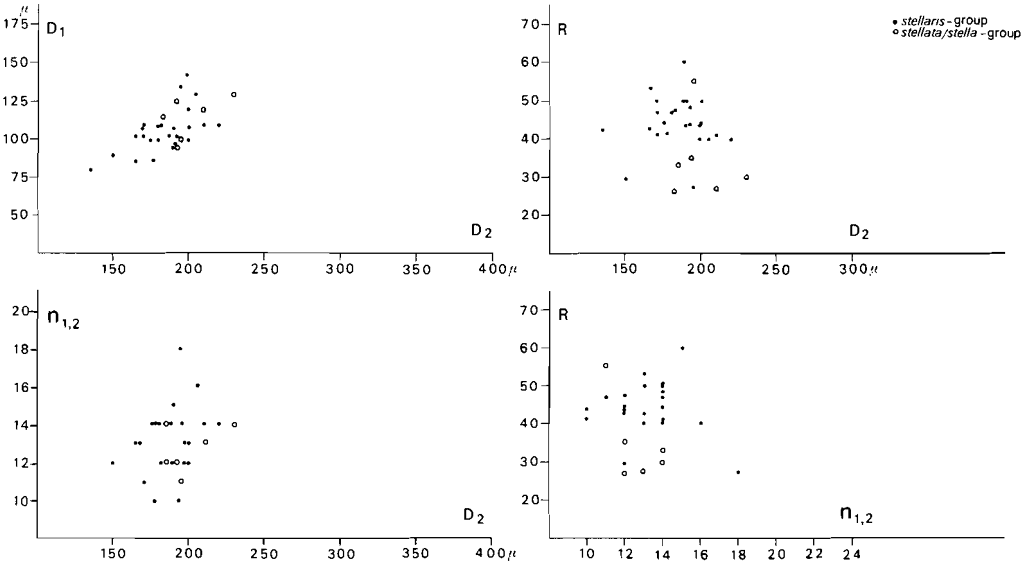


Fig. 21 Scatter diagrams of four combinations of the parameter values for *Asterocyclina* from sample Pr. 49.

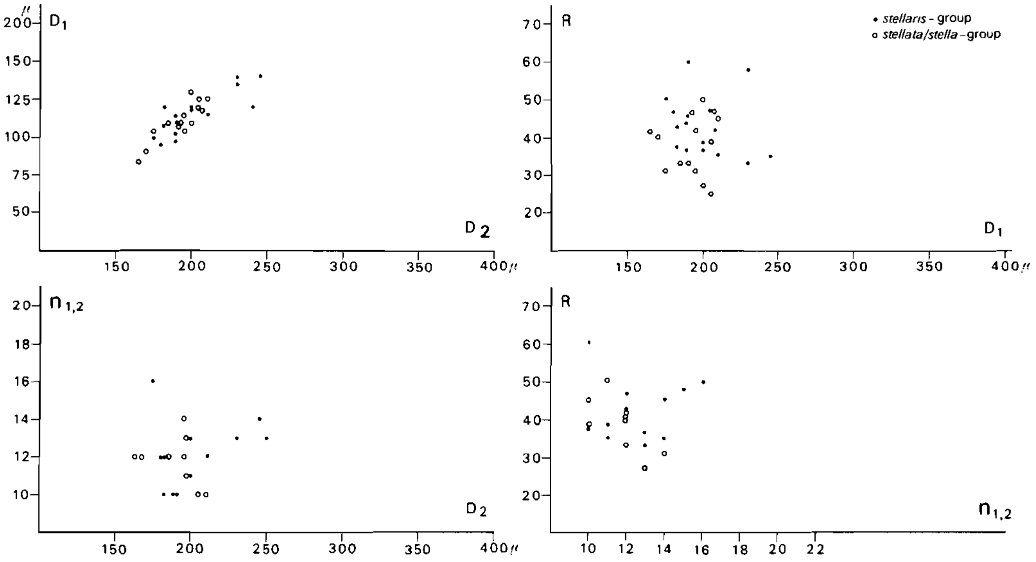


Fig. 22 Scatter diagrams of four combinations of the parameter values for *Asterocyclina* from sample Pr. 55.

V.2.5.4. *Internal characteristics of Asterocyclina*

Scatter diagrams for D_1–D_2, $n_{1,2}$–D_2, R–D_2 and R–$n_{1,2}$ are given in figures 21, 22, 23 and 24 for all four samples.

Notwithstanding the fact that we are dealing with two types on external features, the scatter diagrams for internal features of both lower samples show single clusters. The *stellaris* and *stellata/stella* groups cannot be disentangled by means of any of the parameter combinations. Also histograms (not figured) show unimodal frequency distributions with fairly narrow ranges of variation. All specimens are thought to have been derived from homogeneous "populations", which consist of mixtures of two different external types. These combined groups we designated as *Asterocyclina* I. The scatter diagrams show the fair, positive correlations between the size parameter pairs, and to a lesser degree between D_2 and $n_{1,2}$, but in the combinations D_2–R and R–$n_{1,2}$ there is no correlation whatsoever. For Pr. 49 there is a vague

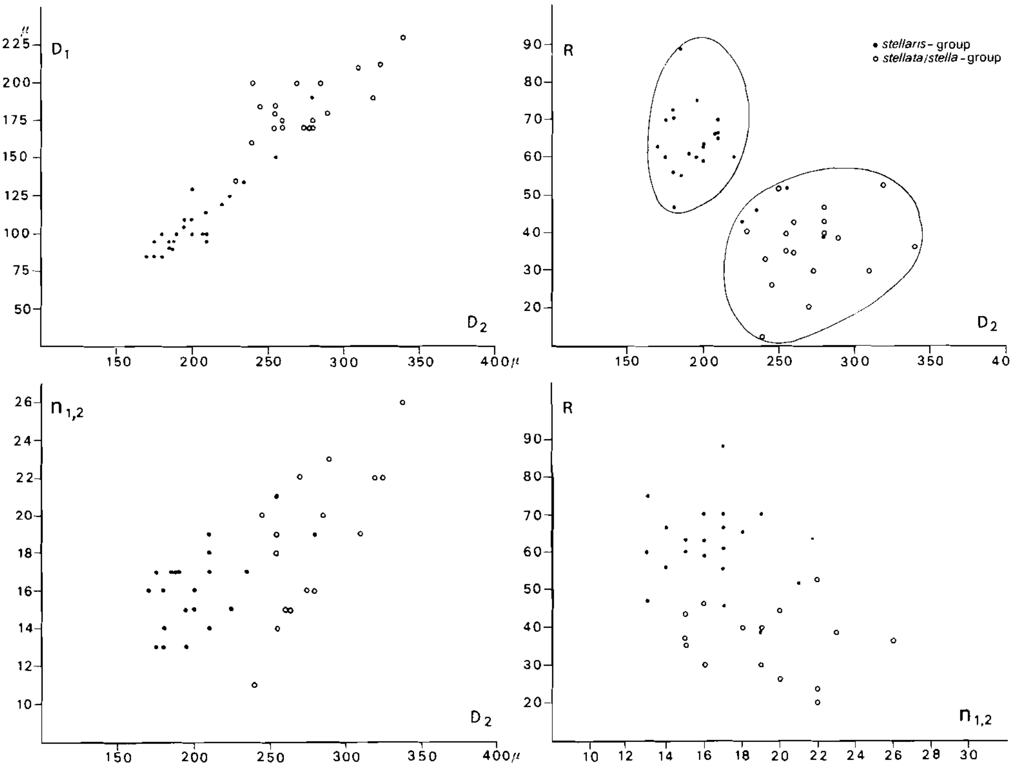


Fig. 23 Scatter diagrams of four combinations of the parameter values for *Asterocyclina* from sample Pr. 126.

suggestion that the relatively few *stellata/stella* types have the lower R values in the cluster, but this is not confirmed in Pr. 55.

The differences between the $\overline{D_2}$, $\overline{R}$ and $\overline{n_{1,2}}$ values of both lower samples are nowhere significant. Since the stratigraphic distance between both samples is 2.5 metres we must conclude that the populations remained approximately constant over a fair period of time.

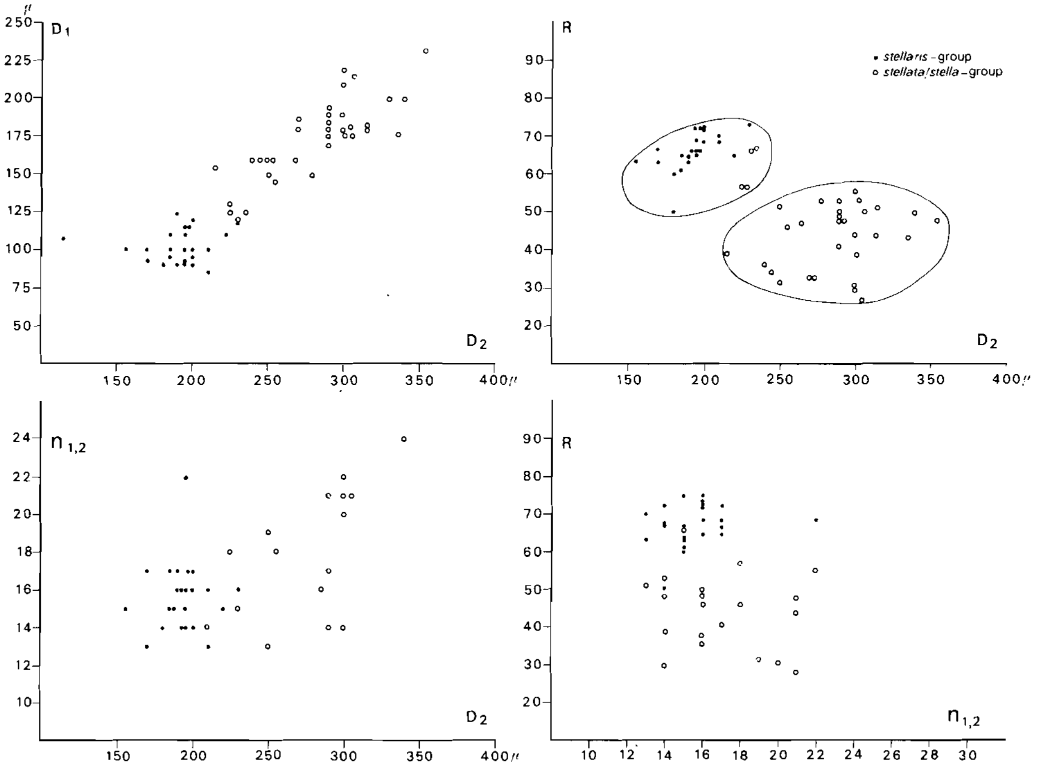


Fig. 24 Scatter diagrams of four combinations of the parameter values for *Asterocyclina* from sample Pr. 135.

In the two upper samples Pr. 126 and Pr. 135 the values of all parameters show a much wider variation and some of the histograms (not figured) are distinctly bimodal. The suggestion of the presence of at least two groups is most apparent in the scatter diagrams (figs. 23 and 24); especially those of the R–D_2 combination give a good separation of two clusters. The two clusters appear to correspond fairly well to the two groups made on external features. However, four *stellaris*-type specimens fall in the *stellata/stella* cluster in Pr. 126, whereas in Pr. 135 it is better to place four specimens of the

		Asterocyclina II			*Asterocyclina* III			*Discocyclina* III		
		range	mean±SE	N	range	mean±SE	N	range	mean±SE	N
Pr.135	D_1	85-130	105±2.6	27	145-234	180±3.9	31	65-105	80±3.6	10
	D_2	155-235	199±3.8	27	210-353	288±5.8	30	155-195	171±4.8	10
	H_1	80-130	99±2.3	27	110-222	159±4.7	30	65-90	74±2.6	9
	$H_{1,2}$	160-225	188±3.3	27	245-399	311±6.7	31	145-180	162±3.9	10
	Hc	30-60	44±1.6	27	20-70	51±2.2	30	15-40	31±2.4	8
	n_2	9-18	11.9±0.35	27	9-19	13.4±0.51	21	9-12	11±0.37	8
	$n_{1,2}$	13-22	15.7±0.37	27	13-24	17.4±0.7	20	12-16	14.5±0.46	8
	R	50-75	66.3±1.14	27	29-56	43.7±1.53	29	38-69	48.6±3.6	9

		Asterocyclina II			*Asterocyclina* III			*Discocyclina* III			*Discocyclina* IV		
		range	mean±SE	N	range	mean±SE	N	range	mean±SE	N	range	mean±SE	N
Pr.126	D_1	85-130	100±2.6	20	125-230	179±5.4	24	65-95	81±1.7	26	210-215	212±1.7	3
	D_2	170-220	193±3.3	20	225-340	270±6.3	24	140-200	164±2.9	26	475-510	487±11.6	3
	H_1	75-115	96±2.4	20	105-210	157±5.3	24	60-90	74±1.5	26	200-240	215±12.6	3
	$H_{1,2}$	150-205	134±3.2	20	230-410	302±8.6	24	140-190	163±2.1	26	425-440	432±4.4	3
	Hc	30-60	43±1.7	20	30-55	44±1.5	23	20-40	32±1.0	26	75-100	83±8.3	3
	n_2	10-15	12±0.4	17	6-18	13.3±0.65	20	8-14	12±0.4	19	24-49	27±1.5	3
	$n_{1,2}$	13-19	15.7±0.44	17	11-26	18.6±0.8	20	12-18	15.6±0.4	19	28-33	30.3±1.45	3
	R	47-89	64.7±1.9	20	12-53	37.3±2.0	24	31-67	48.2±1.7	26	75-79	76.6±1.3	3

		Asterocyclina I			*Discocyclina* I			*Discocyclina* II		
		range	mean±SE	N	range	mean±SE	N	range	mean±SE	N
Pr.55	D_1	85-140	113±2.4	30	95-190	133±3.3	44	165-490	244±24.9	14
	D_2	165-245	197±3.3	30	195-360	291±5.9	44	375-1170	547±62.0	14
	H_1	68-114	94±2.0	30	85-150	123±2.4	44	150-420	216±21.4	14
	$H_{1,2}$	171-240	207±3.2	30	195-330	272±4.6	44	375-1000	536±51.2	14
	Hc	25-60	43.2±1.46	30	30-80	51±1.9	44	45-105	76±4.3	14
	n_2	7-12	8.9±0.26	25	18-34	26.8±0.55	43	32-82	44±3.8	13
	$n_{1,2}$	10-16	12.2±o.36	22	21-38	30.3±0.61	37	35-82	49.1±3.94	11
	R	25-60	40.7±1.5	30	45-96	75.6±2.0	44	71-100	87.9±2.78	14

		Asterocyclina I			*Discocyclina* I			*Discocyclina* II		
		range	mean±SE	N	range	mean±SE	N	range	mean±SE	N
Pr.49	D_1	80-142	109±2.7	36	95-235	143±4.3	45	110-400	205±24.8	11
	D_2	135-230	186±3.3	36	235-400	305±6.1	45	270-950	490±52.9	11
	H_1	70-114	92±1.8	36	95-210	131±3.2	45	110-380	195±22.2	11
	$H_{1,2}$	142-228	196±2.7	36	210-450	284±6.3	45	240-810	463±42.4	11
	Hc	29-65	44±1.3	35	40-90	62±1.8	45	40-120	72±8.34	10
	n_2	6-12	9.8±0.24	33	18-37	26.4±0.61	43	24-57	41.8±2.87	11
	$n_{1,2}$	9-18	13±0.32	33	23-43	30.5±0.61	43	26-57	43.7±2.75	11
	R	26-60	42.1±1.47	35	45-100	73.6±1.8	45	68-100	93.7±2.76	11

TABLE V: Means, standard errors and numbers of specimens of the internal parameters of *Asterocyclina* and *Discocyclina*.

latter group in the *stellaris* cluster. After regrouping all specimens following these suggestions we calculated ranges, means and S.E. for both new groups separately (table V). We called these groups *Asterocyclina* II (mainly *stellaris* types) and *Asterocyclina* III (mainly *stellata/stella* types), because neither of them corresponds well to our *Asterocyclina* I of the lower two samples (see figs. 21 and 22).

After the regrouping of the individuals we found the correlation values between parameter pairs for the two separate groups to be similar to those found for the *Asterocyclina* I clusters in both lower samples.

In each of the two upper samples the groups of *Asterocyclina* II and III are clearly different because of significant differences in $\overline{n_{1,2}}$ and especially in $\overline{R}$ and in $\overline{D_2}$ and the other size parameters (see table V and figs. 23, 24 and 25).

The observation that in both samples the individuals with the smaller embryons belong to the larger specimens reinforces the suggestion that we are dealing with two independent populations rather than with two morphotype groups of a single species.

In *Asterocyclina* II there are no notable changes in parameter mean values between Pr. 126 and Pr. 135, but in *Asterocyclina* III the increase in $\overline{D_2}$ and $\overline{R}$ values is on the verge of significance.

V.2.5.5. *Conclusions from the combination of data*

When we compare the sums of external and internal morphological data for the species *Asterocyclina* II and *Asterocyclina* III in the Priabonian unit IV with those for *Asterocyclina* I lower down the column (unit II D) we are at a loss concerning the interpretation in terms of phylogenetic links. One might well doubt whether either of the former two species has descended from *Asterocyclina* I.

If we accept that the three species were related, there remains little doubt that the upper two species were independent of each other; they might have the same ancestor but at the levels we found them they can easily be separated on the basis of internal features but not on the basis of the external appearance. If they had both evolved from *Asterocyclina* I we might suppose that this species in Pr. 49 and Pr. 55 was heterogeneous, consisting of two populations with different types of exterior, but otherwise indistinguishable in the measured internal features.

In the possible *stellaris* line of descent leading to *Asterocyclina* II the size parameters of the embryon would have remained stable, but there would have been an increase in the number of nepionic chambers and especially in the degree of enclosure of both embryonic chambers. In particular the latter change would seem logical from the theoretical point of view, but it is far

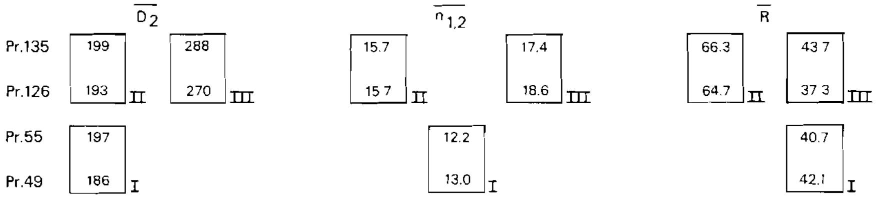


Fig. 25 Means of D_2, $n_{1,2}$ and R placed in stratigraphical order to show the relation between the three biometrically defined species of *Asterocyclina*.

from certain whether the principle of embryonic acceleration was valid for *Asterocyclina*, as it is for other groups of orbitoidal larger foraminifera.

In the *stellata/stella* line, which would link *Asterocyclina* I to *Asterocyclina* III, such embryonic acceleration (increase in $\bar{R}$) would be entirely absent, but here the embryon would become much larger and the number of nepionic chambers would increase even more strongly than in the other "lineage". Size increase of the embryon might be fitted to theory, but whether the increase in the number of the nepionic chambers in both assumed lines of descent can be compared with nepionic acceleration is open to doubt. Fermont (1982) did not find such a conspicuous increase in $\overline{n_{1,2}}$ in his *Asterocyclina* material from the Lower-Middle Eocene of Israel.

All these assumptions about the relationship of our *Asterocyclina* species seem highly artificial and speculative. For the time being we had better accept these assumptions until further research is done on *Asterocyclina* assemblages from intermediate stratigraphic levels near Priabona or elsewhere.

V.2.5.6. *Asterocyclina I, II and III and the existing names*

It appears difficult to put our biometrically defined species under the existing species names. In the original description there is no or very little documentation on the internal features. Combinations of external and internal characteristics for these species names made by more recent authors lead to a diversity of diagnoses for the same name. Individuals assigned to the same species name by different authors often show considerable differences in embryon size.

We refrained from introducing a set of completely new names because the relationship between our species is obscure and because it is doubtful whether such a procedure would clarify the taxonomy of Discocyclinidae. We preferred to apply one or more existing names to our species because of external resemblance. Since topotype material of the species described earlier was not available we had to rely on the typological species concepts in the literature.

Asterocyclina I (cf. *A. stellaris* (Brunner)) (pl. XVII, figs. 1, 2)

Most specimens of this species show a pentagonal to stellate outline with a well-defined umbo, and with distinct inter-ray areas. Such features agree very well with the description of *Asterocyclina stellaris* (Brunner). An assignment of our populations to this widely accepted species name in the literature seems to be acceptable. *Asterocyclina* I occurs in Pr. 49 and Pr. 55; the internal parameters remain rather constant in this interval (see fig. 25). $\overline{D_2}$ values are 186 μ and 197 μ, $\bar{R}$ values 32.1 and 40.7, and $\overline{n_{1,2}}$ 13.0 and 12.2.

Asterocyclina II (cf. *A. priabonensis* Gümbel) (pl. XVII, fig. 4)

This species is present in Pr. 126 and Pr. 135 and also has a *stellaris*-exterior. The test-size parameters of *Asterocyclina* I and II are not really different either. On the basis of external features only we might refer *Asterocyclina* II to *A. stellaris* as well. However the $\overline{R}$ and $\overline{n_{1,2}}$ values of *Asterocyclina* II are much higher than those of *Asterocyclina* I. $\overline{D_2}$ values are 193 μ and 199 μ, $\overline{R}$ values 64.7 and 66.3 and $\overline{n_{1,2}}$ 15.7 (see fig. 25). Because of its external features *Asterocyclina pentagonalis* (Schafhäutl) may be regarded as a junior synonym of *A. stellaris*. It was recorded by Schweighäuser (1954) as having a higher degree of embryonic enclosure than *A. stellaris*. This suggestion seems too speculative for us to apply this name to our *Asterocyclina* II.

Gümbel (1868) described *A. priabonensis* from the deposits around the village of Priabona. In the literature this species name is considered to be a junior synonym of *A. stellaris*. The abundance of *Asterocyclina* specimens, especially of this species, in Gümbel's material suggests that it was derived from the *Asterocyclina*-beds (our unit IV) like our *Asterocyclina* II (see fig. 5 and table IV). The lack of documentation on internal features in Gümbel's description and the lack of figures prevent us from labelling with certainty our *Asterocyclina* II as *A. priabonensis*. However, we are inclined to give it this name since we are quite convinced that we are dealing with material from the same layers as Gümbel's.

Asterocyclina III (cf. *A. stella* Gümbel) (pl. XVII, fig. 3)

The individuals of this species show a wide range in external features. Lack of a distinct umbo and of conspicuous inter-ray areas are characteristic for nearly all specimens. Somewhat thinner specimens with poorly developed inter-ray areas agree very well with *Asterocyclina stellata* (d'Archiac); other specimens that look stouter due to a large swelling of the central part of the test resemble *A. stella* Gümbel. Complete intergradation between these two extreme external types makes a reliable separation impossible.

On the other hand the internal characteristics seem to fit in with the idea of homogeneous populations, which show $\overline{D_2}$ values of 270 μ and 288 μ, $\overline{R}$ values of 37.3 and 43.7 and $\overline{n_{1,2}}$ values of 18.6 and 17.4.

Gümbel gave an equatorial section of his species; a measurement of his original figure yields internal parameter values for D_2 of about 300–350 μ and for R of about 40.0, which values fit in with those of our *Asterocyclina* III.

V.2.5.7. *External characteristics of Discocyclina*

Our *Discocyclina* specimens show an extremely wide variation in their external features. It was very difficult to make a reliable separation into groups. We decided to make the separation on the basis of the shape of the test, which is either flat or saddle-shaped and on the presence or absence of a distinct umbo. Three major groups were recognized. Their distribution is depicted in table IV.

papyracea-group (pl. XVI, fig. 6)

In this group we put flat specimens of *Discocyclina*, which show a slight median swelling instead of a distinctly raised umbo. The test ornamentation is poorly developed. Vague or delicate pustules are present on several specimens. Whether or not this feature is an artefact, due to the degree of abrasion during or after deposition, cannot be ascertained. The diameter of the test is from 5 mm to 12 mm. The thickness is about 0.7 mm.

dispansa-group (pl. XVI, fig. 5)

Flat individuals of *Discocyclina* showing a more or less well-defined umbo and a distinct surface ornamentation have been brought together in this group. In these specimens we observed a variation in the diameter of the umbo as well as in the dimensions and arrangement of the pustules. Another variable characteristic is in the periphery, which in some specimens is quite thin and in other rather thick and blunt. In Pr. 126 and Pr. 135 the external morphology of this group is rather constant, showing a small but distinct umbo, fine pustules and a thin periphery. The diameter of the test varies from 3 mm to 10 mm. The thickness is about 0.8 mm.

sella-group (pl. XVI, fig. 7)

The individuals of this group are characterized by their large dimensions, and in particular by their saddle-shape. The diameter varies from 10 mm to 22 mm. The degree of curvature is strongly variable. Some specimens bear pustules, concentrically arranged on the marginal part of the test.

These external types are not evenly distributed in our four samples; the content of the lower two samples differs markedly from that of the upper two samples. The internal features suggest that in Pr. 49 and Pr. 55 the *papyracea* and *dispansa* groups are parts of single homogeneous populations. In contrast we found that the *dispansa*-group with a narrower range of external variation dominates the upper two assemblages. This group is the only one represented in the Bryozoa-beds (our unit V). In Pr. 126 a few *papyracea*-like large individuals seem to differ in their internal features as well. The *sella*-like specimens occur in the lower two samples only.

