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Mid- to late Cretaceous Microbiostratigraphy, Palaeo-ecology and Palaeogeography of the Sergipe Basin, northeastern Brazil

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B.Sc. Geology

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VOLUME 1

MID- TO LATE CRETACEOUS MICROBIOSTRATIGRAHY, PALAEO-ECOLOGY AND PALAEOGEOGRAPHY OF THE SERGIPE BASIN, NORTHEASTERN BRAZIL

by

Eduardo Apostolos Machado Koutsoukos

The palaeo-ecology and biostratigraphy of foraminiferal, radiolarian and diatom assemblages have been studied through the upper Aptian to Maastrichtian sedimentary succession of the Sergipe Basin, northeastern Brazil. The systematic taxonomy of the microfauna studied is documented and completely revised. Palaeo-environmental models, mostly derived from micropalaeontological and sedimentological criteria, are proposed for the distribution of the foraminiferal morphogroups. The palaeogeographic reconstruction of the studied area, from the upper Aptian to Maastrichtian, is presented. A refined microbiostratigraphic zonation scheme, based on all sections studied, is proposed and primarily defined for regional application. The composition and distribution patterns of the foraminiferal assemblages (diversity and abundance of morphogroups) are shown to be a direct response to overall palaeoceanographic conditions and to community strategies of exploitation of the trophic resources in the microhabitats. The foraminifera recovered from the oldest, late Aptian, marine sediments reveal a characteristic Tethyan affinity and suggest that this area had at least minimal surface water exchange with low latitude central North Atlantic-western Tethyan bioprovinces, even possibly at intermediate (epi- to mesopelagic) water depths. A shallow Calcite Compensation Depth within upper mesopelagic depths (c. 300-500m) is inferred for the upper Aptian-Albian. Twelve foraminiferal palaeocommunities can be recognised in the succession. These are characterised by the relative dominance of the major foraminiferal groups and related to variations in trophic structures. Their palaeo-environmental distribution is proposed as a model with reference to the Sergipe Cretaceous sequence. Radiolarians and diatoms are documented for the first time from the mid-Cretaceous succession of the Sergipe Basin. Prevailing palaeoceanographic conditions are inferred for the episodes of siliceous radiolarian and diatom biomineralization/preservation. The study indicates that intermittent hypoxic/anoxic events occurred in the basin, most likely associated with the interplay of various processes. Three maxima in oxygen depletion (dysaerobic-anaerobic conditions) are recorded in the succession : 1st) in the upper Aptian-lowermost Albian; 2nd) in the lower Cenomanian; 3rd) in the uppermost Cenomanian-lowermost Turonian. Waning low-oxygen conditions (dysaerobic to aerobic) are apparent in the middle-upper Albian and middle-upper Turonian to Coniacian.

DECLARATION

I hereby declare that the work submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy under the title "MID-TO LATE CRETACEOUS MICROBIOSTRATIGRAPHY, PALAEO-ECOLOGY AND PALAEOGEOGRAPHY OF THE SERGIPE BASIN, NORTHEASTERN BRAZIL" is the true result of my own independent original research. All authors and works consulted are acknowledged and referred in full. No part of this work has been accepted in substance for any other degree nor is it being currently submitted for candidature for any other degree.

During the course of this research the following papers have been published or submitted for publication on the results obtained :

1) "Late Cretaceous anoxic events in the Brazilian continental margin", by M.R. Mello, E.A.M. Koutsoukos, M.B. Hart, S.C. Brassell & J.R Maxwell - Organic Geochemistry, **14** (5): 529-542 (1989).

2) "*Favusella* Michael (1972): evidence of ecophenotypic adaptation of a planktonic foraminifer to shallow-water carbonate environments during the mid-Cretaceous", by E.A.M. Koutsoukos, P.N. Leary & M.B. Hart - Journal of Foraminiferal Research, **19** (4): 324-336 (1989).

3) "Latest Cenomanian-earliest Turonian low-oxygen tolerant benthonic foraminifera: a case study from the Sergipe Basin (NE Brazil) and the western Anglo-Paris Basin (southern England)", by E.A.M. Koutsoukos, P.N. Leary & M.B. Hart - Palaeogeography, Palaeoclimatology, Palaeoecology (in press).

4) "The upper Aptian-Albian succession of the Sergipe Basin, Brazil: an integrated palaeo-environmental assessment", by E.A.M. Koutsoukos, M.R. Mello, N.C. de Azambuja Filho, M.B. Hart & J.R. Maxwell - American Association of Petroleum Geologists Bulletin (in press).