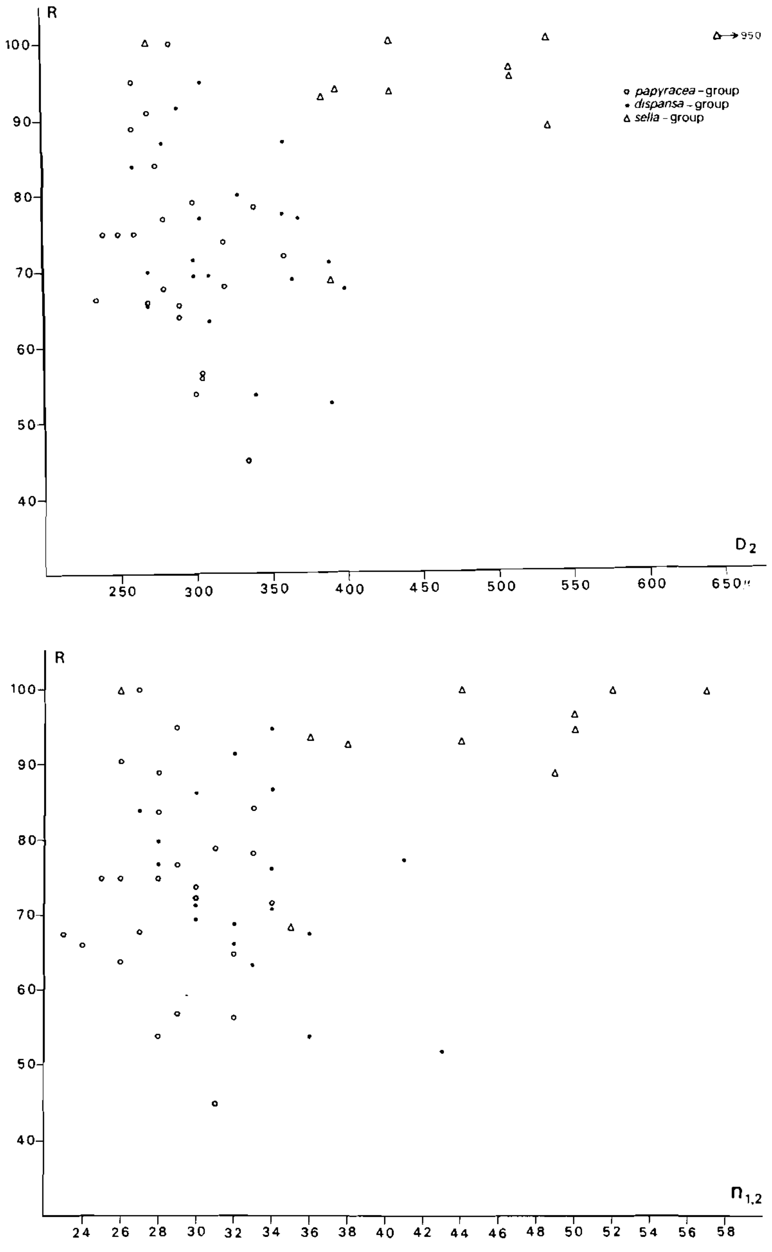
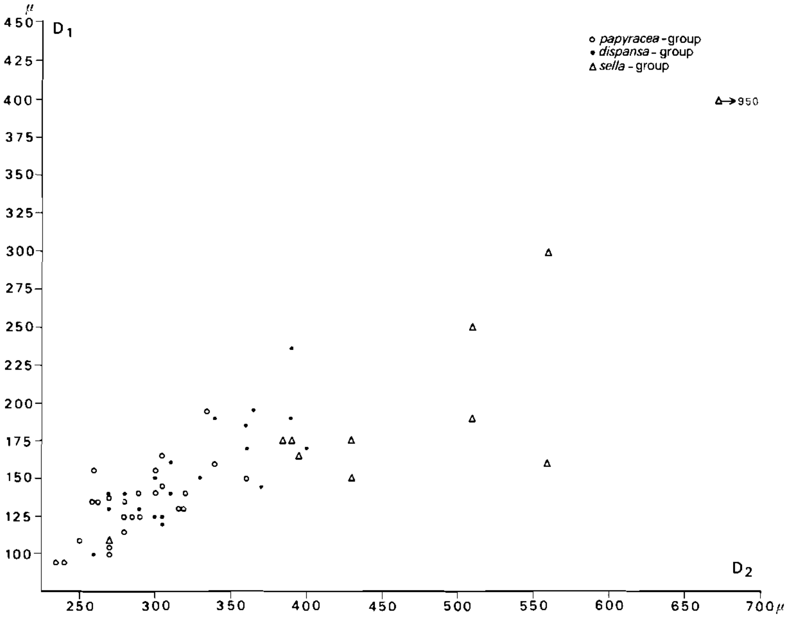


Fig. 26 Scatter diagrams of four combinations of the parameter values for *Discocyclina* from sample Pr. 49.


μ
D1
450
425
400
375
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275
250
225
200
175
150
125
100
○ *papyracea*-group
• *dispansa*-group
△ *sella*-group
950
D2
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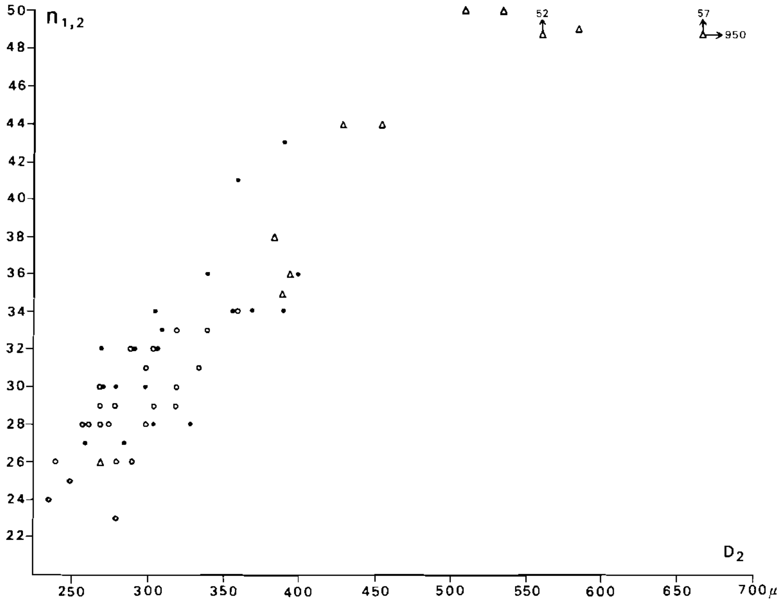
600
650
700μ


n1,2
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42
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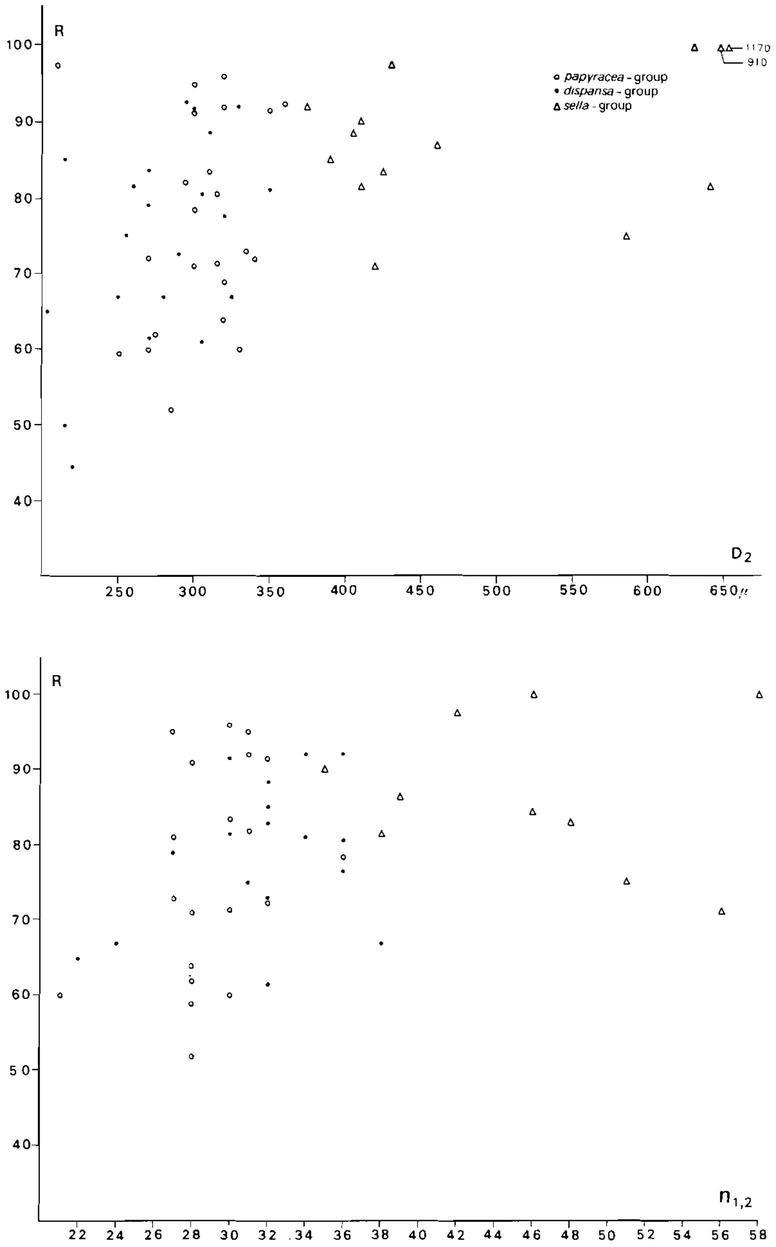
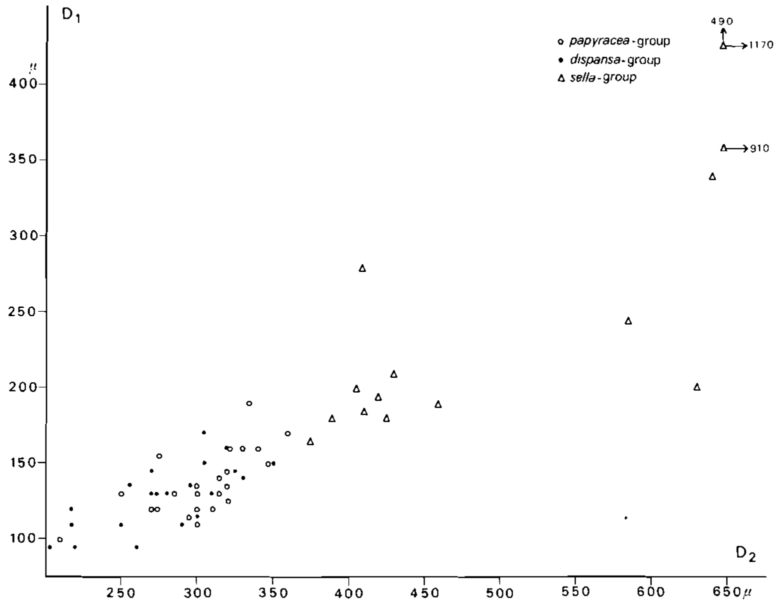


Fig. 27 Scatter diagrams of four combinations of the parameter values for *Discocyclina* from sample Pr. 55.


D1
μ
400
350
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250
200
150
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250
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350
400
450
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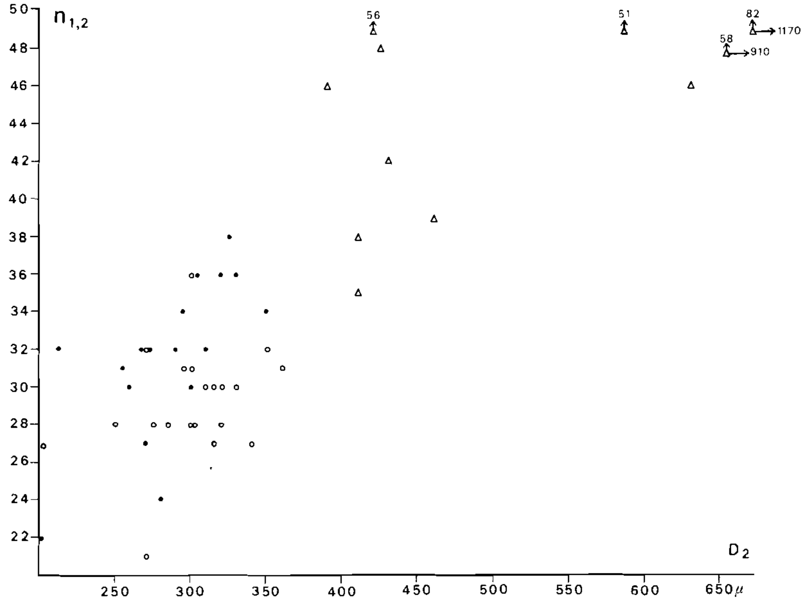
600
650μ
D2
o *papyracea*-group
• *dispansa*-group
Δ *sella*-group
490
1170
910


n1,2
50
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46
44
42
40
38
36
34
32
30
28
26
24
22
250
300
350
400
450
500
550
600
650μ
D2
56
51
82
1170
58
910

V.2.5.8. *Internal characteristics of Discocyclina*

Scatter diagrams for D_1–D_2, R–D_2, $n_{1,2}$–D_2 and R–$n_{1,2}$ are presented in figures 26, 27, 28 and 29 for all four samples.

For the lower two samples single large clusters appear for all parameter combinations consisting of mixtures of individuals of the external groups *papyracea* and *dispansa.* Also histograms (not figured) give good unimodal frequency distributions, fitting in with the idea of single homogeneous populations, which apparently consist of combinations of specimens with a relatively wide variation in external as well as internal features. We called this unified group *Discocyclina* I (see tab. V).

With their higher values for all parameters and their saddle-shape the individuals of the *sella*-group might be regarded as representing separate populations, which we designate as *Discocyclina* II. However, the internal difference between these *Discocyclina* I and II populations is far from sharp; their clusters show overlap in all scatter diagrams. The groups of specimens of *Discocyclina* II show extremely wide ranges with high standard errors for all parameters (see tab. V), so it is in fact questionable whether they belong to only one population.

A good positive correlation between the size parameter pairs and between D_2 and $n_{1,2}$ can be observed in the scatter diagrams, while the R–D_2 and R–$n_{1,2}$ combinations show only a weak positive correlation for the *Discocyclina* of the groups *papyracea* and *dispansa* together.

As in *Asterocyclina* we did not find significant differences between the $\overline{D_2}$, $\bar{R}$ and $\overline{n_{1,2}}$ values of our *Discocyclina* groups in both lower samples. The conclusion that the populations remained relatively constant within that interval may also hold for our *Discocyclina.*

For the upper two samples Pr. 126 and Pr. 135 single, relatively small clusters occur for all parameter combinations. These clusters are composed of specimens with a *dispansa*-exterior, which also show a narrow range of variation in their external features. Also the histograms (not figured) give unimodal frequency distributions with narrow ranges of variation. These distinctly homogeneous populations are characterized by much lower mean values for the embryon size, and for $\bar{R}$ and $\overline{n_{1,2}}$ than the populations of both lower samples. We named this group *Discocyclina* III because no clear relation can be made between it, and the two species in the lower two samples on the basis of any of the internal parameters. The combinations of size parameter pairs give fairly positive correlations, but a weakly positive or no correlation at all is found in the R–D_2, R–$n_{1,2}$ and D_2–$n_{1,2}$ scatters.

No notable changes in parameter means can be concluded for the upper two samples, which are separated from each other by a stratigraphic distance of about 4.5 m. We can assume that *Discocyclina* III continued to live in an unchanged state over rather a long period of time. We found this group with a narrow range of external variation as the only representative of the family Discocyclinidae in the Bryozoa-beds (our unit V).

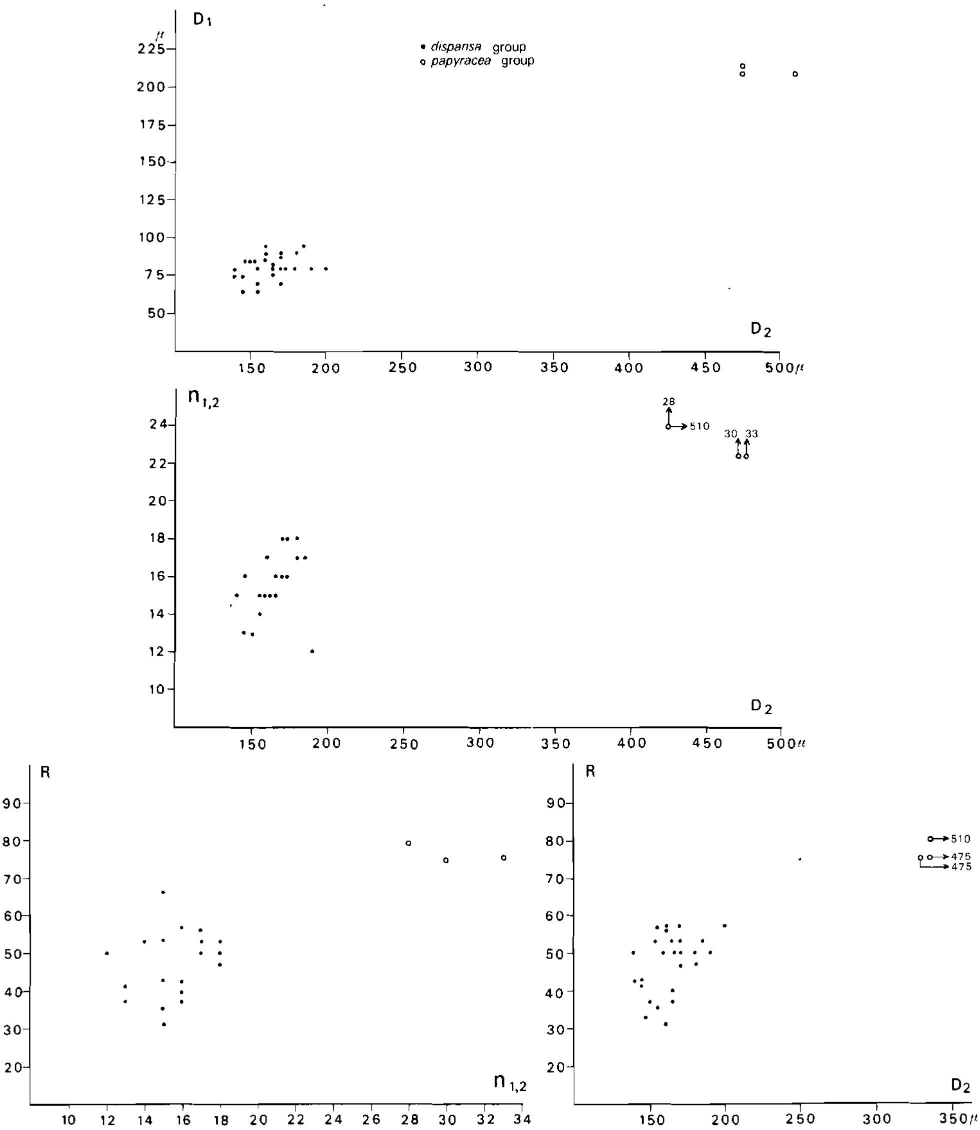

Fig. 28 Scatter diagrams of four combinations of the parameter values for *Discocyclina* from sample Pr. 126.

For Pr. 126 the scatter diagrams also contain three individuals with a *papyracea*-exterior, which are different in that they show much higher values for all internal parameters. Their position in the scatter diagrams is remote from the relatively small clusters of *Discocyclina* III. These separate individuals, which we designate as *Discocyclina* IV, show a strong resemblance to *Discocyclina* II in their large values of the embryon size parameters while the values of R and $n_{1,2}$ correspond well to those of *Discocyclina* I from the lower part of the section.

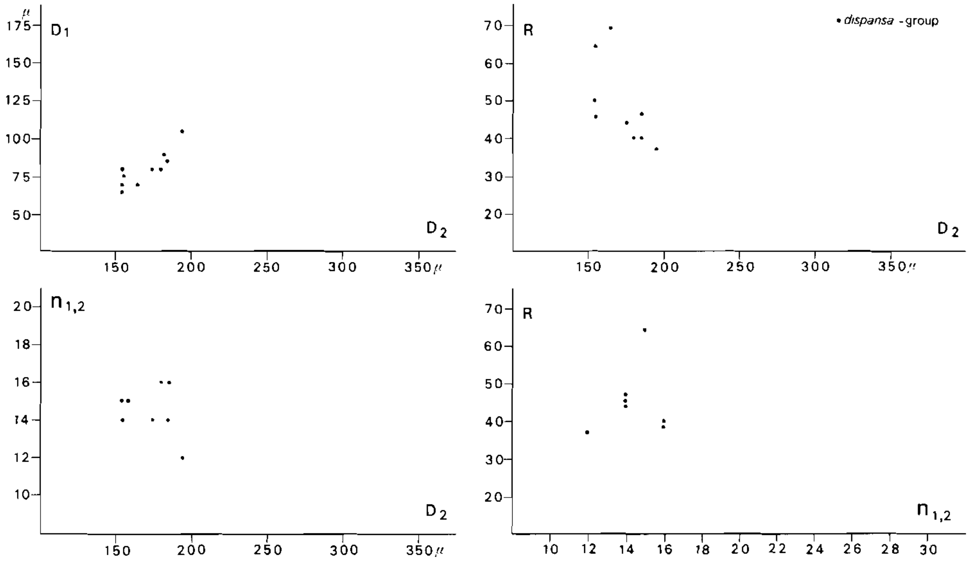

Fig. 29 Scatter diagrams of four combinations of the parameter values for *Discocyclina* from sample Pr. 135.

V.2.5.9. *Conclusions from the combination of data*

From the combined data for external and internal characteristics we conclude that we may indeed be dealing with four different population groups (see fig. 30).

It is hard to believe that *Discocyclina* III with its low values of R, $n_{1,2}$ and D_2, and its narrow range of external variation in the upper two samples evolved from either *Discocyclina* I or *Discocyclina* II lower down the column. If we assume that embryonic/nepionic acceleration is also valid for Discocyclinidae, *Discocylina* III would represent a more primitive stage than that of *Discocyclina* I and II.

If we link *Discocyclina* IV to *Discocyclina* I then there must have been a conspicuous increase in the size of the embryon, while the other parameters remained constant. Such a phenomenon might have a connection with a change in environmental conditions. Such changes have been postulated for other fossil and recent larger foraminifera (Drooger and Raju, 1973; Fermont, 1977).

The possible relationship of our *Discocyclina* species is difficult to understand. Also here we had better accept the assumptions until further research is carried out.

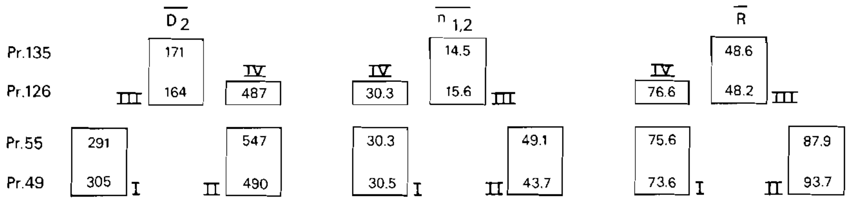

Fig. 30 Means of D_2, $n_{1,2}$ and R placed in stratigraphical order to show the relation between the four biometrically defined species of *Discocyclina.*

V.2.5.10. *Discocylina I, II, III and IV and the existing names*

Discocyclina I (cf. *D. applanata* Gümbel) (pl. XVII, fig. 5)

This species contains two different external types, which have a flat test as a common characteristic. The test has a wide range of ornamentation, varying from rather smooth to distinctly pustulate. Specimens with distinct pustules often show a well-defined umbo as well, and relatively smooth individuals were frequently found with a moderate central swelling. The variation in internal parameters of these two groups is rather wide, and practically the same. $\overline{D_2}$ is 305 or 291 μ, $\overline{R}$ 73.6 and 75.6 and $\overline{n_{1,2}}$ 30.5 and 30.3.

The highly variable external morphology covers a considerable number of species names from the literature. If we take only species from the Upper Eocene into consideration the following species names might be appropriate: *Discocyclina dispansa* (Sowerby), *D. pratti* (Michelin), *D. papyracea* (d'Archiac, non Boubée), *D. applanata* Gümbel, *D. aspera* Gümbel. The species of d'Archiac and Gümbel were recorded from the deposits around Priabona in the original description.

Discocyclina II (cf. *D. sella* (d'Archiac)) (pl. XVII, fig. 6)

The individuals show a sellate shape. Pustules are present in some specimens, concentrically arranged on the marginal part of the test. All parameters reveal relatively high values; $\overline{D_2}$ 490 and 547 μ, $\overline{R}$ 93.7 and 87.9 and $\overline{n_{1,2}}$ 43.7 and 49.1. The extremely wide ranges, in particular for the size parameters associated with high standard errors, may indicate that we are dealing with representatives of heterogeneous assemblages.

Two species names can be given to our *Discocyclina* II. Individuals with high values of the embryon size may belong to *Discocyclina discus* (Rütimeyer, emend. Kaufmann). Kaufmann (1867, Beitr. Geol. Karte Schweiz, no. 5, p. 160) figured a specimen of this species with an embryon of about 1000 μ in height or in width, comparable with either our $H_{1,2}$ or D_2. Specimens with relatively low parameter values are tentatively referred to *Discocyclina sella* (d'Archiac), a widely accepted name for saddle-shaped *Discocyclina* in the Upper Eocene. This species was recorded by the original author from the Vincentinian area.

Discocyclina III (cf. *D. augustae* van der Weijden) (pl. XVII, fig. 7)

As mentioned above, this species has a narrow range of variation of internal as well as external characteristics. The flat test is ornamented with fine pustules and it has a small but distinct umbo. $\overline{D_2}$ values are 164 and 171 μ, $\overline{n_{1,2}}$ 14.5 and 15.6 and $\overline{R}$ values are 48 and 49.

Discocyclina dispansa (Sowerby), *D. submedia* (d'Archiac), *D. applanata* Gümbel and *D. augustae* van der Weijden seem to be applicable. We tend to designate our *Discocyclina* III as *D. augustae* in spite of the most recent date of this name because the original description of this species contains documentation about internal parameters, which biometrically fit those of our *Discocyclina* III very well. There is no notable difference between our *D. augustae* and that described by Fermont (1982) from the Lower Eocene of the Negev, Israel.

Discocyclina IV (pl. XVII, fig. 8).

This species is based on three specimens with a narrow range of external variation in Pr. 126 only. The test is flat and thin with a diameter of about 10 mm. No distinct umbo can be observed; fine pustules are vague.

The ranges of variation of the internal parameters are also fairly narrow. $\overline{D_2}$ is 487 μ, $\overline{n_{1,2}}$ 30.3 and $\overline{R}$ 76.6.

Discocyclina papyracea (d'Archiac, non Boubée), *D. discus* (Rütimeyer) or *D. applanata* Gümbel may fit to these specimens.

Chapter VI

BIOSTRATIGRAPHIC CONCLUSIONS

The type section of the Priabonian and the nearby reference sections of Bressana and Buco della Rana appear to give us no opportunity for making a satisfactory delimitation of the stage in any of the existing biostratigraphic schemes. The reason for this are the extremely poor contents in "index" microfossils, and the fact that the type section has restricted facies in both its basal and top parts. The main body of the type Priabonian corresponds to open marine, fore-slope to off-shore environments, which are sandwiched between purely lagoonal habitats at the base and ill-characterized carbonate platform environments at the top. It is impossible to say with any certainty whether the transgressive-regressive cycle that might be constructed is a local phenomenon only or had a wider geographical meaning.

For a correct chronostratigraphic correlation of our three sections there are severe constraints because of the considerable differences in facies. Without additional correlation tools the details of the microfacies-units we recognized might lead us to make incorrect assumptions about lithostratigraphic continuity.

The relatively small distances between the three sections and the fact that our slope model appears to be largely correct make us fairly confident that the ecostratigraphic zones and boundaries we could recognize are probably almost synchronous.

Without following a strict order from bottom to top we shall review some of these ecostratigraphic correlation possibilities (fig. 31). The microfacies-units will be used as a lithostratigraphic reference frame-work.

In the upper part of the type section there are two ecostratigraphic zones in direct superposition, which can also be recognized in the two other successions. They are the *Asterocyclina* Zone below (Buco della Rana XI, Priabona IV and Bressana III) and the Bryozoan Zone above (Buco della Rana XII–XIII, Priabona V and Bressana IV). In both shallower sections these faunas seem to be entirely autochthonous; the dilution by other elements in Bressana may point to some sedimentary mixture; i.e. the shallower elements may have been partly washed in. The base of the *Asterocyclina* Zone coincides approximately with the boundary between the *Cibicides lobatulus*-Discorbinae Zone and the underlying *Melonis* Zone in both Bressana and Priabona. The "regressive" trend leading to vegetation-bound associations (*Asterocyclina*,

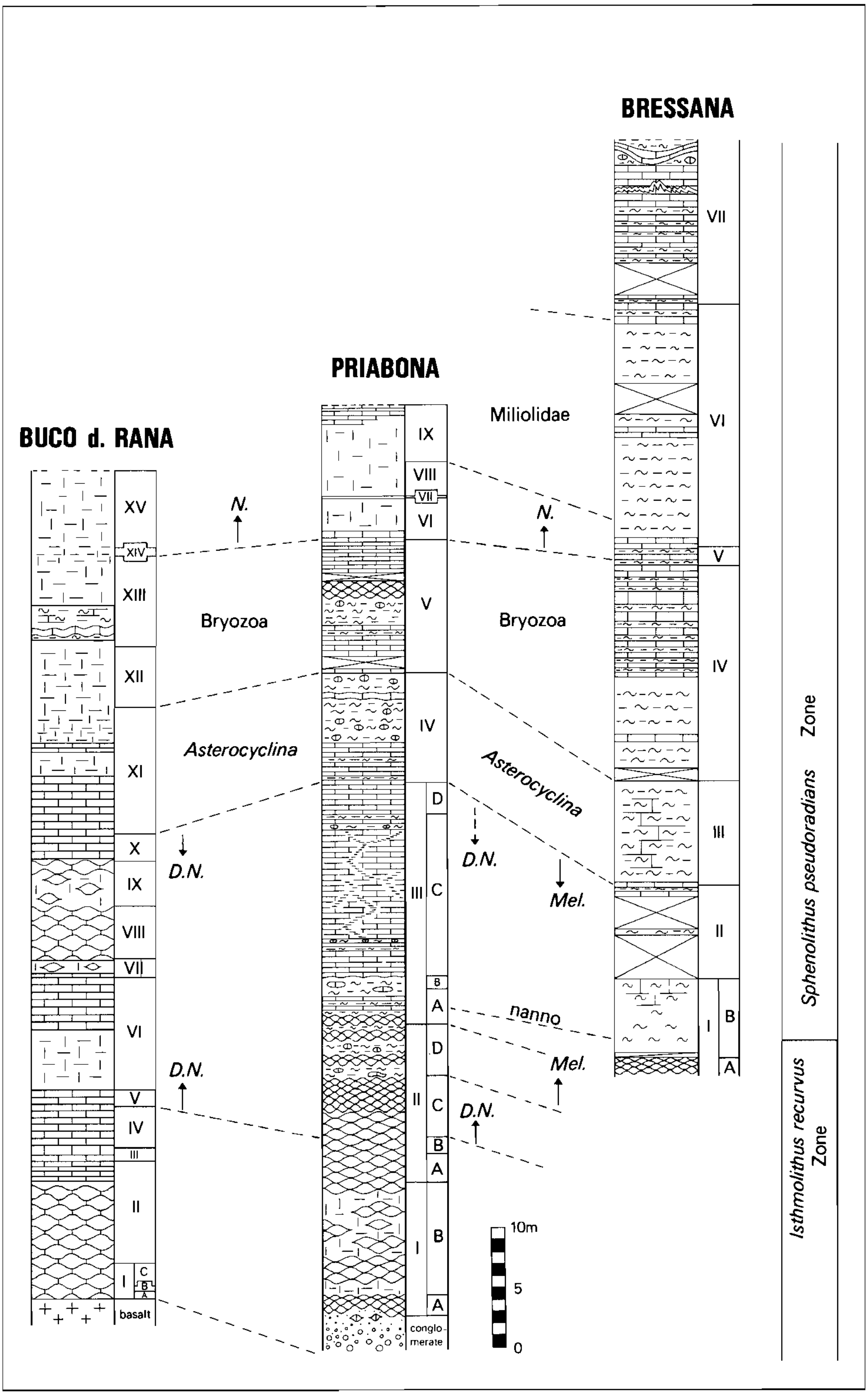

Fig. 31 Biostratigraphic correlation of the three sections, *D.-N.* = *Discocyclina-Nummulites, Mel.* = *Melonis, N.* = *Nummulites* Zones.

Cibicides lobatulus, Discorbinae) can be traced fairly accurately in all three sections, although this change is not "a priori" necessarily synchronous.

Both below and above the two distinct zones mentioned above correlations are more difficult.

In the lower parts of the sections Buco della Rana and Priabona there is a distinct lower limit for the *Discocyclina-Nummulites* Zone at the base of units V en II C, respectively. This ecostratigraphic horizon probably passes underneath our section Bressana, in which the association is already distinctly present in the lowermost sample. Because of a lack of data we cannot pinpoint the limit of the *Melonis* Zone in the Priabona section. Considering the overall facies development in a vertical sense we might expect such a lower limit to exist and in fact the samples from unit II D do show a considerable admixture of epiphytic taxa. This faunal change between II D and III A in Priabona was not found in Bressana, which suggests that a correlation line would similarly pass below our sample sequence in the latter region. This suggestion is corroborated by the fact that *Discocyclina sella* and *Pellatispira,* both present in Priabona unit II D, were not found in the lowermost samples of the section Bressana.

Slightly higher there is another correlation line between Priabona (III A) and Bressana (I B) based on the only nannofossil zonal limit recognized by Verhallen & Romein (see appendix). From here to the lower limit of the *Asterocyclina* Zone the *Discocyclina-Nummulites* association is intermittently present throughout the interval in both Buco della Rana and Bressana. But in Priabona the association is extremely rare in units III C and III D; this absence is difficult to understand for the section in between the two others.

Above the Bryozoan zone correlation possibilities are even more restricted. The Miliolidae Zone in Bressana unit VI has not been recorded in the other two sections. The large numbers of miliolids found in Priabona unit IX may provide a correlation that is in agreement with correlation lines lower down in the column. The same reasoning holds for the *Nummulites* Zone of Bressana units VI and VII. No distinct zone of such character can be pointed out in either of the other sections, although it is true that in both we found only small *Nummulites* above the Bryozoan Zone. The assumption expressed earlier that the marly upper part of Bressana corresponds in time with the upper limestones (Calcareniti di Castelgomberto) of the Monte Grande remains valid after all correlation possibilities have been reviewed.

Considering now the Priabonian as a chronostratigraphic unit we must conclude that only the larger foraminifera seem to show a clear-cut boundary.

The classical idea that the local Bryozoa beds represent the top part of the Priabonian fits in very well with the extinction of all Discocyclinidae in the course of our Bryozoan Zone. The possible suggestion that they disappeared at Priabona because of an unfavourable upward environmental change cannot be upheld for the more off-shore Bressana section in which they disappear as well. Actually the remaining fauna of small *Nummulites* has an Oligocene aspect. Although the disappearance of the Discocyclinidae, *Discocyclina* itself lingering on longest, is likely to have a regional significance, we are still reluctant to regard the extinction of a group as a tool for inter-regional or even world-wide chronostratigraphic correlation.

The other elements of the benthonic fauna may contain some index fossils for the Priabonian, but their ranges are facies-bound, so we cannot really recommend them as such. So far our species of *Discocyclina* and *Asterocyclina* have no index value whatsoever because we have no comparative data. The same is true for *Spiroclypeus granulosus* and *Pellatispira madaraszi.* It is remarkable that we found so few representatives of *Nummulites fabianii*, which is claimed to be an index fossil for at least the lower part of the type Priabonian (Roveda, 1961). A possible index value for other forms, such as *Queraltina epistominoides*, *Schlosserina asterites*, *Maslinella chapmani* and *Victoriella abnormis* cannot be ascertained until we have sufficient data about their range elsewhere.

Unfortunately the planktonic microfossils give no more than a very general idea about the position of the Priabonian type section. The index planktonic foraminifera occur very rarely and are represented only by *Turborotalia cerroazulensis* and *Hantkenina* (Hardenbol, 1968) in unit II of Bressana; this unit corresponds to the middle part of the type section of the Priabonian.

Furthermore we know now that at least the *Isthmolithus recurvus* Zone and the *Sphenolithus pseudoradians* Zone correspond to successive parts of the type Priabonian. The suggestion that the *Discoaster tani nodifera* Zone is present at the base of the type section (Cita, 1969) could not be verified. It is evident that in Bressana the *S. pseudoradians* Zone continues into the strata which might be called Oligocene on the evidence provided by the larger foraminifera.

Chapter VII

TAXONOMY

The classification of the foraminifera is adopted from Loeblich and Tappan (1964).

The categories used to distinguish the frequency distribution are as follows: 1–3% rare, 4–7% few, 8–15% common and > 15% abundant.

Family TEXTULARIIDAE

Genus **Spiroplectammina** Cushman, 1927

Spiroplectammina carinata (d'Orbigny)

Textularia carinata d'Orbigny, 1846, Foram. Foss. Vienne, p. 247, pl. 14, figs. 32–34.
Spiroplectammina carinata (d'Orbigny), Ten Dam and Reinhold, 1942, Med. Geol. St., ser. C-V, no. 2, p. 42, pl. 1, figs. 2, 3; Marks, 1951, Cushm. Found. Foram. Res., Contr. v. 2, p. 35, pl. 6, fig. 2; Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 98, pl. 1, fig. 2; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 140, pl. 1, fig. 12.

Remarks: A few well-preserved individuals, with the characteristic dentate to spinose carina were found in the upper part of microfacies-unit II of section Bressana.

Spiroplectammina carinata (d'Orbigny) var. **deperdita** (d'Orbigny)

Textularia deperdita d'Orbigny, 1846, Foram. Foss. Vienne, p. 244, pl. 14, figs. 23–25.
Spiroplectammina carinata (d'Orbigny) var. *deperdita* (d'Orbigny), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 98, pl. 1, fig. 3; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 140, pl. 1, fig. 13.

Remarks: This variant occurs more frequently than the typical form. A complete gradation between them, as observed by Batjes (1958), is not found in our material.

Genus **Textularia** Defrance, 1824

Textularia agglutinans d'Orbigny

Textularia agglutinans d'Orbigny, in De La Sagra, 1839, Hist. phys. pol. nat. Cuba, p. 144, pl. 1, figs. 17, 18, 32–34; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 141, pl. 1, figs. 14–16; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 121, pl. 1, figs. 7, 8.

Textularia minuta (Terquem)

Textilaria minuta Terquem, 1882, Mém. Soc. Géol. Fr., v. II, ser. III, p. 147, pl. 15, fig. 15.
Textularia minuta (Terquem), Le Calvez, 1970, Cah. Paléont., p. 19, pl. 1, figs. 5, 6; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 122, pl. 1, figs. 9, 10.

Family ATAXOPHRAGMIIDAE

Genus **Gaudryina** d'Orbigny, 1839

Gaudryina rugosa d'Orbigny

Gaudryina rugosa d'Orbigny, 1840, Mém. Soc. Géol. Fr., v. 4, no. 1, p. 44, pl. 4, figs. 20, 21 (fide Ellis and Messina); Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 13, pl. 1, fig. 4; Loeblich and Tappan, 1964, Treatise Invert. Paleont., pt. C, p. 269, figs. 179: 5.

Remarks: Broken individuals occur rather frequently, showing the triserial initial portion. Most frequent in microfacies-unit VII of section Bressana.

Genus **Valvulina** d'Orbigny, 1826

Valvulina triangularis d'Orbigny

Valvulina triangularis d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 270, no. 1 (fide Ellis and Messina); Cushman, 1937, Cushm. Lab. Foram. Res., Spec. Publ. no. 8, p. 5, pl. 1, figs. 8–10; Le Calvez, 1970, Cah. Paléont., p. 25, pl. 2, fig. 6.

Genus **Clavulina** d'Orbigny

Clavulina parisiensis d'Orbigny

pl. VII, fig. 1

Clavulina parisiensis d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 268, no. 3, mod. no. 60 (fide Ellis and Messina); Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 144, pl. 1, figs. 27, 28; Pozaryska, 1965, Palaeont. Polonica, v. 14, p. 54, pl. 4, fig. 9; Le Calvez, 1970, Cah. Paléont., p. 21, pl. 1, fig. 1; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 1, figs. 12, 13.

Remarks: Rare to few in microfacies-unit V of section Priabona and in unit IV of section Bressana.

Remarks on the agglutinated foraminifera:

Part of the increase in the number of agglutinated foraminifera in microfacies-units IV and V of section Priabona, and from unit IV upwards in section Bressana, is due to a group of indeterminable, much deformed forms, which bear some resemblance to the Cretaceous-Paleocene *Marssonella oxycona* (Reuss). This species is recorded from Paleocene and Eocene deposits (Toulmin, 1941, p. 573 and Pozaryska, 1965, p. 55).

Another questionable and rare agglutinated species resembles *Textularia faujasi* (Reuss) as figured by Hofker (1958, Beih. Geol. Jb., v. 27, p. 22, t.fig. 1–4) and Pozaryska (1965, p. 52).

Family MILIOLIDAE

Our miliolid association is very poorly preserved. The specimens are often welded together in aggregates, when even a generic designation becomes impossible. Isolated specimens show dissolution of their test, leaving only internal casts. Many can be assigned to the genus *Quinqueloculina:*

– the stouter and rather large ones resemble Q. *carinata* d'Orbigny (1826), whereas

– the elongate and mostly small forms might be called Q. *juleana* d'Orbigny (1846).

Family NODOSARIIDAE

Genus **Lenticulina** Lamarck, 1804

Lenticulina cf. **arcuato-striata** (Hantken)

Cristellaria (Robulina) arcuato-striata Hantken, 1868, Magyar Kir. földt. int. evkönyve, p. 92, pl. 2, fig. 23 (fide Hantken, 1875).

Robulina arcuato-striata Hantken, Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 56, pl. 6, fig. 7.

Robulus arcuato-striatus (Hantken), Hagn, 1956, Palaeontographica, v. 107, p. 127, pl. 11, fig. 4.

Remarks: This species name is applied to all *Lenticulina* specimens. Most are recrystallized, characterized only by the external shape of the tests. Sufficiently well preserved individuals agree with the original description. Rare to few in Priabona with a slight concentration in unit V; scattered in Bressana.

Genus **Lagena** Walker & Jacob, 1798

Lagena globosa (Montagu)

Vermiculum globosum Montagu, 1803, Test. Brit., p. 523 (fide Ellis and Messina).

Lagena globosa (Montagu), Hagn, 1956, Palaeontographica, v. 107, p. 141, pl. 10, fig. 20; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 179, pl. 7, fig. 27.

Lagena hexagona (Williamson)

Entosolenia squamosa (Montagu) var. *hexagona* Williamson, 1848, Ann. mag. nat. hist., ser. 2, vol. 1, p. 20, pl. 2, fig. 23 (fide Ellis and Messina).

Lagena hexagona (Williamson), Hagn, 1956, Palaeontographica, v. 107, p. 141, pl. 10, fig. 22.

Oolina hexagona (Williamson), Le Calvez, 1970, Cah. Paléont., p. 101, pl. 16, figs. 2, 3.

Lagena striata (d'Orbigny)

Oolina striata d'Orbigny, 1839, Voy. Amériq.-Mérid., Foram., p. 21, pl. 5, fig. 12.
Lagena striata (d'Orbigny), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 119, pl. 3, figs. 6; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 179, pl. 7, fig. 26; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 119, pl. 6, fig. 3.

Lagena tenuis (Bornemann)

Ovulina (Oolina) tenuis Bornemann, 1855, Zschr. Deut. Geol. Ges., v. 7, p. 317, pl. 12, fig. 3.
Lagena tenuis (Bornemann), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 119, pl. 3, fig. 23.

Genus **Bolivinella** Cushman, 1927

Bolivinella cf. **subpectinata** Cushman
pl. VII, fig. 3

cf. *Bolivinella subpectinata* Cushman, 1929, Cushm. Lab. Foram. Res., Contr., v. 5, p. 34, pl. 3, fig. 8; Howe, 1930, J. Paleont., v. 4, p. 264, pl. 21, fig. 1.

Remarks: Many of our *Bolivinella* specimens are tentatively assigned to this species. They often show prominent spines at the edge of the last chambers where the sutures project. Such features are not clearly present in the original description. This species and the following one occur only in section Bressana. For distribution see figure 11.

Bolivinella cf. **rugosa** Howe
pl. VII, fig. 4

cf. *Bolivinella rugosa* Howe, 1930, J. Paleont., v. 4, p. 267, pl. 21, fig. 4a–b.

Remarks: The shape of the specimens, which we tentatively refer to this species, shows a rather wide variation. It varies from triangular to somewhat flabelliform with a blunt to pointed initial portion. No distinct ornamentation has been observed, which fact prevents us from designating our individuals definitively as *B. rugosa.* For distribution see figure 11.

Family GLANDULINIDAE Reuss, 1860

Genus **Fissurina** Reuss, 1850

Fissurina marginata (Walker & Boys)

Serpula (Lagena) marginata Walker & Boys, 1784, Test. min., p. 2, pl. 1, fig. 7 (fide Ellis and Messina).
Entosolenia marginata (Walker & Boys), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 180, pl. 7, fig. 28.

Fissurina marginata (Walker & Boys), Le Calvez, 1970, Cah. Paléont., p. 104, pl. 24, figs. 5, 6; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, pl. 6, fig. 5.

Remarks: The common species of *Fissurina* in our material. Specimens with a slightly wavy carina also occur, resembling *Fissurina karpathica* Samuel (1975, p. 129; from Upper Eocene deposits of Slovakia), which is regarded as an intraspecific variant. Rare to few in section Bressana except in unit VII.

Fissurina laevigata Reuss

Fissurina laevigata Reuss, 1849, Denkschr. Akad. Wiss. Wien, vol. 1, p. 366, pl. 46, fig. 1; Le Calvez, 1970, Cah. Paléont., p. 103; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, pl. 6, fig. 4.

Remarks: Rare in section Bressana except in unit VII.

Genus **Lingulina** d'Orbigny, 1826

Lingulina glabra Hantken

pl. VII, fig. 2

Lingulina glabra Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 42, pl. 13, fig. 14; Hagn, 1956, Palaeontographica, v. 107, p. 139, pl. 13, fig. 2.

Remarks: This distinct species is characterized by its large dimensions. A variation in the width of the adult portion of the tests is observed. Rare to few, only in unit V of section Priabona. Hantken (1875) also recorded this species from the bryozoa marl of Priabona.

Family POLYMORPHINIDAE d'Orbigny

Genus **Globulina** d'Orbigny, in De La Sagra, 1839

Globulina gibba d'Orbigny

Globulina gibba d'Orbigny, 1826, Ann. Sci. Nat. vol. 7, p. 266, no. 63 (fide Ellis and Messina); Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 121, pl. 4, fig. 9; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 183, pl. 8, figs. 6, 7; Le Calvez, 1970, Cah. Paléont., p. 84, pl. 17, figs. 3, 4.

Genus **Guttulina** d'Orbigny, in De La Sagra, 1839

Guttulina irregularis (d'Orbigny)

Globulina irregularis d'Orbigny, 1846, Foram. Foss. Vienne, p. 226, pl. 13, figs. 9, 10.
Guttulina irregularis (d'Orbigny), Kaasschieter, 1861, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 181, pl. 8. figs. 2, 3; Le Calvez, 1970, Cah. Paléont., p. 92, pl. 20, figs. 3.

Family TURRILINIDAE Cushman, 1927

Genus **Turrilina** Andreae, 1884

Turrilina brevispira Ten Dam

Turrilina brevispira Ten Dam, 1944, Med. Geol. St., ser. C-V, no. 3, p. 110, pl. 3, fig. 4; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 188, pl. 9, fig. 1.

Remarks: Rare in both sections; so far only found in Upper Eocene of Belgium, France and the Netherlands.

Genus **Buliminella** Cushman, 1911

Buliminella pulchra (Terquem)
pl. VII, fig. 6

Bulimina pulchra Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser III, p. 114, pl. 12, figs. 8–12.
Buliminella pulchra (Terquem), Cushman & Parker, 1947, Geol. Surv., Prof. Papers, no. 210 D, p. 61, pl. 16, figs. 5, 6; Le Calvez, 1950, Carte Géol. Dét. Fr., p. 33, pl. 2, figs. 21, 22; Le Calvez, 1970, Cah. Paléont., p. 109, pl. 21, fig. 6.

Remarks: The preservation of our *Buliminella* species leaves much to be desired. The determination is established upon the size and the degree to which the last whorl embraces the earlier test.

We distinguish two common species:

– *B. pulchra:* the last whorl forms about one half of the whole test and

– *B. turbinata:* with a very short initial spiral part and a comparatively large last convolution.

In our material we found other *Buliminella* specimens that might be assigned to *B. bullina* Le Calvez (1950, pl. 1, figs. 19, 20) and *B. striatopunctata* (Terquem, 1882, p. 116, pl. 12, fig. 19).

Very rare in unit IV and V of section Priaboña; rare to common in unit VI and VII of section Bressana (see fig. 11).

Buliminella turbinata (Terquem)
pl. VII, fig. 5

Bulimina turbinata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 113, pl. 12, fig. 6 (non fig. 7).
Buliminella turbinata (Terquem), Le Calvez, 1970, Cah. Paléont., p. 110, pl. 21, figs. 3, 5; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 6, fig. 11.

Remarks: In fairly well-preserved individuals vague striae can be observed such as are figured on the scanphoto by Le Calvez (1970). Up to 7% in unit VI of section Bressana.

Family SPHAEROIDINIDAE

Genus **Sphaeroidina** d'Orbigny, 1826

Sphaeroidina bulloides d'Orbigny

Sphaeroidina bulloides d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 267, mod. 65 (fide Ellis and Messina); Ten Dam & Reinhold, 1942, Med. Geol. St., ser. C-V, no. 2, p. 95, pl. 7, fig. 6; Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 140, pl. 6, fig. 11.

Remarks: Very rare in Priabona; up to 5% in unit I B of section Bressana.

Family BOLIVINITIDAE

Genus **Bolivina** d'Orbigny, 1839

Bolivina carinata Terquem, 1882

pl. VII, fig. 10

Bolivina carinata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 148, pl. 15, fig. 19; Cushman, 1937, Cushm. Lab. Foram. Res., Spec. Publ., no. 9, p. 46, pl. 6, figs. 14–16; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 193, pl. 9, figs. 12–14; Le Calvez, 1970, Cah. Paléont., p. 111, pl. 22, fig. 3.

Remarks: The most common *Bolivina* species in our material. Sometimes the initial part is twisted. From thin sections we are assured that the chamber arrangement is biserial throughout.

A slight median ridge, in part associated with fine longitudinal striae, is present on the initial portion of some well-preserved specimens. These specific features can also be observed in *Bolivina antegressa angulata* Sahakjan-Gezaljan, 1960, as figured by Braga *et al.* (1975, p. 106, pl. 5, figs. 4, 5) from the Upper Eocene of section Possagno. This form only differs from *B. carinata* in being more elongate and in having a smaller adult portion.

Bolivina crenulata Cushman

Bolivina crenulata Cushman, 1936, Cushm. Lab. Foram. Res., Spec. Publ., no. 6, p. 50, pl. 7, fig. 13; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 194, pl. 9, figs. 15–17; Le Calvez, 1970, Cah. Paléont., p. 113, pl. 22, fig. 8; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 6, fig. 12.

Remarks: We found a variation in the degree of crenulate sculpture. This species was originally described from Eocene deposits in Hungary. Rare in both sections.

Bolivina nobilis Hantken
pl. VII, fig. 11

Bolivina nobilis Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 65, pl. 7, fig. 13; Cushman, 1937, Cushm. Lab. Foram. Res., Spec. Publ., no. 9, p. 51, pl. 7, fig. 4; Braga *et al.,* 1975, Schweiz. Paläont. Abh., v. 97, p. 106, pl. 5, figs. 1, 2.

Remarks: This large and typical species indicates a relatively deep and open marine environment in the Upper Eocene deposits of section Possagno, according to Braga *et al.* (1975) and Grunig & Herb (1980). Their supposition is confirmed by our facies interpretations (see V.1.3.2.). Some specimens show transitional features to *B. pulchra,* which generally occurs more frequently. Rare in units II, III, and IV of section Priabona; rare to few in units I B, II, III, IV and VI of section Bressana: a maximum frequency was found in unit II.

Bolivina pulchra (Terquem)

Bulimina pulchra (partly) Terquem, 1882, Mém. Soc. Géol. Fr. v. 2, ser. III, p. 114, pl. 12, fig. 8.
Bolivina pulchra (Terquem), Le Calvez, 1950, Carte Géol. Dét. Fr., p. 43, pl. 3, figs. 43–44; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 193, pl. 9, figs. 12–14; Le Calvez, 1970, Cah. Paléont., p. 116, pl. 22, fig. 1.

Remarks: In Terquem's collection two specimens of the genus *Bolivina* were found by Le Calvez labelled as "*Bulimina pulchra*". She decided to name these *Bolivina* specimens: *B. pulchra* (Terquem). *B. gracilis* Cushman sensu Braga *et al.* (1975) is probably synonymous. Rare, almost throughout both sections.

Family BULIMINIDAE

Genus **Bulimina** d'Orbigny, 1826

Bulimina kasselensis Batjes
pl. VII, fig. 16

Bulimina kasselensis Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 127, pl. 5, figs. 4–6; Samuel, 1975, Zàp. Karp., ser. Paleont., v. 1, p. 135, pl. 72, fig. 1, pl. 75, figs. 4, 5.

Remarks: This species is characterized in having a small, pyramidal test, which is subroundedly triangular in transversal section. Coarsely perforated with minute, blunt spines scattered over the whole surface.

As was pointed out by Batjes, this species shows some features in common with the genus *Sagrina* (= *Bitubologenerina*); it resembles the triserial, initial portion of *Sagrina aspera* (Terquem) in our material (see below). The nature of the aperture, however, is decisive for placing this species in the genus *Bulimina.*

Rare and without any distribution pattern in section Priabona; rare to few in units I B, II, IV and VI of section Bressana.

Bulimina ovata d'Orbigny

Bulimina ovata d'Orbigny, 1846, Foram. Foss. Vienne, p. 185, pl. 11, figs. 13, 14; Ten Dam, 1944, Med. Geol. St., ser. C-V, no. 3, p. 111, pl. 3, figs. 10, 11; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 191, pl. 9, fig. 6.

Bulimina tenuistriata Terquem

Bulimina tenuistriata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 118, pl. 12, figs. 24, 25; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 190, pl. 9, fig. 5; Le Calvez, 1970, Cah. Paléont., p. 119, pl. 22, fig. 7.

Remarks: Our specimens agree very well with the original figures of Terquem and of Le Calvez (1950). The coarse perforations as figured by Le Calvez (1970) with a stereoscan photo have not been observed. Slightly more frequent in Bressana than in Priabona.

Bulimina sp.
pl. VII, fig. 15

Remarks: We found some specimens of *Bulimina* in units I B and II of section Bressana which show a similar test to that of *B. kasselensis* in being small, pyramidal and subroundedly triangular in transversal section. These specimens are characterized by having prominent, sharp spines, one on each chamber. The spines appear to be a prolongation of the chambers.

Genus **Reussella** Galloway, 1933

Reussella elongata (Terquem)

Verneuilina elongata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 106, pl. 11, fig. 13.
Reussella elongata (Terquem), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 191, pl. 9, figs. 7–9; Le Calvez, 1970, Cah. Paléont., p. 119, pl. 22, fig. 4.

Remarks: The specimens we assign to this species are mostly shorter than the one in the original figure of Terquem and those of Le Calvez. The periphery is more or less acute, but without the distinct keel used as a criterion for distinguishing *Reussella spinulosa* (Reuss). Even in samples rich in *Reussella* of section Bressana (see fig. 11), this species is rare.

Reussella recurvata (Halkyard)
pl. VII, figs. 7, 8

Verneuilina recurvata Halkyard, 1919, Mem. Proc. Manch. Lit. Phil. Soc., vol. 62, pt. 2, p. 43, pl. 3, fig. 7.

Remarks: Originally described from the Upper Eocene Blue Marl of Biarritz. No other references have been found. It is a species of the genus *Reussella* with long and narrow chambers, which often curve backwards in the adult portion, accentuating the concavity of the lateral faces. A transverse section of the test shows a three-pronged propeller-like figure. Two variants linked by transitional forms exist:

– *R. recurvata* (as figured by Halkyard), the smaller form with moderately concave lateral faces (pl. I, fig. 8) and

– *R. recurvata* var., larger but apparently more fragile forms showing an extreme concavity of the lateral faces (pl. I, fig. 7). In the adult portion of some individuals the chambers remain constant in dimensions or they even tend to decrease in size.

Rare to few only in section Bressana, except in units II and III.

Reussella spinulosa (Reuss)
pl. VII, fig. 9

Verneuilina spinulosa Reuss, 1850, Denkschr. Akad. Wiss. Wien, vol. 1, p. 347, pl. 47, fig. 12.

Reussella spinulosa (Reuss) Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 130, pl. 5, fig. 8; Le Calvez, 1970, Cah. Paléont., p. 121, pl. 22, fig. 5.

Remarks: This species name is applied to specimens with or without spines on their periphery (see Batjes, 1958). The spines are short and rather thick. Some specimens are more elongate resembling *R. elongata* (Terquem), which differs in having a more delicate periphery with no indications of spines or spinose features. For distribution in combination with other *Reussella* species see figures 11 en 17.

Family UVIGERINIDAE

Genus **Uvigerina** d'Orbigny, 1826

Uvigerina eocaena Gümbel
pl. VII, fig. 12

Uvigerina eocaena Gümbel, 1868, Abh. k. bayer. Akad. Wiss., v. II, p. 67, pl. 2, fig. 78; Hagn, 1956; Palaeontographica, v. 107, p. 149, pl. 13, figs. 9, 10, Braga *et al.*, 1975, Schweiz. Paläont. Abh., v. 97, p. 107, pl. 5, fig. 17; Berggren & Aubert, 1976, Micropaleontology, v. 22, p. 316, pl. 3, figs. 15–18.

Remarks: This species name is given to individuals with a more or less pointed initial portion and a widely expanding adult part, as well as to specimens which taper more gradually. The aperture is accentuated by a small neck. The longitudinal costae are mostly well-developed. This feature can also be seen on juvenile specimens, which occur rather frequently. Rare in unit III of section Priabona; rare to common in units I B and II of section Bressana.

Genus Sagrina d'Orbigny

Sagrina aspera (Terquem)

Textilaria aspera Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 147, pl. 15, fig. 4.

Bigenerina selseyensis Heron-Allen & Earland, 1909, Jour. R. Micr. Soc. Lond., p. 330, pl. 15, fig. 15–17.

Bitubologenerina aspera (Terquem), Le Calvez, 1950, Carte Géol. Dét. Fr., p. 44, pl. 4, fig. 56.

Sagrina aspera (Terquem), Le Calvez, 1970, Cah. Paléont., p. 125; Samuel, 1975, Zàp. Karp., ser. Paleont., v. 1, p. 138, pl. 74, fig. 10.

Sagrina selseyensis (Heron-Allen & Earland), Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 121, pl. 7, fig. 4.

Remarks: We agree with Le Calvez, who regards *Sagrina selseyensis* (Heron-Allen & Earland) to be a junior synonym of this species. All individuals collected show the tendency to become uniserial. The apertural end is usually damaged and hard to recognize. The initial, triserial part is similar to *Bulimina kasselensis* Batjes. Rare and scattered occurrence in both sections.

Genus Trifarina Cushman, 1923

Trifarina gracilis (Reuss)

pl. VII, fig. 13

Uvigerina gracilis Reuss, 1851, Zschr. Deut. Geol. Ges., vol. 3, p. 77, pl. 5, fig. 39; Cushman & Edwards, 1938, Cushm. Lab. Foram. Res., Contr., v. 14, p. 74, pl. 13, figs. 3–6.

Angulogerina gracilis (Reuss), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 134, pl. 6, figs. 1, 2.

Remarks: This species is characterized by its finely hispid wall, a rather rounded triangular shape in transverse section and the tendency to become uniserial. There is no transition to *Trifarina tenuistriata* (Reuss), which will be treated as a separate species in our material. Rare in samples that are rich in other *Trifarina* species in Priabona and Bressana.

Trifarina tenuistriata (Reuss)

pl. VII, fig. 14

Uvigerina tenuistriata Reuss, 1870, Sitz.-Ber. K. Akad. Wiss. Wien, p. 485; v. Schlicht, 1870, Foram. Sept. thon Pietzp., p. 22, figs. 34–37.

Angulogerina tenuistriata (Reuss), Cushman & Edwards, 1938, Cushm. Lab. Foram. Res., Contr., v. 14, p. 84, pl. 15, figs. 1—7; Berggren & Aubert, 1976, Micropaleontology, v. 22, p. 317, pl. 4, figs. 2, 3.

Angulogerina gracilis (Reuss) var. *tenuistriata* (Reuss), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 136, pl. 6, fig. 5.

Remarks: This species name is applied to all our *Trifarina* specimens with longitudinal costae and a distinctly triangular transversal section. The periphery is more or less acute. Most specimens show somewhat depressed sutures and/or slightly excavated lateral faces. Rare up to unit III C and rare to very common in units IV and V of section Priabona; in section Bressana fluctuating quantities but rather common in units II, III and IV and in the lower part of unit VI.

Trifarina wilcoxensis (Cushman & Ponton)

Pseudouvigerina wilcoxensis Cushman & Ponton, 1932, Cushm. Lab. Foram. Res., Contr., v. 8, p. 66, pl. 8, fig. 18.

Trifarina wilcoxensis (Cushman & Ponton), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 199, pl. 10, figs. 6, 7; Le Calvez, 1970, Cah. Paléont., p. 127, pl. 23, fig. 5; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 122, pl. 7, fig. 5.

Remarks: Similar to *T. tenuistriata* but more elongate and without any ornamentation. The periphery of some individuals is somewhat rounded. A stereoscan photo of this species given by Le Calvez (1970) shows a specimen with fine perforation. Rare in samples that are rich in other *Trifarina* species in both sections.

Family DISCORBIDAE

Genus **Discorbis** Lamarck, 1804

Discorbis perovalis (Terquem)

pl. VIII, fig. 3

Rotalina perovalis Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 70, pl. 6, fig. 5.

Rotalia perovalis (Terquem), Le Calvez, 1952, Carte Dét. Géol. Fr., p. 49, pl. 4, figs. 47, 48.

Discorbis perovalis (Terquem), Le Calvez, 1970, Cah. Paléont., p. 136, text-fig. 45.

Remarks: On account of the generally poor preservation we apply this species name to all those *Discorbis* specimens in our material with the following characteristics: test plano-convex, almost rounded in transversal section throughout the last whorl, with a more or less distinct periphery, 5 to 7 chambers in the last whorl, with radiate to somewhat curved sutures on the umbilical side and with an umbilical knob. Relatively better preserved and larger specimens of section Bressana fit very well to the original figures and those of Le Calvez.

However, we cannot exclude the presence of *Discorbis discoides* (d'Orbigny) and *Discorbis perplexa* Le Calvez in our material since they closely resemble this species. Rare or few throughout the section Priabona; common in some samples in unit VI and in the upper part of unit VII in section Bressana.

Genus **Rosalina** d'Orbigny

Rosalina douvillei (Cushman)
pl. VIII, fig. 2

Discorbis douvillei Cushman, 1928, Bull. Soc. Sc. Seine et Oise, ser. 2, vol. 9, pt. 4, p. 54, pl. 3, fig. 1.
Rosalina douvillei (Cushman), Le Calvez, 1970, Cah. Paléont., p. 140, pl. 29, figs. 3–5, Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 121, pl. 9, figs. 3, 5, 6.

Remarks: Rare to few in most samples of the section Priabona, absent in unit III B and in the lower part of unit III C; in section Bressana rare or few in units III, IV and VI, but common in some samples of unit VII.

Rosalina limbata (Terquem)

Rotalina limbata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 80, pl. 8, fig. 6.
Discorbis limbata (Terquem), Le Calvez, 1949, Carte Dét. Géol. Fr., p. 19, pl. 2, figs. 30–32; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 207, pl. 10, fig. 16.
Rosalina limbata (Terquem), Le Calvez, 1970, Cah. Paléont., p. 141, pl. 29, fig. 9.

Remarks: Common in some samples of units III, IV and VI of section Bressana; otherwise scattered occurrences in both sections.

Rosalina obvoluta (Terquem)
pl. VIII, fig. 1

Rotalina obvoluta Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser III, p. 81, pl. 8, fig. 7.
Discorbis obvoluta (Terquem), Le Calvez, 1949, Carte Dét. Géol. Fr., p. 20, pl. 2, figs. 33–35.
Rosalina obvoluta (Terquem), Le Calvez, 1970, Cah. Paléont., p. 142, text-figs. 52–54.

Remarks: Mostly concentrated in units IV and V of section Priabona and units III, IV and VI of section Bressana, otherwise occurring in several samples of both sections.

Rosalina quadrata Terquem

Rosalina quadrata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser III, p. 98, pl. 10, fig. 12a, b; Le Calvez, 1970, Cah. Paléont., p. 143, pl. 29, fig. 8.
Discorbis quadrata (Terquem), Le Calvez, 1949, Carte Dét. Géol. Fr., p. 25, pl. 2, figs. 21–23; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 208, pl. 10, fig. 17.

Remarks on the genera Discorbis and Rosalina:

Apart from the species described above there are "discorbid" and/or "rosalinid" forms, which have the following features in common: flattened to slightly concave umbilical side, all chambers visible at the convex spiral side, periphery angled, some specimens with more or less distinct keel, 5 to 6 chambers in the last whorl increasing rapidly in size. Such specimens occur rather frequently throughout and have almost the same distribution pattern as the other representatives of the Discorbinae. They have been counted under this subfamily.

Genus **Laticarinina** Galloway & Wissler, 1927

Laticarinina altocamerata (Heron-Allen & Earland)
pl. VIII, fig. 4

Truncutulina tenuimargo var. *altocamerata* Heron-Allen & Earland, 1922, Brit. Antarc. (Terra Nova) Exp., Prot., pt. 2, Foram., p. 209.

Laticarinina altocamerata (Heron-Allen & Earland), Loeblich & Tappan, 1964, Treatise Invert. Paleont., vol. C, p. 580, fig. 457: 4.

Remarks: When visible the aperture is not peripheral but on the convex side of the test. No supplementary openings have been observed in our specimens. Common in some samples of units II D, III A, III B and III C in Priabona; in section Bressana rare or few in the samples from the lower part of subunit I B.

Genus **Baggina** Cushman, 1926

Baggina cf. **dentata** Hagn
pl. IX, figs. 1, 2

cf. *Baggina dentata* Hagn, 1956, Palaeontographica, v. 107, p. 165, pl. 15, figs. 7a, b; Ferrer, 1971, Schweiz. Pal. Abh., vol. 90, p. 50, pl. 6, figs. 21, 22.

Remarks: Our specimens resemble more the figures of Ferrer than those of Hagn. According to Hagn his species has a smooth surface, which cannot be maintained for our material. The presence of sediment filling in the umbilical region hides the dentate ornamentation, if it exists at all. Therefore we only tentatively refer our individuals to this species. For distribution see figure 17.

Genus **Cancris** De Montfort, 1808

Cancris auriculus (Fichtel & Moll) var. **primitivus** Cushman & Todd
pl. VIII, fig. 5

Cancris auriculus (Fichtel & Moll) var. *primitivus* Cushman & Todd, 1942, Cushm. Lab. Foram. Res., Contr., v. 18, p. 77, pl. 19, figs. 1, 2; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 214, pl. 12, figs. 9, 10; Le Calvez, 1970, Cah. Paléont., p. 145, pl. 37, figs. 5, 6.

Cancris subconicus (Terquem)
pl. VIII, fig. 6

Rotalina subconica Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 61, pl. 4, fig. 5.
Cancris subconicus (Terquem), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 213, pl. 12, figs. 6–8; Le Calvez, 1970, Cah. Paléont., p. 145, pl. 43, fig. 6; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 9, figs. 12–14.

Remarks: Specimens with a poreless umbilical-apertural region occur, as well as fully-perforated ones. Best represented in subunit II D of section Priabona, otherwise rare in scattered samples of both sections.

Family GLABRATELLIDAE

Genus **Glabratella** Dorreen, 1948

Remarks: Poor preservation makes identification of our *Glabratella*-associations difficult. Most individuals can be referred to the following species. It is, however, not possible to exclude the possiblity that our material contains other species too. For distribution see figure 11.

Glabratella turbinata (Terquem)
pl. VIII, fig. 7

Rotalina turbinata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 75, pl. 7, fig. 5a, b.
Discorbis turbinata (Terquem), Le Calvez, 1949, Carte Dét. Géol. Fr., p. 22, pl. 3, figs. 45–47.
Glabratella turbinata (Terquem), Le Calvez, 1970, Cah. Paléont., p. 149, pl. 30, figs. 4, 5; Samuel, 1975, Zàp. Karp., ser. Paleont., v. 1, p. 143, pl. 84, figs. 5–7.

Glabratella ubiqua (Le Calvez)

Discorbis ubiqua Le Calvez, 1949, Carte Det. Géol. Fr., p. 23, pl. 2, figs. 27–29.
Glabratella ubiqua (Le Calvez), Le Calvez, 1970, Cah. Paléont., p. 149, pl. 35, fig. 7; Samuel, 1975, Zàp. Karp., ser. Paleont., v. 1, p. 144, pl. 85, fig. 2.

Family SIPHONINIDAE

Genus **Siphonina** Reuss, 1850

Siphonina reticulata (Czjzek)
pl. IX, fig. 4

Rotalina reticulata Czjzek, 1848, Haid. Nat. Abh., vol. 2, p. 145, pl. 13, figs. 7, 8.
Siphonina fimbriata Reuss, 1850, Denkschr. K. Akad. Wiss. Wien, vol. 1, p. 372, pl. 47, fig. 6.

Siphonina reticulata (Czjzek), Cushman, 1927, Proc. U.S. Nat. Mus., no. 2716, p. 7, pl. 1, figs. 1, 2, pl. 3, fig. 4; Marks, 1951, Cushm. Found. Foram. Res., Contr. v. 2, p. 65, pl. 8, fig. 8a–c, Le Calvez, 1970, Cah. Paléont., p. 150.

Remarks: Only notably present in unit V of section Priabona; rare in unit IV of section Bressana.

Family ASTERIGERINIDAE

Genus **Asterigerina** d'Orbigny, 1839

Asterigerina aberystwythi Haynes, 1956

Asterigerina aberystwythi Haynes, 1956, Cushm. Found. Foram. Res., Contr. v. 7, p. 97, pl. 17, fig. 6; Le Calvez, 1970, Cah. Paléont., p. 151, pl. 31, fig. 1.

Remarks: Rare to common, almost throughout in section Bressana, but less frequent or absent in unit VI.

Asterigerina brencei Haque

pl. IX, fig. 3

Asterigerina brencei Haque, 1960, Mem. Pakist. Geol. Surv., v. 2, pt. 2, p. 33, 34, pl. 2, fig. 3a–c.

Remarks: First described from the Lower to Middle Eocene of Pakistan, it is characterized by its spinose periphery. The spines are often broken; they are hyaline/transparent and attached to each chamber of the last whorl. Up to 13% in some samples of units II D, III A and III B of section Priabona; rare to few in some samples of unit I B and of the middle part of unit VII of section Bressana.

Asterigerina bartoniana (Ten Dam)

Rotalia granulosa Ten Dam (not *Rotalia granulosa* (Karrer) = *Rosalina granulosa* Karrer), 1944. Med. Geol. St., ser. C-V, no. 3, p. 121, pl. 4, fig. 2.

Rotalia granulosa Ten Dam, 1947, J. Paleont., vol. 21, p. 186.

Asterigerina bartoniana (Ten Dam), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 158, pl. 10, fig. 1, 8; Le Calvez, 1970, Cah. Paléont., p. 151, pl. 31, fig. 6.

Family SPIRILLINIDAE

Genus **Spirillina** Ehrenberg, 1843

Spirillina simplex Le Calvez

Spirillina simplex Le Calvez, 1949, Carte Dét. Géol. Fr., p. 13, pl. 1, fig. 1; Le Calvez, 1970, Cah. Paléont., p. 155, pl. 33, fig. 3.

Remarks: This species name is applied to all planispiral specimens with a proloculus followed by an enrolled tubular second chamber. No ornamentation and/or perforation was observed. One side may be slightly concave. Rare in units II D and III A; up to few in unit IV and V of section Priabona; rare to few in unit I B, III, IV, VI and VII, incidentally common in unit VII of section Bressana.

Genus **Planispirillina** Bermudez, 1952

Planispirillina striatogranulosa (Terquem)

Spirillina striato-granulosa Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 33, pl. 1, fig. 30; Le Calvez, 1949, Carte Dét. Géol. Fr., p. 11, pl. 1, figs. 3–4.
Planispirillina striatogranulosa (Terquem), Le Calvez, 1970, Cah. Paléont., p. 156, pl. 33, fig. 4.

Remarks: We use this species name for all individuals with distinctly truncate periphery, and with some ornamentation on both sides of the test. The quality of our material does not allow us to identify the exact nature of the ornamentation. An excellent scan-photo was made by Le Calvez (1970), on which the ornamentation appears to be of the nature of pronounced pits or perforations. Up to few in units IV and V of section Priabona; up to few in units III, IV, VI and VII of section Bresana.

Genus **Patellina** Williamson, 1858

Patellina *lucida* Le Calvez

pl. X, fig. 1

Patellina lucida Le Calvez, 1949, Carte Dét. Géol. Fr., p. 15, pl. 1, figs. 9, 10; Le Calvez, 1970, Cah. Paléont., p. 157, pl. 33, fig. 6.

Remarks: This species shows roughly the same distribution as *Planispirillina striatogranulosa.*

Family ROTALIIDAE

Genus **Ammonia** Brunnich, 1772

? **Ammonia** sp.

pl. IX, figs. 5, 6

Remarks: We came across individuals from section Bressana which have the following characteristics in common: test trochospiral, wall finely perforated and/or rather coarsely textured, 5 to 7 chambers in the last whorl, more or less rounded periphery, extremely depressed sutures especially in the umbilical region accentuating a deep umbilicus. Aperture not distinct, probably interiomarginal.

In the literature we found two references which resemble our specimens:

– *Gavelinella lellingensis* Brotzen, 1948, Sver. Geol. Undersök., v. 42, no. 2, ser. c, no. 493, p. 75, pl. 11, figs. 1, 2.

– *Ammonia beccarii* Sacal & Debourle (non Linné), 1957, Mém. Soc. Géol. Fr., no. 78, pt. 2, p. 39, pl. 16, fig. 2 (not figs. 4, 6).

The first differs from our specimens in being coarsely perforated and in having apertural lips; the second in having a smooth surface. We therefore refrained from naming our material. Superficially the specimens somewhat resemble planktonic foraminifera, but their distribution makes this assumption highly improbable. Rare to few only in unit VI of section Bressana.

Ammonia trochus (Roemer)

pl. IX, figs. 7, 8

Rotalia trochus Roemer, 1838, N. Jb. Min., p. 388, pl. 3, fig. 47 (fide Ellis and Messina); Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 168, pl. 12, fig. 9.

Remarks: In addition to typical forms with a broad, conspicuous keel (fig. 8), specimens with a less pronounced keel also occur in our material (fig. 7). Their chambers on the umbilical side are also slightly more inflated. Up to common in unit VI of section Bressana only.

Genus **Pararotalia** Le Calvez, 1949

Remarks: Confusion still exists as to the identification of species of the genus *Pararotalia.* As the preservation of our material leaves much to be desired, we distinguished only two species:

– *P. audouini:* relatively large specimens with 6 to 8 chambers in the last whorl, depressed sutures on the umbilical side, more or less distinct umbilical plug, lobate keel with often pronounced spines.

– *P. armata:* comparatively smaller forms, with less depressed sutures, 5 to 6 chambers in the last whorl, gradually increasing in size; a conspicuous plug; keeled periphery often ornamented with fine, transparent spines.

Pararotalia audouini (d'Orbigny)

Rotalia audouini d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 273, no. 19, pl. 7 fig. 1 (fide Ellis and Messina); Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 241, pl. 16, figs. 8–10.

Pararotalia audouini (d'Orbigny), Le Calvez, 1970, Cah. Paléont., p. 162, pl. 34, fig. 8; Braga *et al.,* 1975, Schweiz. Paläont. Abh., v. 97, p. 107, pl. 6, figs. 8, 9.

Remarks: Up to few in some samples in unit VI and of the lower part of unit VII of section Bressana.

Pararotalia armata (d'Orbigny)

Rotalia armata d'Orbigny, 1850, Podrom. Pal. Strat. Univ. Anim. Moll. Ray., vol. 3, p. 157.
Pararotalia armata (d'Orbigny), Loeblich and Tappan, 1957, Smith. Miscel. Coll., v. 135, no. 2, p. 9, pl. 5, fig. 2; Le Calvez, 1970, Cah. Paléont., p. 161, pl. 39, fig. 1.

Remarks: Rare to few in some samples of unit VI and of the lower part of unit VII in section Bressana.

Family ELPHIDIIDAE

Genus **Elphidium** De Montfort, 1808

Elphidium latidorsatum (Reuss)

pl. XII, fig. 2

Polystomella latidorsata Reuss, 1864, Denkschr. K. Akad. Wiss. Wien, v. 23, p. 10, pl. 1, fig. 6.
Elphidium latidorsatum (Reuss), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 240, pl. 15, figs. 13, 14; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, pl. 12, fig. 10; Braga *et al.,* 1975, Schweiz. Paläont. Abh., v. 97, p. 108, pl. 5, fig. 18.

Remarks: Variation is observed in the length of the ridges connecting two successive chambers. For distribution in combination with *Protelphidium* see figure 11.

Genus **Protelphidium** Haynes, 1956

Protelphidium sp.

pl. XII, fig. 1

Protelphidium sp. 1 Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 115, pl. 12, figs. 12, 13.

Remarks: There is still confusion in the taxonomy of "nonionid" forms throughout Eocene and Oligocene. Murray and Wright (1974) refer specimens with radial calcitic walls to *Protelphidium* and those with granular calcitic walls to *Nonion.* Our individuals fit their figures very well; as we cannot examine the wall structure, they are tentatively assigned to this genus. Characteristic is the subacute periphery and the relatively weak umbilical ornamentation. For ditribution in combination with *Elphidium latidorsatum* see figure 11.

Family HANTKENINIDAE

Genus **Pseudohastigerina** Banner & Blow, 1959

Pseudohastigerina micra (Cole)

Nonion micrus Cole, 1927, Bull. Am. Paleont., v. 14, no. 51, p. 22, pl. 5, fig. 12.
Globigerinella micra (Cole), Subbotina, 1953 (1971, English translation), Foss. Foram. USSR, p. 122–124, pl. 13, figs. 16–17.
Hasterigerina micra (Cole), Bolli, 1957, U.S. Nat. Mus., Bull. no. 215, p. 161, pl. 35, figs. 1–2.
Pseudohasterigerina micra (Cole), Blow, 1969, Proc. 1st. Int. Conf. Plankt. Microfoss., v. 1, p. 275, 376, pl. 53, figs. 1, 4–6; Stainforth *et al.*, 1975, Paleont. Contr. Univ. Kansas, Art. 62, p. 207, fig. 68; Toumarkine & Bolli, 1975, Schweiz. Paläont. Abh., v. 97, p. 82, pl. 1, figs. 1–2.

Remarks: Scattered occurrence in Bressana.

Family GLOBOROTALIIDAE

Genus **Turborotalia** Cushman & Bermudez, 1937

Turborotalia cerroazulensis cocoaensis (Cushman)

pl. XV, fig. 6

Globorotalia cocoaensis Cushman, 1928, Cushm. Lab. Foram. Res., Contr. v. 4, p. 75, p. 10, fig. 3; Bolli, 1957, U.S. Nat. Mus., Bull. no. 215, p. 169, pl. 39, figs. 5–7.
Globorotalia (Turborotalia) cerroazulensis (Cole), Blow & Banner, 1962, in Eames, F. E. *et al.*, Fundamentals of Mid-Tertiary stratigraphical correlations, p. 118, figs. 12d–e, pl. 12, figs. D–F; Blow, 1969, Proc. 1st. Int. Conf. Plankt. Microfoss., v. 1, p. 347, pl. 36, figs. 3, 4.
Globorotalia cerroazulensis cocoaensis Cushman, Toumarkine & Bolli, 1970, Rev. Micropaléont., v. 13, p. 144, pl. 1, figs. 28–33, pl. 2, figs. 6–8, 27; Stainforth *et al.*, 1975, Paleont. Contr. Univ. Kansas, Art. 62, p. 258, figs. 7 D, E, fig. 108; Toumarkine & Bolli, 1975, Schweiz. Paläont. Abh., v. 97, p. 80, pl. 2, figs. 16–18.

Remarks: Only a single specimen of this stratigraphically important species was found in one sample (Brs. 13) of the section Bressana. The presence of this species concurs with the biostratigraphic zonation by means of calcareous nannoplankton of the Upper Eocene (Toumarkine & Bolli, 1970, 1975; Proto Decima *et al.*, 1975).

Hardenbol (1968) recorded the occurrence of *G. cerroazulensis* and *Hantkenina* sp. from approximately the same interval of his Ghenderle section (= Bressana section, in this paper).

Family GLOBIGERINIDAE

Genus **Globigerina** d'Orbigny, 1826

Globigerina eocaena Gümbel

pl. XV, fig. 5

Globigerina eocaena Gümbel, 1868, Abh, k. bayer. Akad. Wiss. II, Cl. X, v. 2, p. 84, pl. 2, fig. 109;

Stainforth *et al.*, 1975, Paleont. Contr. Univ. Kansas, Art. 62, p. 268, fig. 115; Toumarkine & Bolli, 1975, Schweiz. Paläont. Abh., v. 97, p. 76, pl. 4, figs. 1, 2.

Globigerina yeguaensis Weinzierl & Applin, 1929, J. Paleont., v. 3, p. 408, pl. 43, fig. 1; Bolli, 1957, U.S. Nat. Mus., Bull. no. 215, p. 163, pl. 35, figs. 14–15.

Globigerina yeguaensis yeguaensis Weinzierl & Applin, Blow & Banner, 1962, in Eames, F. E. *et al.*, Fundamentals of Mit-Tertiary stratigraphical correlations, p. 99, p. 13, fig. H, M.

Globigerina (Subbotina) eocaena Gümbel, Hagn & Lindenberg, 1969, Proc. 1st. Int. Conf. Plankt. Microf., v. 2, p. 236–245, pl. 1, figs. 1, 6.

Remarks: This species name is used for all our *Globigerina* individuals which show a distinctly cancellate test-surface. Nearly always 4 chambers in final whorl. Umbilicus small and deep; aperture a low arch, often with a lip.

We agree with Stainforth *et al.* (1975) who regard *G. yeguaensis* as a junior synonym of this species.

Large and fairly well-preserved specimens were found in microfacies-units I B and II of the section Bressana, otherwise scattered occurrence in both sections.

Globigerina officinalis Subbotina
pl. XV, fig. 4

Globigerina officinalis Subbotina, 1953 (1971, English translation), Foss. Foram. USSR, p. 105, 108, pl. 11, figs. 1–7; Blow & Banner, 1962, in Eames, F. E. *et al.*, Mid-Tertiary stratigraphical correlations, p. 88, figs. 16, pl. 9, figs. A–C; Blow, 1969, Proc. 1st. Int. Conf. Plankt. Microfoss., v. 1, p. 320, pl. 1, figs. 1–3; Stainforth *et al.*, 1975, Paleont. Contr. Univ. Kansas, Art. 62, p. 211, fig. 71; Toumarkine & Bolli, 1975, Schweiz. Paläont. Abh., v. 97, p. 77.

Remarks: Specimens which we assigned to this species are characterized by a more or less smooth to slightly ornamented (probably spinose) test-surface. They are smaller than specimens referred to *G. eocaena.*

Family EPONIDIDAE

Genus **Eponides** De Montfort, 1808

Eponides ocalana Cushman
pl. X, figs. 5, 6

Eponides ocalana Cushman, 1933, Cushm. Lab. Foram. Res., Contr., v. 9, p. 17, pl. 2, fig. 7.

Remarks: Our forms fit very well the figures of Cushman from the Upper Eocene Jackson Formation. *Eponides tethycus* Dorreen (1948, J. Paleont., v. 22, p. 295, pl. 39, fig. 3) recorded from the Lower Oligocene Kisczell Clay of Budapest, might represent a junior synonym of this species. Two species desecribed as *Globorotalites* (*G. lobata* Brotzen, 1948, Sver. Geol. Undersök., v. 42, no. 2, ser. C, no. 493, p. 91, pl. 17, fig. 3; *G. granulatus* Pozaryska and

Szczechura, 1968, Palaeont. Polonica, no. 20, p. 67–68, pl. 8, figs. 1–7) are also similar. Some larger specimens show a coarse ornamentation, especially on the spiral side. In this respect they resemble *Anomalina alemendaris* Cushman and Bermudez (1937, Cushm. Lab. Foram. Res., Contr. v. 13, p. 27, pl. 2 fig. 62; not fig. 60, which is the holotype).

Hagn (1956, p. 163, pl. 14, fig. 17) records *Eponides* aff. *polygonatus* (Gümbel) (= *Rotalia polygonata* Gümbel, 1868, p. 73, pl. 2, fig. 89) from the Upper Eocene in Northern Italy. According to Hagn's description this species has 7 chambers in the last whorl but the figured specimen shows only 4½ to 5 chambers, making it similar to our specimens. Up to few in some samples in unit IV and V of section Priabona.

Eponides polygonus Le Calvez
pl. X, fig. 2

Eponides polygonus Le Calvez, 1949, Carte Dét. Géol. Fr., p. 28, pl. 5, figs. 90–92; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 210, pl. 12, fig. 1; Le Calvez, 1970, Cah. Paléont., p. 176, pl. 37, figs. 1, 9; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, pl. 14, figs. 9, 11, 12.

Remarks: We use this species name for representatives of this genus with a plano-convex test, 5 to 6 chambers in the last whorl, gradually increasing in size as added, wall distinctly perforated but for the apertural face. Few in the lowermost part of unit II D, rare to few in units IV and V of section Priabona; rare to few in units III and IV of section Bressana.

Eponides toulmini Brotzen
pl. X, figs. 3, 4

Eponides boueana (not *Rotalia boueana* d'Orbigny), Toulmin, 1941, J. Paleont., v. 15, p. 601, pl. 81, figs. 6, 7.

Eponides toulmini Brotzen, 1948, Sver. Geol. Undersök., v. 42, no. 2, ser. c, no. 493, p. 78, pl. 10, fig. 16; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 211, pl. 12, fig. 2; Le Calvez, 1970, Cah. Paléont., p. 176, pl. 37, fig. 8; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, pl. 14, figs. 10, 13, pl. 15, fig. 1.

Remarks: This species name is applied to specimens with a biconvex test, 6 to 7 (rarely 5 or 8) chambers in the last whorl, increasing rather rapidly in size but only moderatedly inflated. Perforation is usually distinct, often coarse, but finely perforated and relatively smooth specimens occur as well. The last forms closely resemble *Epistominella acutimargo* (Halkyard) (= *Pulvinulina acutimargo* Halkyard, 1919, Mem. Proc. Manchester Lit. Phil. Soc., v. 62, pt. II, p. 120, pl. 7, fig. 4), but the aperture of our specimens is an interiomarginal slit. Rare to few in units IV and V of section Priabona; up to few in units II, III and IV of section Bressana.

Genus Neoeponides Reiss, 1960

Neoeponides schreibersii (d'Orbigny)

Rotalina schreibersii d'Orbigny, 1846, Foram. Foss. Vienne, p. 154, pl. 8, figs. 4–6.
Eponides schreibersii (d'Orbigny), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 210, pl. 11, figs. 14, 15.
Neoeponides schreibersii (d'Orbigny), Reiss, 1960, Is. Geol. Surv., Bull., v. 29, p. 17; Le Calvez, 1970, Cah. Paléont., p. 177, pl. 42, fig. 3.

Remarks: This species is rare to few only in the middle part of unit III C of section Priabona; rare in the upper part of subunit I B and in the lower part of unit II of section Bressana.

Family CIBICIDIDAE

Genus Cibicides De Montfort, 1808

Remarks: As *Cibicides* is the most frequent genus in our material, its species will be treated at some length. They represent a highly variable group with not too clear boundaries between "species". The associations generally show three distinct types: *dutemplei*, *tenellus* and *lobatulus*, which are interconnected by intermediate forms: *sulzensis* and *westi* (see tab. V). *C. carinatus* is regarded as a variant of the *lobatulus*-type. No distinction is made between *Cibicides* and *Heterolepa*, as the distinguishing wall structure could not be observed.

species features	*dutemplei*	*sulzensis*	*tenellus*	*westi*	*lobatulus*	*carinatus*
test	biconvex	biconvex to planoconvex	± plano-convex	distinctly planoconvex	± plano-convex	± plano-convex
sutures on umbilical side	slightly curved	slightly curved	slightly curved	relatively strongly curved	slightly to strongly curved	slightly curved
umbilical knob	absent	absent/present	absent/present	absent/present	absent	absent/present
ways in which chambers increase	gradually	gradually	gradually	gradually	rapidly, often irregularly	rapidly, often irregularly
perforation	coarse	coarse to fine	fine	not visible	not visible	not visible
periphery/ keel	prominent, opaque	prominent, translucent	prominent, translucent	relatively less prominent	relatively less prominent, often lobulate	prominent, carinate

TABLE VI: Relationship within the *Cibicides*-assemblages. Arrows indicate the presence of transitional forms.

Cibicides carinatus (Terquem)

Truncatulina carinata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser. III, p. 94, pl. 10, figs. 1, 2.
Cibicides carinatus (Terquem), Le Calvez, 1949, Carte Dét. Géol. Fr., p. 45, pl. 4, figs. 72–74; Kaasschieter, 1962, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 221, pl. 14, fig. 6; Le Calvez, 1970, Cah. Paléont., p. 180, textfig. 66–68; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 15, figs. 4–6.

Cibicides lobatulus (Walker & Jacob)
pl. XI, fig. 2

Nautilus lobatulus Walker & Jacob, 1798, Adams Essays, Kanm. Ed., p. 642, pl. 14, figs. 36 (fide Ellis and Messina).
Cibicides lobatulus (Walker & Jacob), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 153, pl. 9, figs. 7, 8; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 221, pl. 14, figs. 6; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 15, figs. 13–15.

Remarks: Few to very common up to the middle part of subunit III C and common to abundant in the remaining upper part of section Priabona; few to common in subunit I B and common to abundant in the other units of section Bressana.

Cibicides dutemplei (d'Orbigny)
pl. XI, fig. 4

Rotalina dutemplei d'Orbigny, 1846, Foram. Foss. Vienne, p. 157, pl. 8, figs. 19–21.
Cibicides dutemplei (d'Orbigny), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 150, pl. 9, figs. 9–11; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 218, pl. 12, fig. 15.
Heterolepa dutemplei (d'Orbigny), Braga *et al.*, 1975, Schweiz. Paläont. Abh., v. 97, p. 109, pl. 6, figs. 1–3.

Remarks: The wall structure of our recrystallized material cannot be examined. Specimens assigned to *C. dutemplei* appear to have a somewhat opaque wall, especially at the periphery. This feature is used to separate this species from those of the *tenellus*-group. For distribution see figures 11 and 17.

Cibicides tenellus (Reuss)
pl. XI, fig. 3

Truncatulina tenellus Reuss, 1865, Sitzb. K. Akad. Wiss. Wien, v. 50, p. 477, pl. 5, fig. 6.
Cibicides tenellus (Reuss), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 151, p. 9, figs. 3–4; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 219, pl. 14, figs. 2; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 16, figs. 12–14.

Remarks: Not only the umbilical knob but also the keel seems to be hyaline in the specimens of this group. Transitional forms to the *lobatulus*-group often present problems in the determination. For distribution see figures 11 and 17.

Cibicides sulzensis (Herrmann)
pl. XI, fig. 1

Discorbina sulzensis Herrmann, 1917, Mitt. Geol. Anst. Els.-Loth., v. 10, pt. 3, p. 290, pl. 3, fig. 2.
Cibicides sulzensis (Herrmann), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 149, pl. 9, fig. 5; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 223, pl. 13, fig. 11.

Cibicides westi Howe

Cibicides westi Howe, 1939, Louis. Dept. Cons., Geol. Bull., v. 14, p. 88, pl. 13, figs. 20–22; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 218, pl. 13, figs. 6, 7; Le Calvez, 1970, Cah. Paléont., p. 184, pl. 43, figs. 9; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 117, pl. 17, figs. 3–5.

Remarks: This species is characterized by its curved sutures and strongly inflated chambers on the umbilical side.

Family HOMOTREMATIDAE

Genus **Victoriella** Chapman & Crespin, 1930

Victoriella abnormis (Hantken)
Pl. XII, fig. 4

Rhynchospira abnormis Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 69, pl. 7, figs. 17–19.
Victoriella abnormis (Hantken), Glaessner & Wade, 1959, Micropaleontology, v. 5, p. 199, pl. 1, fig. 6.

Remarks: Our specimens fit very well the figures and descriptions of Hantken and Glaessner & Wade from the Lower Oligocene of Hungary. The perforation of all specimens is very distinct, especially in the last chambers. The earlier stage is rough due to the fact that prominent pustules obliterate the pores. The aperture is often accentuated by a distinct neck. Rare to few in units III A, III B, IV and V of section Priabona.

Genus **Maslinella** Glaessner & Wade, 1959

Maslinella chapmani Glaessner & Wade
pl. XII, fig. 3

Maslinella chapmani Glaessner & Wade, 1959, Micropaleontology, v. 5, p. 203, pl. 1, figs. 1–4; Loeblich and Tappan, 1964, Treatise Inv. Paleont., p. 709, figs. 583: 1–4.

Remarks: for distribution see figures 11 and 17.

Family CAUCASINIDAE Bykova

Genus **Fursenkoina** Loeblich & Tappan, 1961

Fursenkoina schreibersiana (Czjzek)
pl. XII, fig. 6

Virgulina schreibersiana Czjzek, 1848, Haiding. Nat. Abh., Wien. vol. 2, Abt. 1, p. 147, pl. 13, figs. 18–21 (fide Ellis and Messina); Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 63, pl. 7, fig. 15.
Fursenkoina schreibersiana (Czjzek), Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 118, p. 17, figs. 13–14.

Remarks: In our material it is difficult to distinguish *Fursenkoina vicksburgensis* (Cushman) and *F. dibollensis* (Cushman & Applin) from this species. For distribution see figures 11 and 17.

Family CASSIDULINIDAE

Genus **Globocassidulina** Voloshinova, 1960

Globocassidulina globosa (Hantken)
pl. XII, fig. 5

Cassidulina globosa Hantken, 1875, Mitt. Jb. Kön. Ungar. Geol. Anst., v. 4, p. 64, pl. 16, fig. 2; Hagn, 1956, Paleontographica, v. 107, p. 167, pl. 14, figs. 9, 10.
Globocassidulina globosa (Hantken), Braga *et al.,* 1975, Schweiz. Paläont. Abh., v. 97, p. 108, pl. 6, fig. 4.

Remarks: Some of the specimens are somewhat compressed and resemble *G. subglobosa* (Brady). For distribution see figures 11 and 17.

Family NONIONIDAE

Genus **Nonion** De Montfort, 1808

Nonion elongatum (d'Orbigny)
pl. XII, fig. 8

Nonionina elongata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 294, no. 20 (fide Ellis and Messina).
Nonion elongatum (d'Orbigny), Le Calvez, 1970, Cah. Paléont., p. 192, pl. 26, fig. 6.
Florilus elongatum (d'Orbigny), Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 120, pl. 18, figs. 4–5.

Remarks: Test more or less compressed, planispiral, involute to slightly evolute with 9 to 11 chambers, increasing in size as added, but increasing more rapidly in length than in breadth. Wall smooth, umbilical region depressed, in some specimens filled with somewhat granulose matter. Periphery rounded to slightly subacute. These characteristics fit two of d'Orbigny's species names: *elongatum* and *commune.* In our material it is impossible to separate them. Rare and scattered in both sections.

Nonion scaphum (Fichtel & Moll)

Nautilus scaphum Fichtel & Moll, 1798, Test. Micr., p. 105, pl. 19, figs. d, f (fide Ellis and Messina).
Nonion scaphum (Fichtel & Moll), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 204, pl. 11, fig. 5; Braga *et al.*, 1975, p. 108, pl. 5, figs. 22, 23.

Remarks: This species is characterized by its flaring last chambers and large apertural face. It may well prove to be a ecophenotype of *N. elongatum.* Rare and scattered in both sections.

Nonion parvulum (Grzybowski}
pl. XII, fig. 7

Anomalina parvula Grzybowski, 1896, Akad. Umiej. Krakowie, Wydz. Nat. Rrzyr. Krakow, vol. 30, p. 302, pl. 2, fig. 6a–b; Le Calvez, 1970, Cah. Paléont., p. 198, pl. 44, fig. 11.
Nonion parvulum (Grzybowski), Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 116, pl. 13, figs. 14, 15.

Remarks: We agree with Murray and Wright, who assign this species to *Nonion* rather than to *Anomalina,* as it seems to be planispiral not trochospiral. Rare and scattered in both sections.

Genus Nonionella Cushman, 1926

Nonionella spissa Cushman

Nonionella hantkeni (Cushman & Applin) var. *spissa* Cushman, 1931, Cushm. Lab. Foram. Res. Contr., v. 7, p. 58, pl. 7, fig. 13.
Nonionella spissa Cushman, Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 205, pl. 11, figs. 7, 8; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 120, pl. 18, figs. 6, 7 and 9.

Remarks: N. wemmelensis Kaasschieter might be included in our present species as both types are not separable in our poorly-preserved material. Rare in units II D, III A, III B and IV, few in unit III C (especially in the upper part of this unit).

Genus Pullenia Parker & Jones, 1862

Pullenia quinqueloba (Reuss)

Nonionina quinqueloba Reuss, 1851, Zschr. Deut. Geol. Ges., v. 3, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 139, pl. 6, fig. 8; Kaasschieter, 1961, Inst, R. Sci. Nat. Belg., Mém. no. 147, p. 202, pl. 11, figs. 1, 2; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 120, pl. 18, figs. 13, 14.

Family ALABAMINIDAE

Genus **Alabamina** Toulmin, 1941

Alabamina obtusa (Burrows & Holland)

pl. XIII, fig. 3

Pulvinulina exigua (Brady) var. *obtusa* Burrows & Holland, 1897, Proc. Geol. Assoc., v. 15, p. 49, pl. 2, fig. 5.

Alabamina obtusa (Burrows and Holland), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 227, pl. 13, figs. 15; Murray & Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 116, pl. 19, figs. 1, 2.

Remarks: Most of our *Alabamina* specimens show the rounded periphery typical for this species. Very rare representatives, with a more acute periphery, which can be identified as *A. wilcoxensis* Toulmin, are included in this category for counting purposes. For distribution in combination with *A. perlata* see figures 11 and 17.

Alabamina perlata (Andreae)

pl. XIII, figs. 1, 2

Pulvinulina perlata Andreae, 1884, Abh. Geol. Sp. krt. Els.-Loth., v. 2, pt. 3, p. 216, pl. 8, fig. 12.

Discorbis tuberculata (Balkwill & Wright) var. *australiensis* Chapman, Parr & Collins, 1934, Linn. Soc. Jour., v. 38, no. 262, p. 563, pl. 8, fig. 9.

Svratkina australiensis (Chapman, Parr & Collins), Pokorny, 1956, Univ. Carolina, v. 2, Geol., no. 3, p. 257.

Alabamina perlata (Andreae), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 157, pl. 8, figs. 8, 9.

Svratkina perlata (Andreae), Berggren & Aubert, 1976, Micropaleontology, v. 22, p. 318, pl. 4, figs. 21, 22.

Remarks: This species is referred to *Alabamina* because ornamented ("typical" for *Svratkina*) as well as smooth specimens occur in the same sample without any other differential characteristics. Our individuals show the following variations:

– test from biconvex to slightly planoconvex and from rather compressed to inflated,

– wall smooth to coarsely perforate,

– periphery rounded to subacute.

Specimens with biconvex test and subacute periphery resemble *Eponides toulmini* Brotzen (see there), which differs in having a distinct keel and a different aperture. Rare to few practically throughout section Priabona; rare to few in units I B, II, III, IV and VI of section Bressana.

Genus **Gyroidina** d'Orbigny

Gyroidina octocamerata Cushman & Hanna
pl. XIII, figs. 5, 6

Gyroidina soldanii d'Orbigny var. *octocamerata* Cushman & Hanna, 1927, Calif. Acad. Sci., Proc., ser. 4, v. 16, p. 223, pl. 14, figs. 16–18.

Gyroidina octocamerata Cushman & Hanna, Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 212, pl. 13, fig. 2; Le Calvez, 1970, Cah. Paléont., p. 195, pl. 42, figs. 4, 5.

Gyroidinoides octocamerata (Cushman & Hanna), Pozaryska, 1965, Palaeont. Polonica, no. 14, p. 107, pl. 18, figs. 3, 5.

Remarks: Many specimens with typically 8 chambers are present; however, specimens with a somewhat more compressed test and only 6 chambers in the last whorl as figured by Pozaryska are also included. This species is consistently less ventroconvex than *G. soldanii.* Rare in subunit II D and in unit V, up to common in other units of section Priabona; rare to common throughout section Bressana.

Gyroidina soldanii d'Orbigny
pl. XIII, fig. 4

Gyroidina soldanii d'Orbigny, 1826, Ann. Sci. nat., ser. 1, v. 7, p. 278, mod. 36 (fide Ellis and Messina); Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 147, pl. 7, figs. 12–15.

Gyroidinoides soldanii (d'Orbigny), Braga *et al.*, 1975, Schweiz. Paläont. Abh., v. 97, p. 109, pl. 6, figs. 10, 11.

Remarks: Periphery rounded to subacute, shape very ventroconvex. Very rare, relatively large specimens with an acute periphery, which could be assigned to *G. girardana* (Reuss), are included. The distribution pattern is similar to that of *G. octocamerata* (figs. 11 and 17).

Family ANOMALINIDAE

Genus **Anomalina** d'Orbigny, 1826

Anomalina acuta Plummer
pl. XIV, fig. 3

Anomalina ammonoides (Reuss) var. *acuta* Plummer, 1926, Univ. Tex., Bull., no. 2644, p. 149, pl. 10, fig. 2.

Anomalina acuta Plummer, Toulmin, 1941, J. Paleont., v. 15, p. 608, pl. 82, figs. 9, 10; Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 216, pl. 12, figs. 12, 13.

Anomalinoides acuta (Plummer), Brotzen, 1948, Sver. Geol. Undersök., v. 42, no. 2, ser. c, no. 493, p. 87, pl. 14, fig. 2; Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 116, pl. 19, figs. 3, 4 and 7.

Remarks: Most specimens show a central glassy knob on one side and a rim formed by the last chambers of the last whorl on the opposite side. Rare to few in unit II D to the lower part of unit IV of section Priabona; rare to common in units I B and II, rare in units III, IV and VI of section Bressana.

Anomalina alazanensis Nuttall
pl. XIV, fig. 2

Anomalina alazanensis Nuttall, 1932, J. Paleont., v. 6, p. 31, pl. 8, figs. 5–7.
Anomalinoides alazanensis (Nuttall), Butt, 1966, L. Olig. Escorn., p. 62, pl. 7, figs. 4; Berggren & Aubert, 1976, Micropaleontology, v. 22, p. 315, pl. 2, figs. 14–17.

Remarks: Distinguished from *A. acuta*, with which it nearly always occurs together, in having a rounded to subacute periphery and in lacking a central ornamentation. Distribution, including *A. acuta* see figures 11 and 17.

Anomalina grosserugosa (Gümbel)
pl. XIV, fig. 1

Truncatulina grosserugosa Gümbel, 1868, Abh. k. bayer. Akad. Wiss. II, cl. X, v. 10, p. 82, pl. 2, fig. 104.
Anomalina grosserugosa (Gümbel), Kaasschieter, 1961, Inst. R. Sci. Nat. Belg., Mém. no. 147, p. 217, pl. 12, fig. 14; Le Calvez, 1970, Cah. Paléont., p. 198, pl. 40, fig. 2.

Remarks: This species is characterized by its coarse perforation. A variation is observed in the degree to which the chambers increase in relative length. Forms with a lobate periphery and those with an entire periphery occur together. Rare in unit III D and rare to few in units IV and V of section Priabona; rare in units II, III, IV and VI of section Bressana.

Genus **Boldia** van Bellen, 1946

Boldia lobata (Terquem)
pl. XIV, fig. 4

Rotalina lobata Terquem, 1882, Mém. Soc. Géol. Fr., v. 2, ser III, p. 63, pl. 4, fig. 11.
Boldia lobata (Terquem), Le Calvez, 1952, Carte Géol. Dét. Fr., p. 50, pl. 4, figs. 40, 41; Le Calvez, 1970, Cah. Paléont., p. 199, pl. 45, fig. 1.

Remarks: Very rare in section Priabona; rare to few in unit VI and unit VII of section Bressana. See also figure 11.

Genus **Melonis** De Montfort, 1808

Melonis affinis (Reuss)
pl. XIV, figs. 5, 6

Nonionina affinis Reuss, 1851, Zschr. Deut. Geol. Ges., v. 3, p. 72, pl. 5, fig. 32.
Nonion affine (Reuss), Batjes, 1958, Inst. R. Sci. Nat. Belg., Mém. no. 143, p. 140, pl. 6, fig. 12; Le Calvez, 1970, Cah. Paléont., p. 190, pl. 27, fig. 2.
Melonis affinis (Reuss), Murray and Wright, 1974, Paleont. Assoc., Spec. Paper no. 14, p. 119, pl. 20, figs. 4, 7; Braga *et al.*, 1975, Schweiz. Paläont. Abh., v. 97, p. 109, pl. 5, figs. 19–21.

Remarks: As this species shows a relatively more coarse perforation and a more translucent wall, rather than having the more or less smooth, apparently opaque wall of our *Nonion*-group, it has been placed in *Melonis* rather than in *Nonion*.

Both compressed, and inflated specimens, the latter with a more broadly rounded periphery, are present. These characteristics are considered to be features of intergrading variants. For distribution see figure 11 and 17.

Genus **Queraltina** Marie, 1950

Queraltina epistominoides Marie
pl. XV, figs. 2, 3

Queraltina epistominoides Marie, 1950, Bull. Soc. Géol. Fr., ser. V, v. 20, p. 74–77, textfigs. 1–3, 8, 9; Loeblich and Tappan, 1964, Treatise Inv. Paleont., p. 764, pl. 628: 6, 7.

Remarks: In our material this species shows a suite of ontogenic stages, shown by the size of the test:

– type I (fig. 3): juveniles, showing only a single keel and moderate perforation,

– type II (fig. 2): Common forms, with a double keel, a relatively more convex umbilical side, and a distinct, coarse perforation on both sides,

– type III has more or less the same features as type II but the spiral side is covered by crystalline growth accumulating in pustules or irregularly raised ornamentation.

Juvenile specimens of type I with a minimum of perforation are somewhat similar to *Laticarinina altocamerata* (Heron-Allen & Earland) (see there). The symmetrically rounded chambers on the umbilical side and the broad but thin keel of the latter, rather than the somewhat acute, asymmetrical chamber outline in *Queraltina* can be used as distinguishing features. For distribution see figures 11 and 17.

Only type II occurs in section Priabona; in the lower part of section Bressana we found type I and type II while in the upper part only type II and type III are present.

Family CERATOBULIMINIDAE

Genus Schlosserina Hagn, 1954

Schlosserina asterites (Gümbel)
pl. XV, fig. 1

Rosalina asterites Gümbel, 1868, Abh. k. bayer. Akad. Wiss. II, Cl. X, v. II, p. 80, pl. 2, fig. 101.
Schlosserina asterites (Gümbel), Hagn, 1954. Cushm. Found. Foram. Res., Contr., v. 5, p. 18, pl. 3, fig. 15; Loeblich and Tappan, 1964, Treatise Inv. Paleont., p. 777, fig. 610: 1.

Remarks: Large areal pores are scattered over the final chamber face in most specimens of this distinctive species. The primary aperture as described by Hagn and Loeblich & Tappan could not be observed in our material. For distribution see figures 11 and 17.

List of species of extremely low frequency (in alphabetical order):
Astacolus decoratus (Reuss) = *Cristellaria decorata* Reuss, 1855
Astacolus gladius (Philippi) = *Marginulina gladius* Philippi, 1843
Baggina papillostoma Le Calvez, 1949
Bolivina anglica Cushman, 1936
Bolivina eocenica Terquem, 1882
Bulimina alsatica Cushman & Parker, 1937
Bulimina elongata d'Orbigny, 1846
Caucasina alpina Espitalié & Sigal, 1961
Chiloguembelina midwayensis (Cushman) = *Guembelina midwayensis*, Cushman, 1940.
Cylindroclavulina rudislosta (Hantken) = *Clavulina rudislosta* nom. nov., Hantken, 1889
Dentalina communis (d'Orbigny) = *Nodosaria (Dentaline) communis*, d'Orbigny, 1826
Elphidium hiltermanni Hagn, 1952
Fissurina orbignyana Seguenza, 1862
Glabratella diadematoides (Le Calvez) = *Pseudoruttenia diadematoides*, Le Calvez, 1959
Guembelitria triseriata (Terquem) = *Textilaria triseriata* Terquem, 1882
Halkyardia minima (Liebus) = *Cymbalopora radiata* Hagenow var. *minima* Liebus, 1911
Haplophragmoides latidorsatus (Bornemann) = *Nonionina latidorsata* Bornemann, 1855
Karreria fallax Rzehak, 1891
Karreriella siphonella (Reuss) = *Gaudryina siphonella* Reuss, 1851

Loxostomum teretum Cushman, 1936
Marginulinopsis behmi (Reuss) = *Cristellaria (Cristellaria) behmi* Reuss, 1866
Neoflabellina budensis (Hantken) = *Flabellina budensis* Hantken, 1875
Nodosaria emaciata (Reuss) = *Dentalina emaciata* Reuss, 1851
Nodosaria pyrula d'Orbigny, 1826
Nonionella lobsanensis (Andreae) = *Pulvinulina lobsanensis* Andreae, 1884
Planorbulina difformis Roemer, 1838
Planulina costata (Hantken) = *Truncatulina costata* Hantken, 1875
Saracenaria arcuata d'Orbigny, 1846
Trifarina muralis (Terquem) = *Uvigerina muralis* Terquem, 1882
Tritaxia szaboi (Hantken) = *Clavulina szaboi* Hantken, 1868
Vaginulinopsis vaginella (Reuss) = *Marginulina vaginella* Reuss, 1851
Valvulineria petrolei (Andreae) = *Pulvinulina petrolei* Andreae, 1884

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Plate VII

Fig. 1	*Clavulina parisiensis* d'Orbigny, 24 X, sample Pr. 147.
Fig. 2	*Lingulina glabra* Hantken, 10 X, sample Pr. 146.
Fig. 3	*Bolivinella* sp. cf. *subpectinata* Cushman, 66 X, sample Brs. 63.
Fig. 4	*Bolivinella* sp. cf. *rugosa* Howe, 66 X, sample Brs. 61.
Fig. 5	*Buliminella turbinata* (Terquem), 66 X, sample Brs. 61.
Fig. 6	*Buliminella pulchra* (Terquem), 66 X, sample Brs. 58.
Fig. 7	*Reussella recurvata* (Halkyard); 48 X, sample Brs. 53.
Fig. 8	*Reussella recurvata* (Halkyard), 48 X, sample Brs. 53.
Fig. 9	*Reussella spinulosa* (Reuss), 48 X, sample Brs. 4.
Fig. 10	*Bolivina carinata* Terquem, 42 X, sample Pr. 147.
Fig. 11	*Bolivina nobilis* Hantken, 33 X, sample Brs. 18.
Fig. 12	*Uvigerina eocaena* Gümbel, 33 X, sample Pr. 89.
Fig. 13	*Trifarina gracilis* (Reuss), 42 X, sample Pr. 134.
Fig. 14	*Trifarina tenuistriata* (Reuss), 66 X, sample Pr. 132.
Fig. 15	*Bulimina* sp., 66 X, sample Brs. 13.
Fig. 16	*Bulimina kasselensis* Batjes, 66 X, sample Brs. 50.

Plate VII

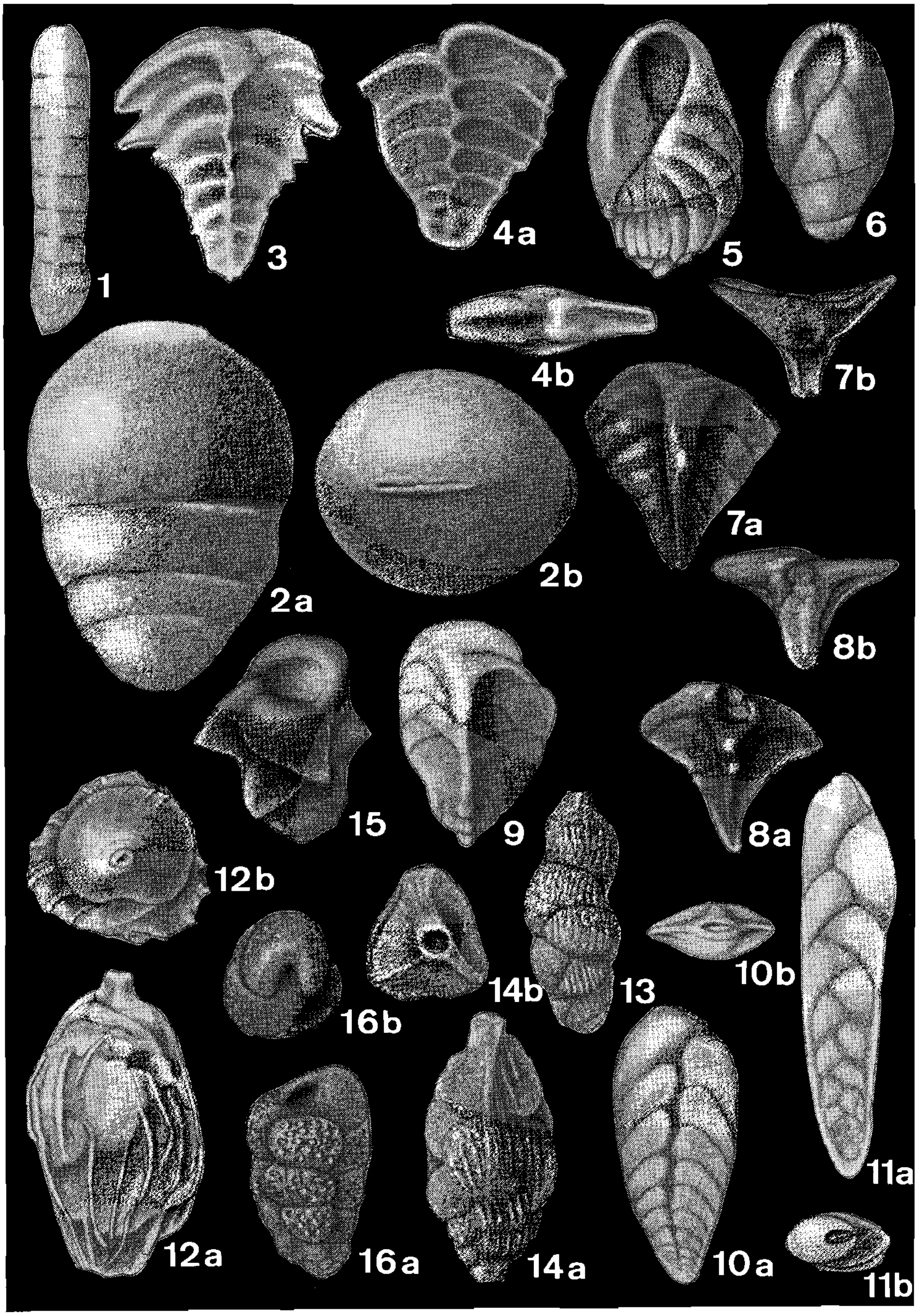
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Plate VIII

Fig. 1	*Rosalina obvoluta* (Terquem), 66 ×, sample Pr. 123.
Fig. 2	*Rosalina douvillei* (Cushman), 21 ×, sample Brs. 29.
Fig. 3	*Discorbis perovalis* (Terquem), 33 ×, sample Brs. 34.
Fig. 4	*Laticarinina altocamerata* (Heron-Allen & Earland), 42 ×, sample Pr. 49.
Fig. 5	*Cancris auriculus* (Fichtel & Moll) var. *primitivus* Cushman and Todd, 21 ×, sample Brs. 29.
Fig. 6	*Cancris subconicus* (Terquem), 48 ×, sample Brs. 7.
Fig. 7	*Glabratella turbinata* (Terquem), 96 ×, sample Brs. 57.

Plate VIII

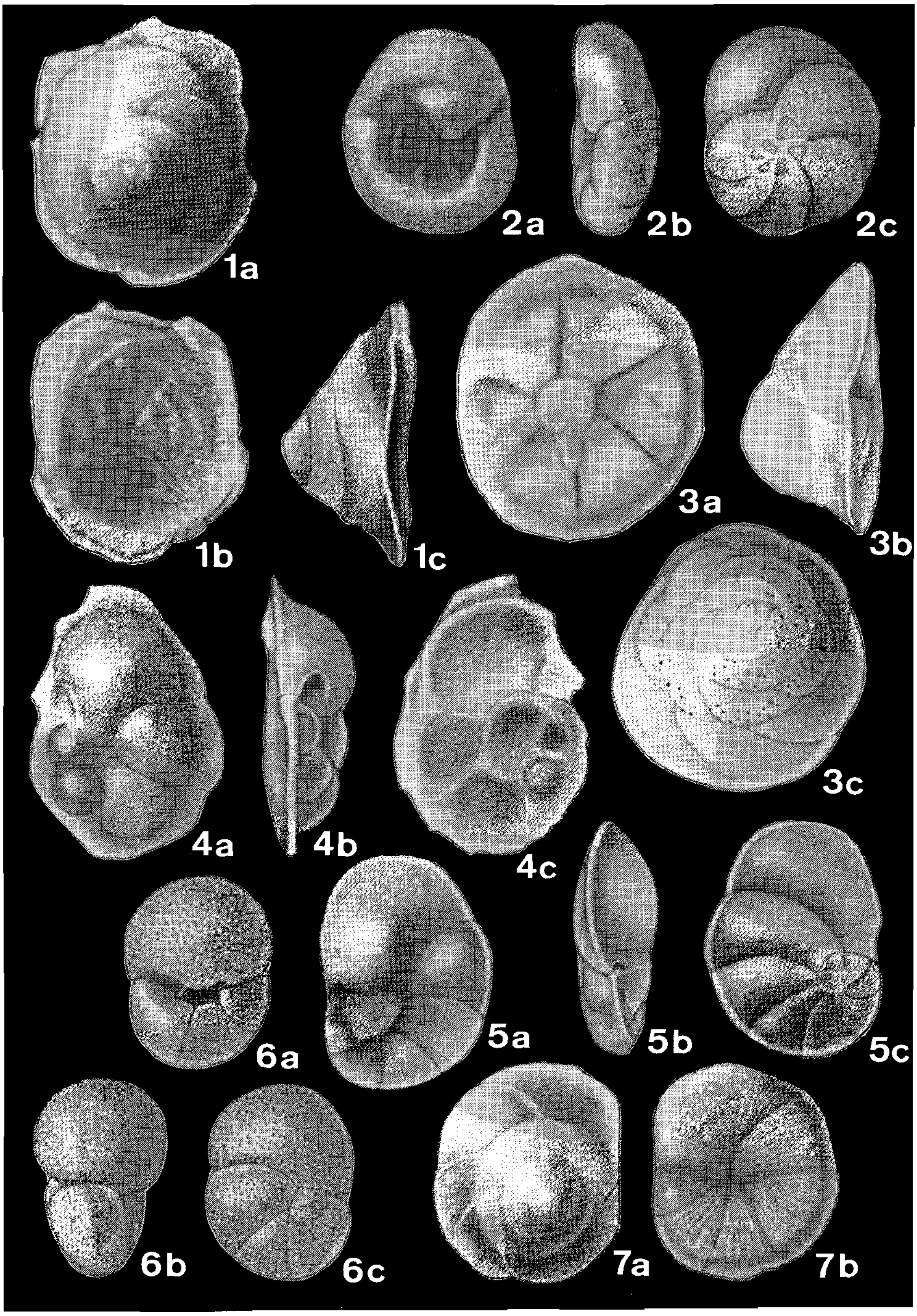


Plate IX

Fig. 1 *Baggina* cf. *dentata* Hagn, 66 X, sample Pr. 131.

Fig. 2 *Baggina* cf. *dentata* Hagn, 66 X, sample Pr. 134.

Fig. 3 *Asterigerina brencei* Haque, 96 X, sample Pr. 69.

Fig. 4 *Siphonina reticulata* (Czjzek), 64 X, sample Pr. 147.

Fig. 5 *Ammonia* sp., 66 X, sample Brs. 63.

Fig. 6 *Ammonia* sp., 66 X, sample Brs. 57.

Fig. 7 *Ammonia trochus* (Roemer), 48 X, sample Brs. 61.

Fig. 8 *Ammonia trochus* (Roemer), 66 X, sample Brs. 61.

Plate IX

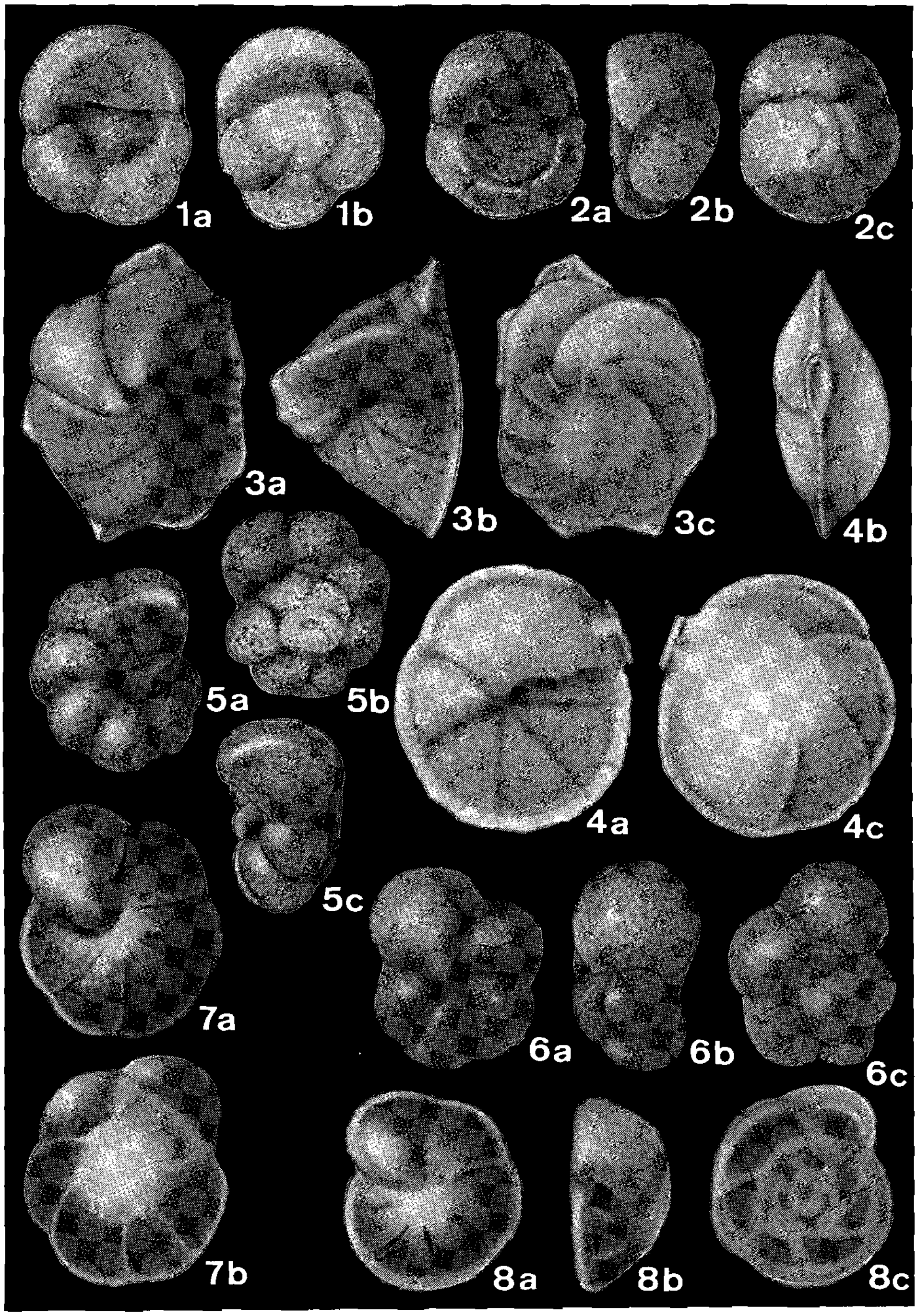


Plate X

Fig. 1 *Patellina lucida* Le Calvez, 66 X, sample Brs. 57.

Fig. 2 *Eponides polygonus* Le Calvez, 21 X, sample Pr. 80.

Fig. 3 *Eponides toulmini* Brotzen, 10 X, sample Pr. 49.

Fig. 4 *Eponides toulmini* Brotzen, 66 X, sample 147.

Fig. 5 *Eponides ocalana* Cushman, 10 X, sample Pr. 146.

Fig. 6 *Eponides ocalana* Cushman, 10 X, sample 146.

Plate X

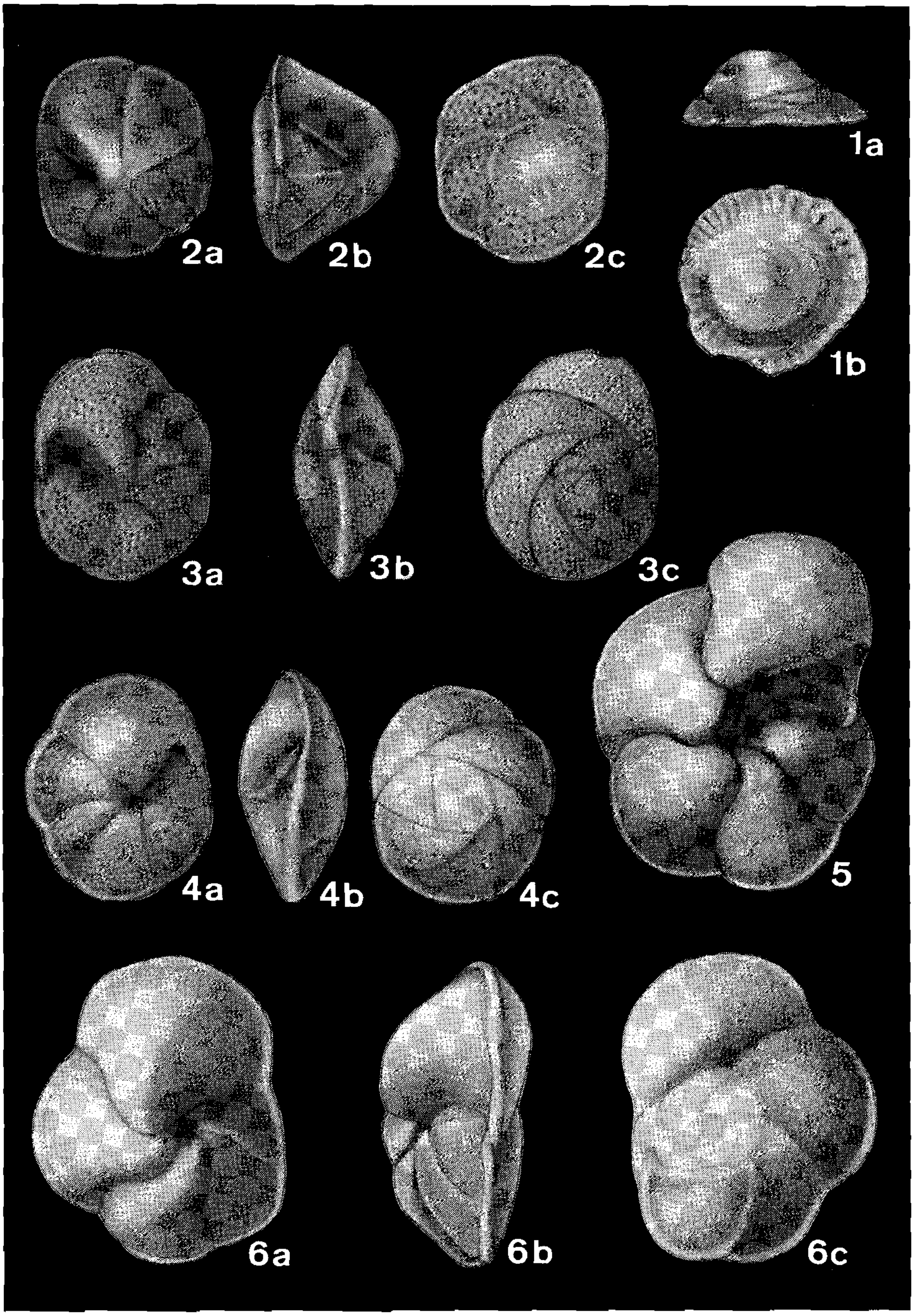


Plate XI

Fig. 1 *Cibicides sulzensis* Herrman, 33 X, sample Pr. 69.

Fig. 2 *Cibicides lobatulus* (Walker & Jacob), 33 X, sample Pr. 147.

Fig. 3 *Cibicides tenellus* (Reuss), 48 X, sample Pr. 147.

Fig. 4 *Cibicides dutemplei* (d'Orbigny), 33 X, sample Pr. 64.

Plate XI

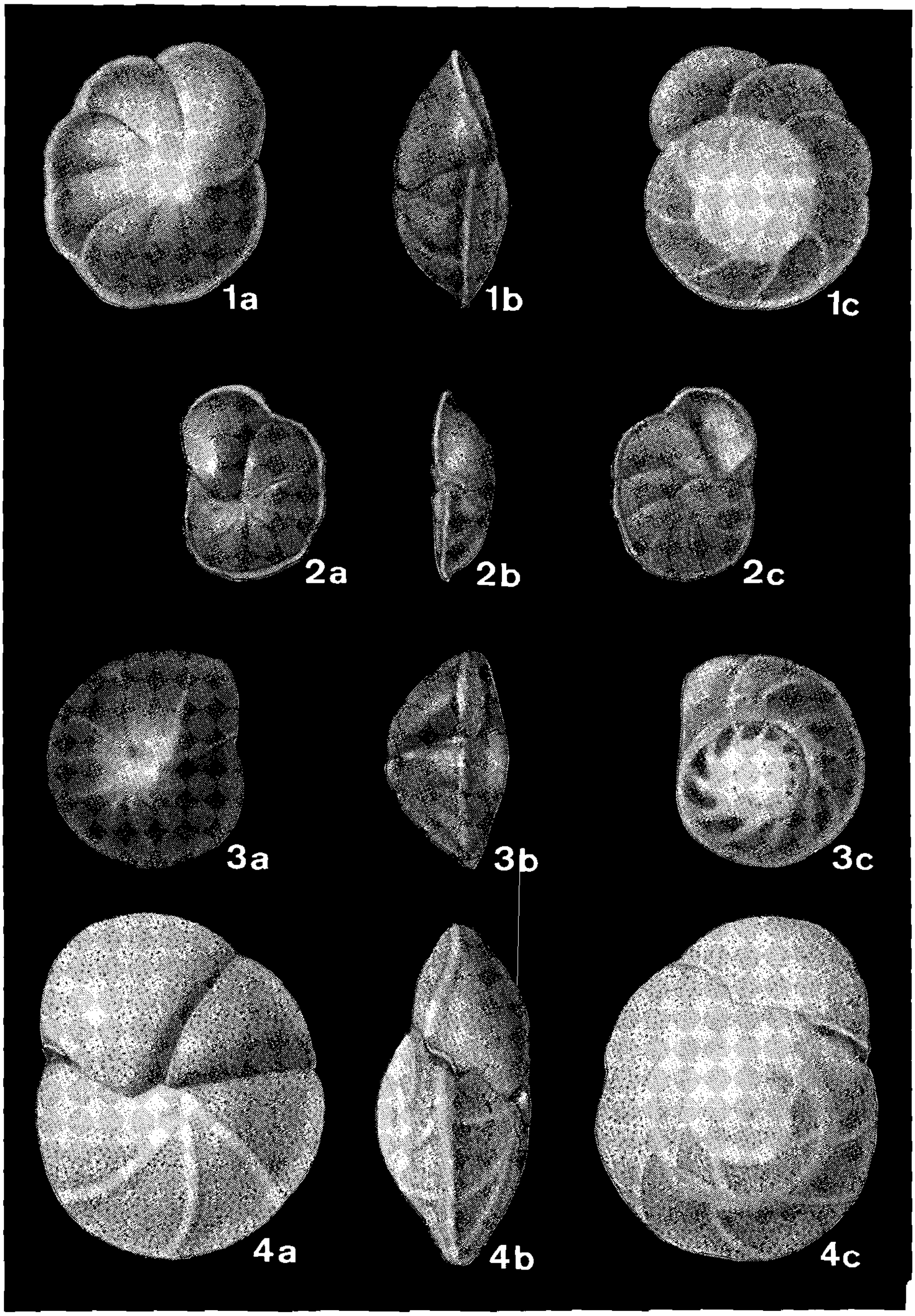


Plate XII

Fig. 1	*Protelphidium* sp., 66 ×. sample Brs. 53.
Fig. 2	*Elphidium latidorsatum* (Reuss), 66 ×, sample Brs. 55.
Fig. 3	*Maslinella chapmani* Glaessner & Wade, 21 ×, sample Pr. 70.
Fig. 4	*Victoriella abnormis* (Hantken), 17 ×, sample Pr. 146.
Fig. 5	*Globocassidulina globosa* (Hantken), 66 ×, sample Pr. 146.
Fig. 6	*Fursenkoina schreibersiana* (Czjzek), 48 ×, sample Brs. 3.
Fig. 7	*Nonion parvulum* (Grzybowski), 48 ×, sample Brs. 51.
Fig. 8	*Nonion elongatum* d'Orbigny, 42 ×, sample Brs. 33.

Plate XII

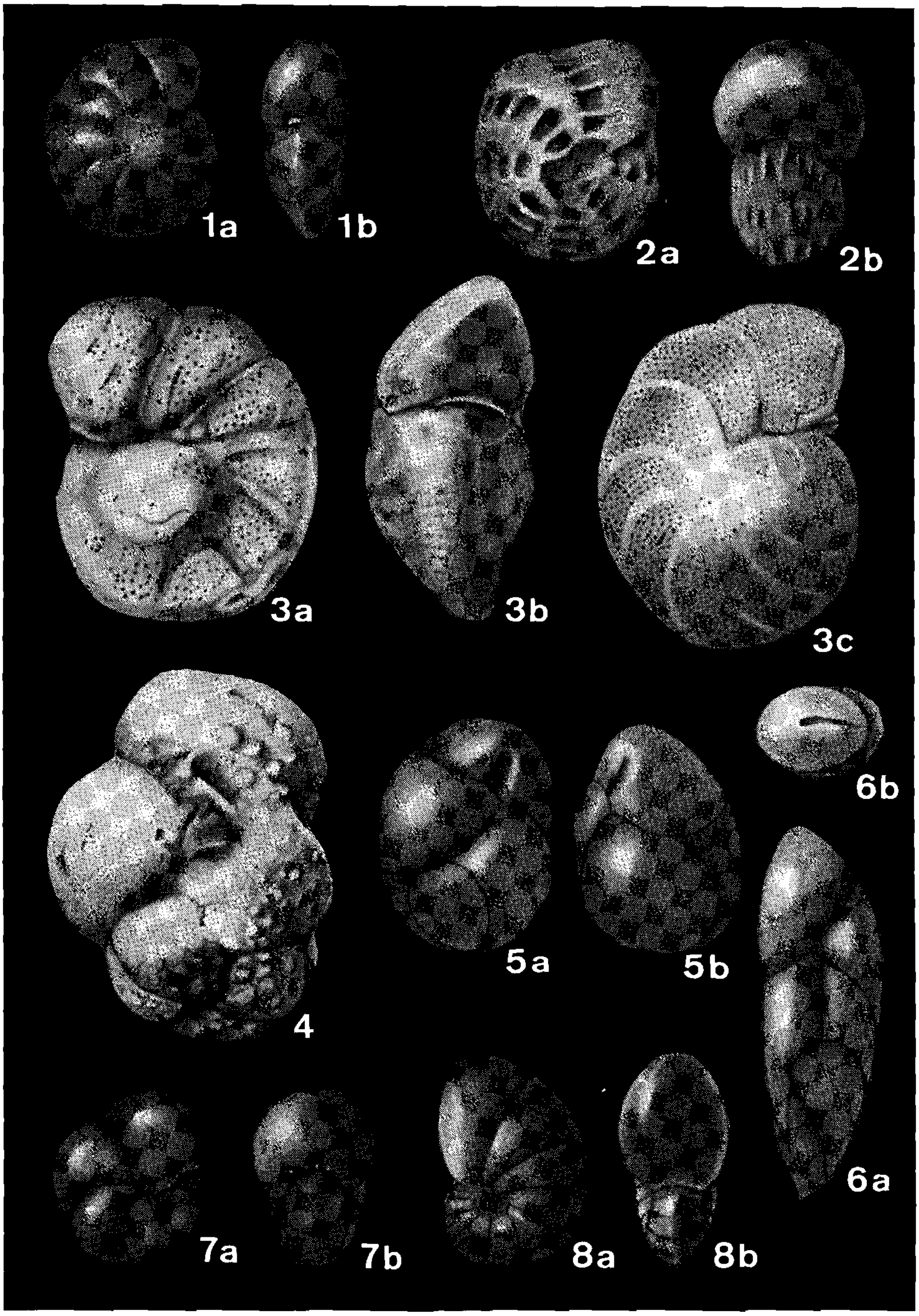


Plate XIII

Fig. 1 *Alabamina perlata* (Andreae), 48 X, sample Pr. 89.

Fig. 2 *Alabamina perlata* (Andreae), 66 X, sample Pr. 147.

Fig. 3 *Alabamina obtusa* (Burrows & Holland), 42 X, sample Pr. 147.

Fig. 4 *Gyroidina soldanii* d'Orbigny, 66 X, sample Pr. 64.

Fig. 5 *Gyroidina octocamerata* Cushman & Hanna, 33 X, sample Pr. 89.

Fig. 6 *Gyroidina octocamerata* Cushman & Hanna, 66 X, sample Pr. 64.

Plate XIII

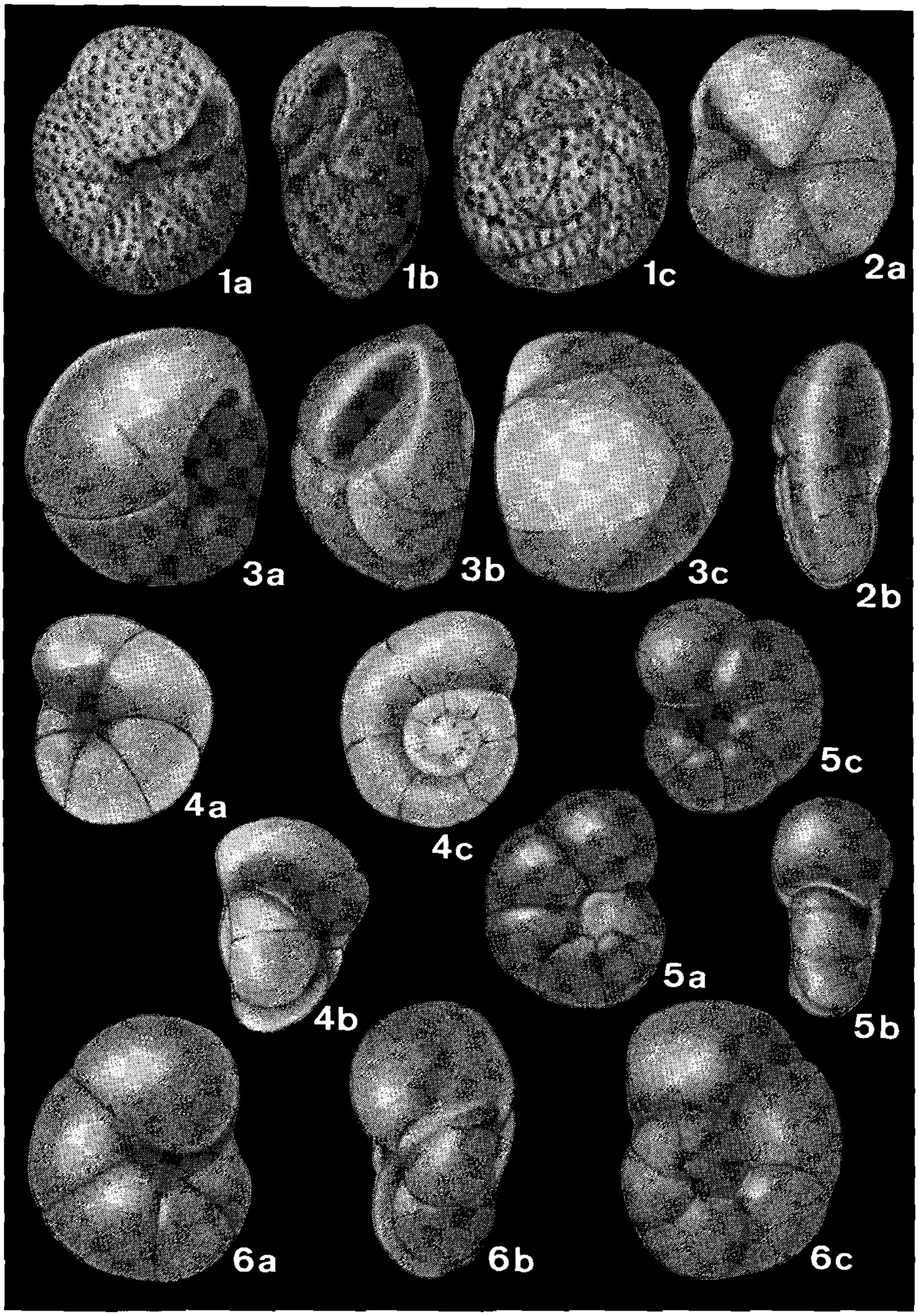


Plate XIV

Fig. 1	*Anomalina grosserugosa* (Gümbel), 48 X, sample Brs. 23.
Fig. 2	*Anomalina alazanensis* Nuttall, 33 X, sample Pr. 55.
Fig. 3	*Anomalina acuta* Plummer, 33 X, sample Pr. 57.
Fig. 4	*Boldia lobata* (Terquem), 42 X, sample Brs. 58.
Fig. 5	*Melonis affinis* (Reuss), 48 X, sample Pr. 57.
Fig. 6	*Melonis affinis* (Reuss), 33 X, sample Pr. 55.

Plate XIV

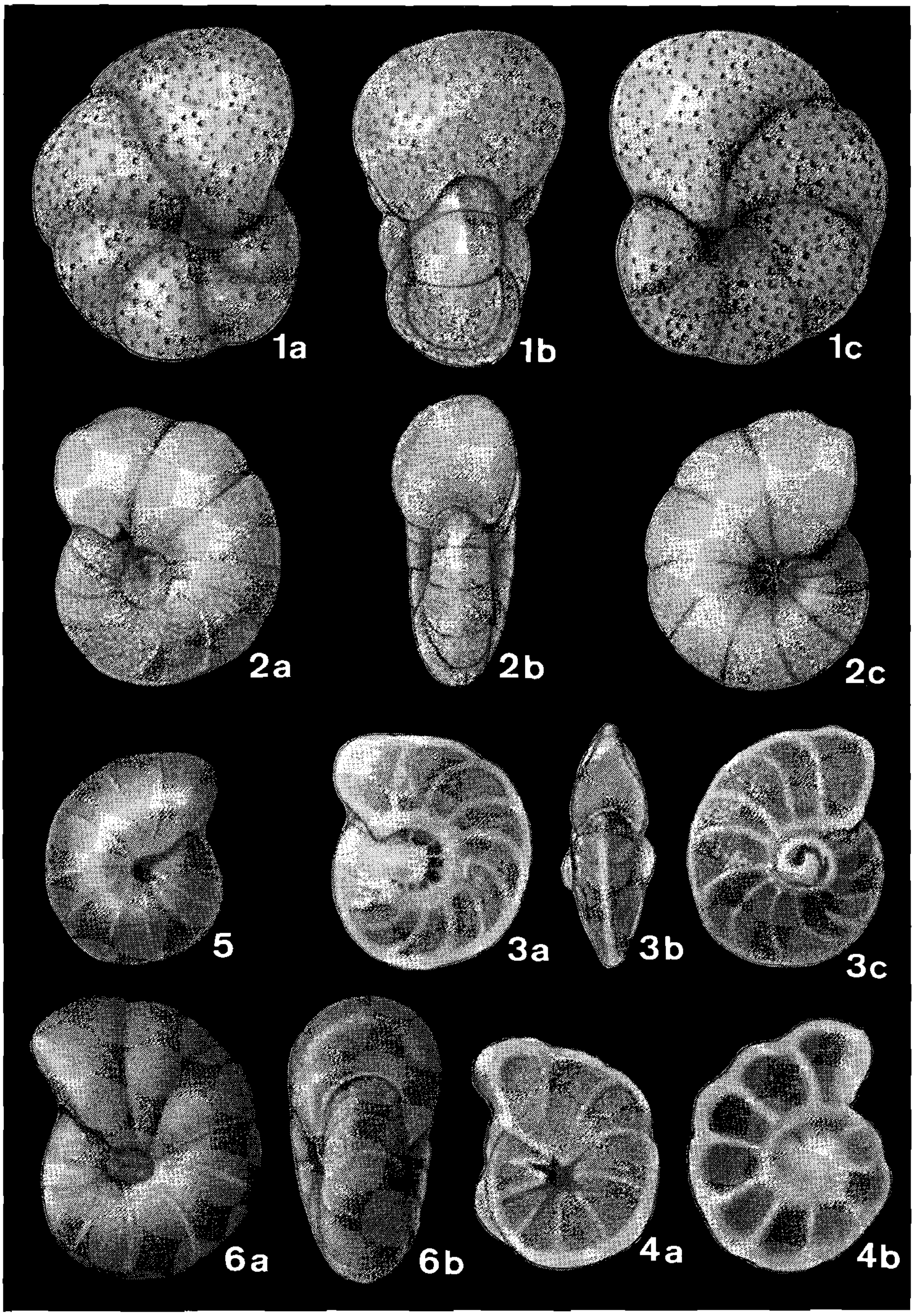


Plate XV

Fig. 1	*Schlosserina asterites* (Gümbel), 17 ×, sample Pr. 98.
Fig. 2	*Queraltina epistominoides* Marie, 33 ×, sample Pr. 89.
Fig. 3	*Queraltina epistominoides* Marie, 33 ×, sample Brs. 3.
Fig. 4	*Globigerina officinalis* Subbotina, 66 ×, sample Pr. 55.
Fig. 5	*Globigerina eocaena* Gümbel, 42 ×, sample Pr. 70.
Fig. 6	*Turborotalia cerroazulensis cocoaensis* (Cushman), 48 ×, sample Brs. 13.

Plate XV

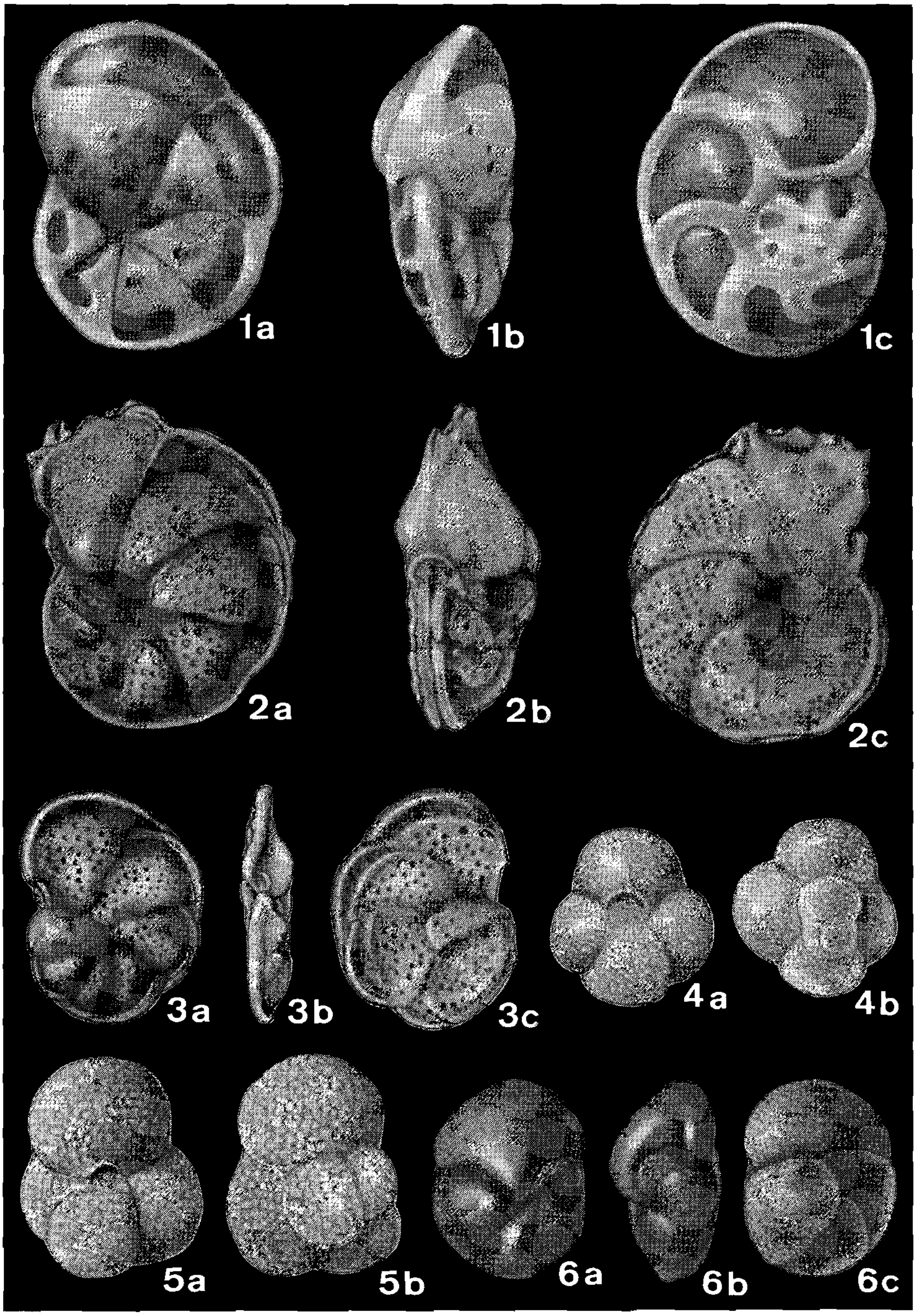


Plate XVI

Fig. 1	*Asterocyclina* (*stellaris*-group), 6 X, sample Pr. 135.
Fig. 2	*Asterocyclina* (*stellaris*-group), 6 X, sample Pr. 135.
Fig. 3	*Asterocyclina* (*stellata/stella*-group), 20 X, SEM photo, sample Pr. 126.
Fig. 4	*Asterocyclina* (*stellata/stella*-group), 13 X, SEM photo, sample Pr. 126.
Fig. 5	*Discocyclina* (*dispansa*-group), 11 X, SEM photo, sample Pr. 55.
Fig. 6	*Discocyclina* (*papyracea*-group), 11 X, SEM photo, sample Pr. 49.
Fig. 7	*Discocyclina* (*sella*-group), approximately 4 X, sample Pr. 49.

Plate XVI

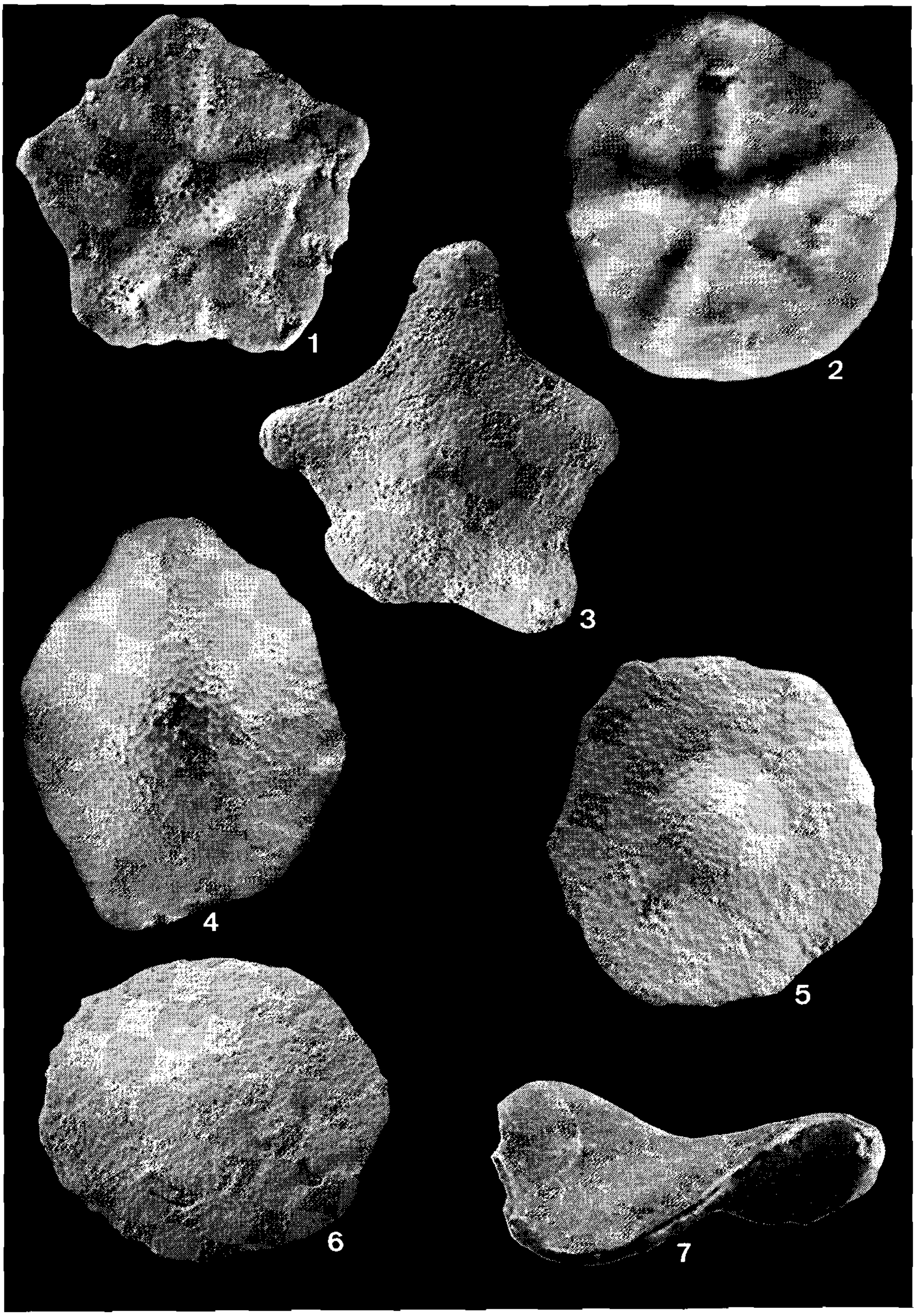
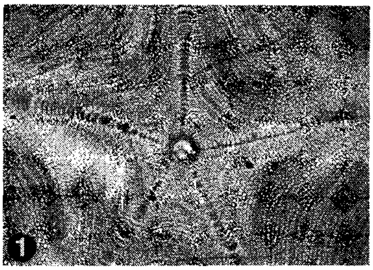


Plate XVII

Fig. 1	*Asterocyclina* I (cf. *A. stellaris* (Brunner)), 15 ×, sample Pr. 49.
Fig. 2	*Asterocyclina* I (cf. *A. stellaris* (Brunner)), 70 ×, sample Pr. 49.
Fig. 3	*Asterocyclina* III (cf. *A. stella* Gümbel), 50 ×, Pr. 135.
Fig. 4	*Asterocyclina* II (cf. *A. priabonensis* Gümbel), 70 ×, sample Pr. 135.
Fig. 5	*Discocyclina* I (cf. *D. applanata* Gümbel), 50 ×, sample Pr. 49.
Fig. 6	*Discocyclina* II (cf. *D. sella* (d'Archiac)), 20 ×, sample Pr. 49.
Fig. 7	*Discocyclina* III (cf. *D. augustae* van der Weijden), 50 ×, sample Pr. 135.
Fig. 8	*Discocyclina* IV, 40 ×, sample Pr. 126.

Plate XVII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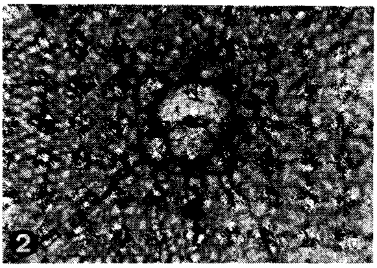
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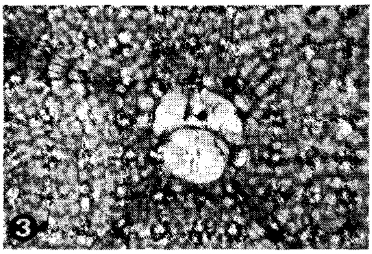
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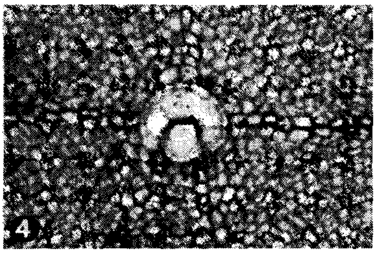
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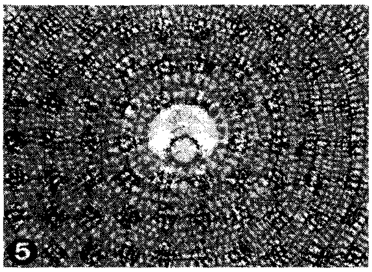
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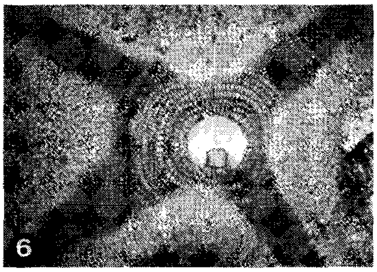
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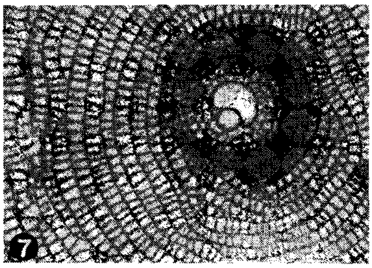
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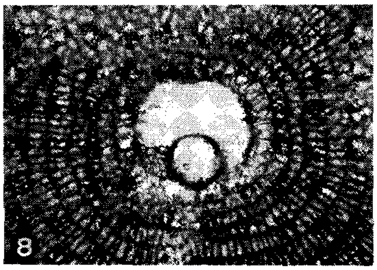
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Appendix

CALCAREOUS NANNOFOSSILS FROM THE PRIABONIAN STRATOTYPE AND CORRELATIONS WITH THE PARASTRATOTYPES

P. J. J. M. VERHALLEN and A. J. T. ROMEIN

Introduction

At the "Colloque sur l'Eocène" (Paris, 1968) five sections were introduced as parastratotypes of the Priabonian type section near the village of Priabona; these are the sections Granella, Ghenderle (here called section Bressana), Brendola, Mossano and Possagno. The marls and limestones of the type section and of (most of) the parastratotypes were deposited in shallow marine environments. As a consequence, planktonic foraminifera are either absent or extremely rare in most of these sequences, which severely hampers biostratigraphic correlations. Calcareous nannofossils were known to be present, however, and expecting that they could be used as a correlative tool we attempted to draw up a semi-quantitative inventory of the floras in the type section and in the nearby section Bressana. In addition some material from the other parastratotypes is considered in this study. For the descriptions of the localities and the lithologies of the sequences the reader is referred to the proceedings of the "Colloque sur l'Eocène" and to Setiawan (this volume).

Previous investigations

The calcareous nannofloras from the stratotype and the parastratotypes of the Priabonian have formed the subject of several studies (fig. 1):

Cita (1969) assigned the type section to the *Isthmolithus recurvus* Zone (of Hay, Mohler and Wade, 1966). The Priabonian s.l. should correspond to the *Discoaster tani nodifer* Zone, the *Isthmolithus recurvus* Zone and the *Ellipsolithus subdistichus* Zone.

Proto Decima (1969) assigned the Brendola marls to the *Isthmolithus recurvus* Zone (of Hay, Mohler and Wade, 1966).

Martini (1971) assigned a single sample from the type section to the *I. recurvus* Zone (NP 19), Roth et al. (1971) concluded that "the type Priabonian contained the *Sphenolithus pseudoradians* Zone as the highest Zone", based on a study of two samples from its upper part, one from the "*Asterocyclina* beds" and one from the "Bryozoan beds",

The rich floras from the Possagno section were studied by Proto Decima et al. (1975); they correlate the upper part of the Scaglia cinerea, and the Marne di Possagno with the type Priabonian (*I. recurvus Zone* and *S. pseudoradians Zone*), but on the basis of indirect correlations by means of planktonic and larger benthic foraminifera they draw the Middle/Upper Eocene

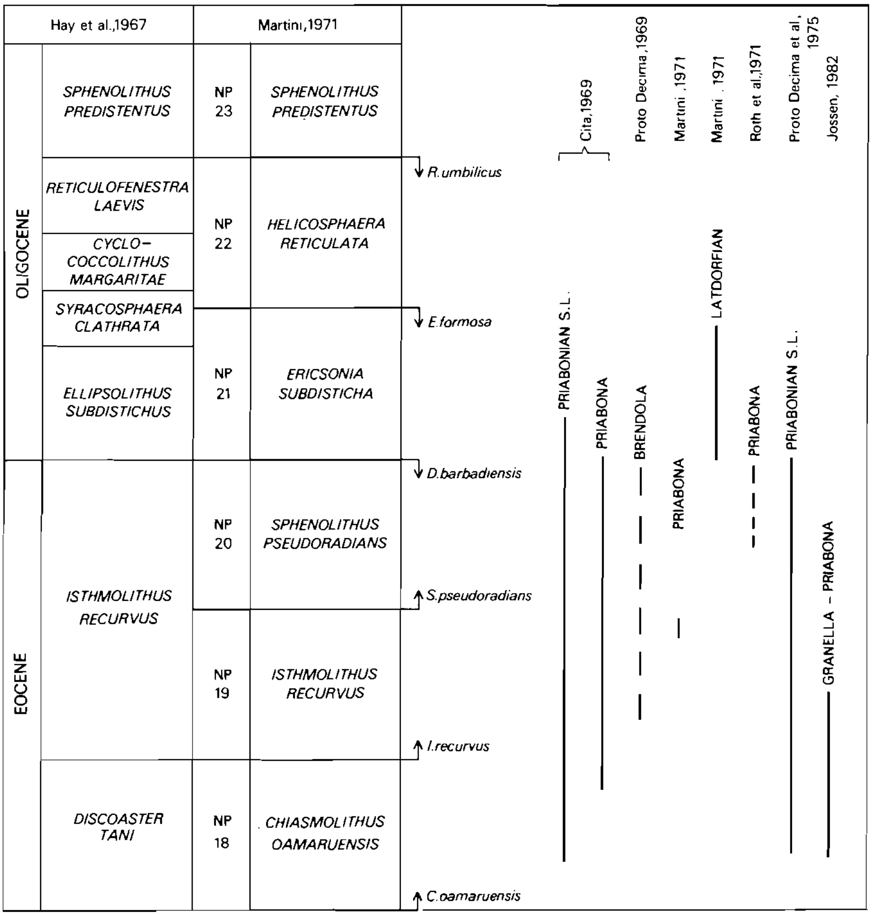

Fig. 1 Scheme showing biozonations in the Upper Eocene/Lower Oligocene and the position of the Priabonian stratotype and parastratotypes according to different authors. Scheme based on equal spacing of NP Zones.

boundary (= base of their Priabonian s.l.) in the *Chiasmolithus oamaruensis* Zone.

In a recent paper Jossen (1982) assigned the sequence at Granella and the type sequence to the *C. oamaruensis* Zone and the *I. recurvus* Zone because he found the *I. recurvus* entry at a level within the section and did not detect *S. predistentus*.

Working method

From the samples collected by Setiawan at Priabona and Bressana we selected the marly ones and of these smear slides were prepared. The preservational state of the floras in these samples appeared to be bad, being worst in the type section; both dissolution phenomena and overgrowth with secondary calcite were observed in all samples. After a selection on preservation one hundred nannoliths were counted and the relative frequencies noted for each slide; in addition half an hour more was spent on each slide to record the rare species. Obviously reworked specimens were noted separately.

Biozonation

Calcareous nannofossil biostratigraphy in the Upper Eocene/Lower Oligocene interval is still problematic. The lower boundaries of Martini's (1971) *Chiasmolithus oamaruensis* Zone, *Isthmolithus recurvus* Zone and *Spenolithus pseudoradians* Zone are all based on the entries of species which are latitudinally restricted, facies dependent and/or ill defined. The upper boundaries of the *S. pseudoradians* Zone, the *Ericsonia subdisticha* Zone and the *Helicosphaera reticulata* Zone are all defined by last occurrences of species, which makes them highly unreliable, especially in shallow marine sediments where reworking can be expected. As a consequence the position of the Eocene/Oligocene boundary in terms of calcareous-nannofossil biostratigraphy is still under discussion (Beckmann et al. 1981). On the basis of its floral composition (Haq, 1969; 1972) and on arguments given by Cavelier (1972, 1975, 1979) we prefer to include the Latdorfian in the Eocene and to regard the Rupelian as the lowest stage in the Oligocene. The *Ericsonia subdisticha* Zone has too few positive features to be recognizable as a separate zone. As a consequence the "last occurrence" of *Ericsonia formosa* is in an interval that straddles the Eocene/Oligocene boundary.

For the biostratigraphic subdivision we applied the following modified version of two of Martini's zones (fig. 2):

Isthmolithus recurvus Zone (NP19): interval from the first occurrence of *I. recurvus* to the first occurrence of *Sphenolithus predistentus*. In Martini's scheme the top of this zone is marked by the first occurrence of *Sphenolithus pseudoradians*. The entry of this species is, however, hard to pin-point in our sequences as the marker is very similar to overgrown specimens of the related *Sphenolithus radians*. We have the impression that *S. predistentus* enters the assemblages somewhat earlier than *S. pseudoradians*, as is the case in the Possagno section (Proto Decima et al., 1975).

Sphenolithus pseudoradians Zone (NP 21/21): interval from the first occurrence of *Sphenolithus predistentus* to the last occurrence of *Ericsonia formosa*. The disappearance of discoasters of the *barbadiensis/saipanensis* group falls within this zone.

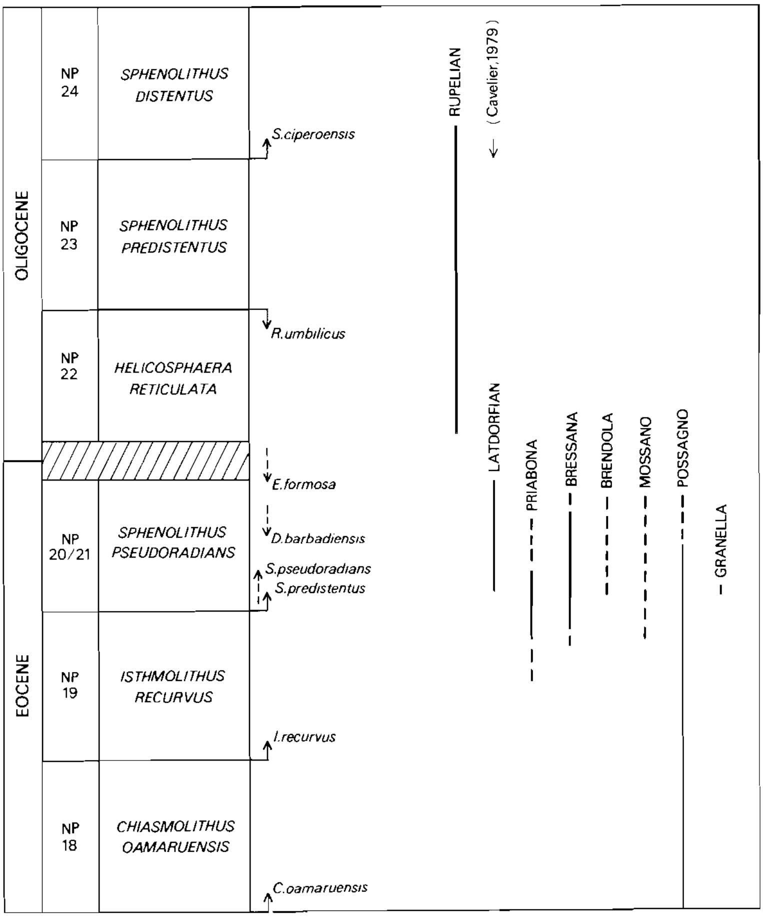

Fig. 2 Biozonation and positions of the Priabonian stratotype and the parastratotypes proposed in this paper.

Results

Section Priabona

The distribution of species in the sequence is given in figure 3; unfortunately the lowest sample which could be used has already a distance of 22 m. from the base of the section (unit IID). The highest sample is from unit V;

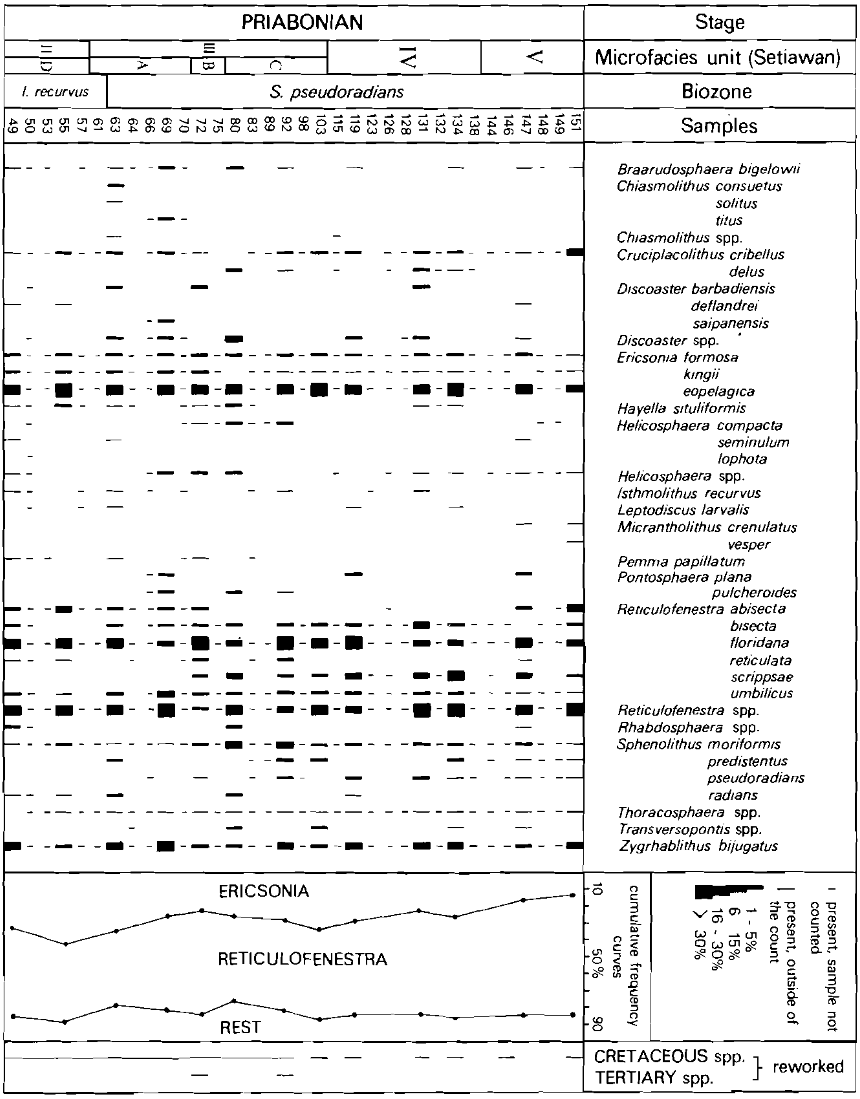

Fig. 3 Distribution and relative frequencies of species in the section Priabona.

material from unit IIID could not be used. The floras are dominated by species of the genera *Reticulofenestra* and *Ericsonia*. During a preliminary investigation we had the impression that the ratio *Reticulofenestra/Ericsonia* increased upwards in the section, which might have a value as a correlative tool; our impression was corroborated to some extent by the counts (the ratio changes from ± 2 in the basal part of the section to ± 6 in the upper part). *Discoaster barbadiensis* and *Discoaster saipanensis* are rare throughout the sequence; both disappear from the record below the top-part of the section (which, if we strictly apply Martini's scheme, would mean that the Eocene/Oligocene boundary falls within the Priabonian stratotype). *S. predistentus* first occurs in sample 63 (unit IIIA), but the species is only intermittently present in higher samples. Both *S. predistentus* and *S. pseudoradians* continue upwards to our highest sample.

Section Bressana

Only a limited number of samples from this section could be used (fig. 4). Unit IA and unit V are not represented. An increase in the *Reticulofenestra/Ericsonia* ratio was only observed in units II and III (from ± 2 to ± 6) and possibly these units correspond to units IV and V in the type section. The relatively high frequencies of the rest-group in comparison with the type section is not well understood; it might be an expression of the relatively more open marine sedimentary environment in Bressana. The same argument may be applied for explaining the larger quantity of reworked nannofossils: Priabona may have had a more sheltered position with respect to the supply of terrigenous material. *S. predistentus* enters the assemblages in sample 5 (unit IB).

Section Brendola

Both *S. predistentus* and *E. formosa* are present in all our samples. Representatives of the *D. barbadiensis/D. saipanensis* group are almost absent. The sequence is assigned to the *S. pseudoradians* Zone.

Sections Mossano, Possagno and Granella

S. predistentus starts its range in our sample suite from Mossano, it occurs in all our samples from Possagno and it is present in the only usable sample from Granella. *E. formosa* is consistently present in all studied intervals.

Conclusions

Due to the bad state of preservation of the floras and the absence of reliable biostratigraphic events the correlation of the type Priabonian, even with the nearby parastratotype at Bressana is problematic. The type section

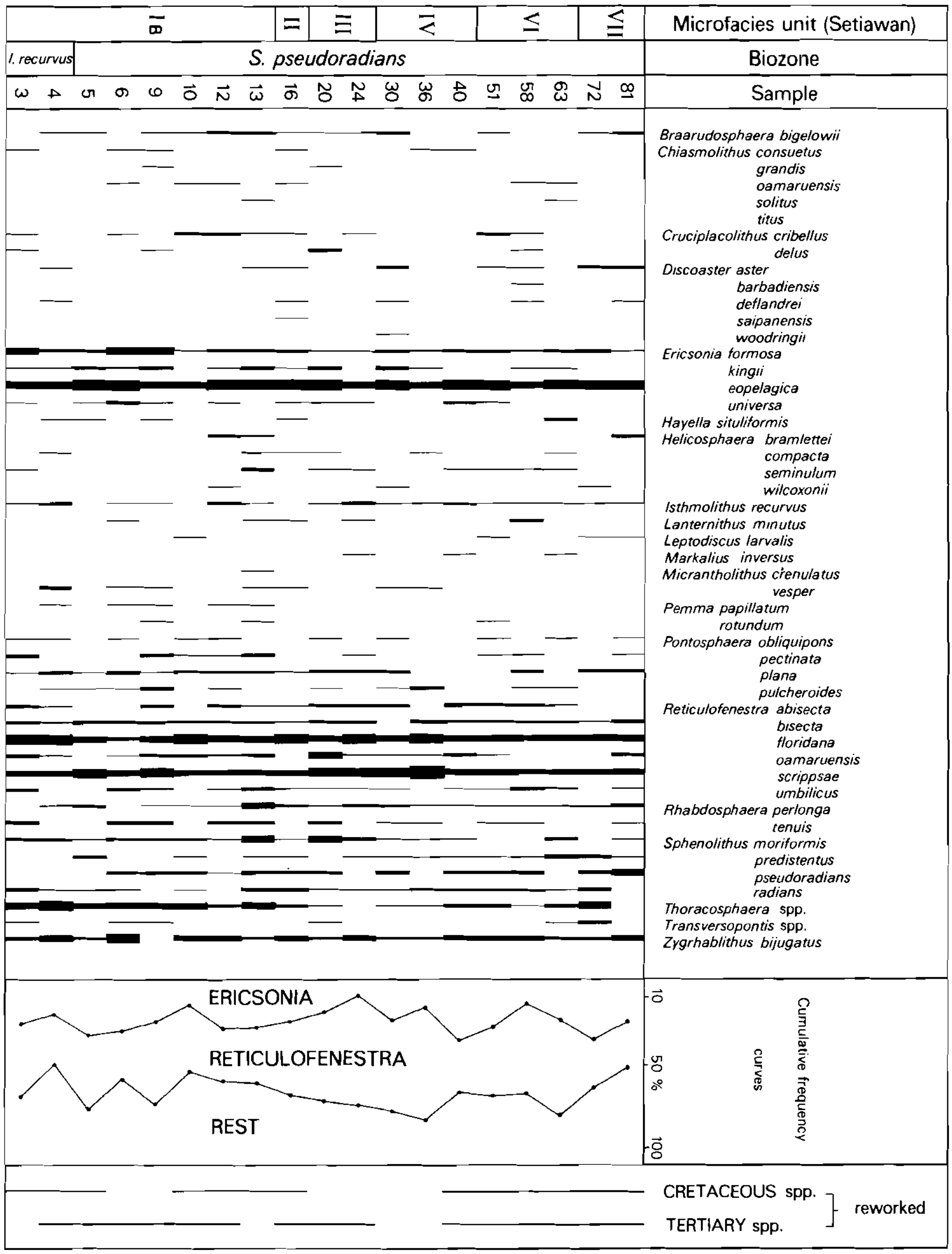

Fig. 4 Distribution and relative frequencies of species in the section Bressana.

probably corresponds to the upper part of the *Isthmolithus recurvus* Zone and (part of) the *Sphenolithus pseudoradians* Zone as defined in this study.

Remarks

Braarudosphaera bigelowii (Gran and Braarud) Deflandre, 1947.

Although the species is thought to be indicative for shallow marine water, or water with aberrant salinities (a.o. Bukry, 1974), it occurs only intermittently in Priabona and Bressana, where it never exceeds 5%.

Cruciplacolithus cribellus (Bramlette and Sullivan) Romein, 1979.

In the section Priabona the maximum length of the specimens increases from about 4 microns in the base of the section to about 10 microns in the top; in the section Bressana the maximum length does not exceed 6 microns.

Isthmolithus recurvus Deflandre, 1954.

In the basal part of section Priabona we found a transition from specimens known in the literature as *I. triplus* Levin and Joerger, 1967 at the base, to typical *I. recurvus* higher up. In the Bressana section, however, both types co-occur.

Lanternithus minutus Stradner, 1962.

This species is extremely rare (section Bressana) or absent (section Priabona), but it is a very common species in the *S. pseudoradians* Zone in the Possagno section.

Reticulofenestra abisecta (Müller) nov. comb.

The specimens assigned to this species are very similar to *Dictyococcites abisectus* (Müller); according to the literature, however, this species has its first occurrence in the Oligocene.

Reticulofenestra bisecta (Hay, Mohler and Wade) nov. comb.; *Reticulofenestra scrippsae* (Bukry and Percival) nov. comb.; *Reticulofenestra floridana* (Roth and Hay) nov. comb.

The systematic position of these species is still unclear; we assigned them provisionally to the genus *Reticulofenestra*.

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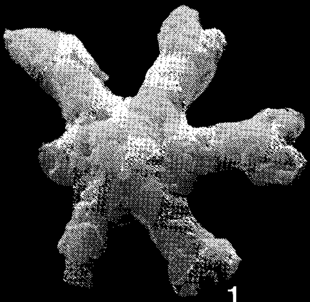
Fig. 1	*Discoaster deflandrei* Bramlette & Riedel, X 3500.
Fig. 2	*Discoaster barbadiensis* Tan Sin Hok, X 3500.
Fig. 3	*Holodiscolithus solidus* (Deflandre), X 6250.
Fig. 4	*Ericsonia eopelagica* (Bramlette & Riedel) X 3000.
Fig. 5	*Reticulofenestra umbilicus* (Levin) X 3000.
Fig. 6	*Reticulofenestra scrippsae* Bukry & Percival.
Figs. 7, 8	*Sphenolithus predistentus* Bramlette & Wilcoxon.
Fig. 9	*Sphenolithus radians* Deflandre.
Fig. 10	Same specimen, in 45° position.

All L.M.-photographs (6–10) X 4500, crossed nicols.

All specimens from sample 58, section Bressana.



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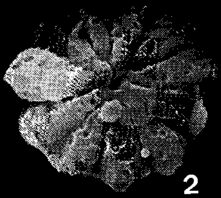

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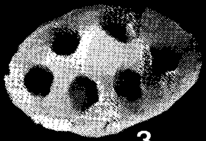

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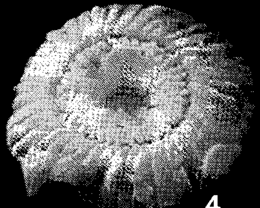

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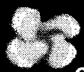

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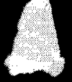

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