5) "Radiolarians and diatoms from the mid-Cretaceous succession of the Sergipe Basin, northeastern Brazil: palaeoceanographic assessment", by E.A.M. Koutsoukos & M.B. Hart - Journal of Micropalaeontology - London (in press).

6) "Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: a case study from the Sergipe Basin, Brazil", by E.A.M. Koutsoukos & M.B. Hart - Transactions of the Royal Society of Edinburgh: Earth Sciences (submitted).

7) "Late Aptian to Maastrichtian foraminiferal biogeography and palaeoceanography of the Sergipe Basin, Brazil", by E.A.M. Koutsoukos - Proceedings of the Symposium on "Biogeographic Patterns in the Cretaceous Ocean" (Strasbourg, France, 20-23rd March, 1989), European Union of Geosciences - Palaeogeography, Palaeoclimatology, Palaeoecology (submitted).

8) "Micropalaeontological and geochemical evidence of mid-Cretaceous hypoxic/anoxic environments in the Sergipe Basin, NE Brazil", by E.A.M. Koutsoukos, M.R. Mello & N.C. de Azambuja Filho - Proceedings of the Meeting on "Modern and Ancient Continental Shelf Anoxia" (London, 17-19th May, 1989), Special Publications of the Geological Society of London (submitted).

Copies of the published papers are bound into this thesis as Appendix 3.

EDUARDO A. M. KOUTSOUKOS

MALCOLM B. HART MBHart
(Research Supervisor)

TO TÂNIA, KARINA AND VICTOR

WITH LOVE

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CHAPTER 1

INTRODUCTION

During the last two decades a number of palaeontological studies have been carried out along the Brazilian continental margin, especially following the start of active offshore oil exploration by Petróleo Brasileiro S.A. (PETROBRÁS), the Brazilian state oil company, in 1968. The understanding of the biostratigraphical and palaeobiogeographical characteristics of its Cretaceous stratigraphic sequence is of foremost significance for studies relating to the early geological history and subsequent palaeoceanographic evolution of the northern South Atlantic Ocean.

The present research was directed towards microbiostratigraphical, palaeo-ecological and palaeobiogeographical studies of the marine Cretaceous succession of the Sergipe Basin, a passive marginal basin in northeastern Brazil (Figs 1.1, 1.2). A major part of the research was also concerned with the systematic taxonomy of the foraminiferal, radiolarian and diatom species. For the basin, the availability of well sections (cores and ditch-cuttings) and extensive outcrop samples, with refined biostratigraphic control (e.g., the mid-Cretaceous ammonite zonal schemes for the basin of Beurlen, 1967a,b, 1970; Schaller, 1970; and Bengtson, 1983), affords an almost complete marine Cretaceous sedimentary record spanning the late Aptian to Maastrichtian (Fig. 1.3).

Part of the investigation has been carried out on the Cretaceous outcrops, where several localities were studied. A major part of the research was subsequently concerned with well-sections drilled onshore and offshore in the basin.

1.1 - SCOPE OF THE RESEARCH

The principal aims of the research were as follow:

1) Investigation and systematic taxonomy of the planktonic and benthonic foraminifera, radiolarians and diatoms with a quantitative evaluation of the relative abundances of the microfauna, curating of a type collection and the scanning electron photomicrographic record of the species.

2) To establish a refined microbiostratigraphical framework, based mainly on foraminiferal assemblages, which can be applied to the studied sections enhancing cross-basin stratigraphical correlation.

3) To delineate the general distribution patterns of foraminiferal morphogroups and palaeocommunities and the main environmental and physiological controlling forces behind them. Emphasis has been placed upon the determination of the palaeo-environmental evolution and the identification of specialised microfaunal patterns in mid-Cretaceous organic-rich sediments that are associated with hypoxic/anoxic events.

4) To provide a set of regional data that allow the reconstruction of the palaeogeographical and palaeoceanographical history of the basin from the late Aptian to Maastrichtian, with emphasis on the following :

.to identify palaeoceanographical events of regional and/or world-wide scale.

.to assess the importance and magnitude of unconformities, palaeo-environmental discontinuities, facies changes, and structural controls of pre-oceanic tectonism;

.to reconstruct the basin palaeobathymetric and palaeogeographic evolution and evaluate the distribution trend-patterns of deposits with reservoir-bearing potential on the onshore area and on the continental margin.

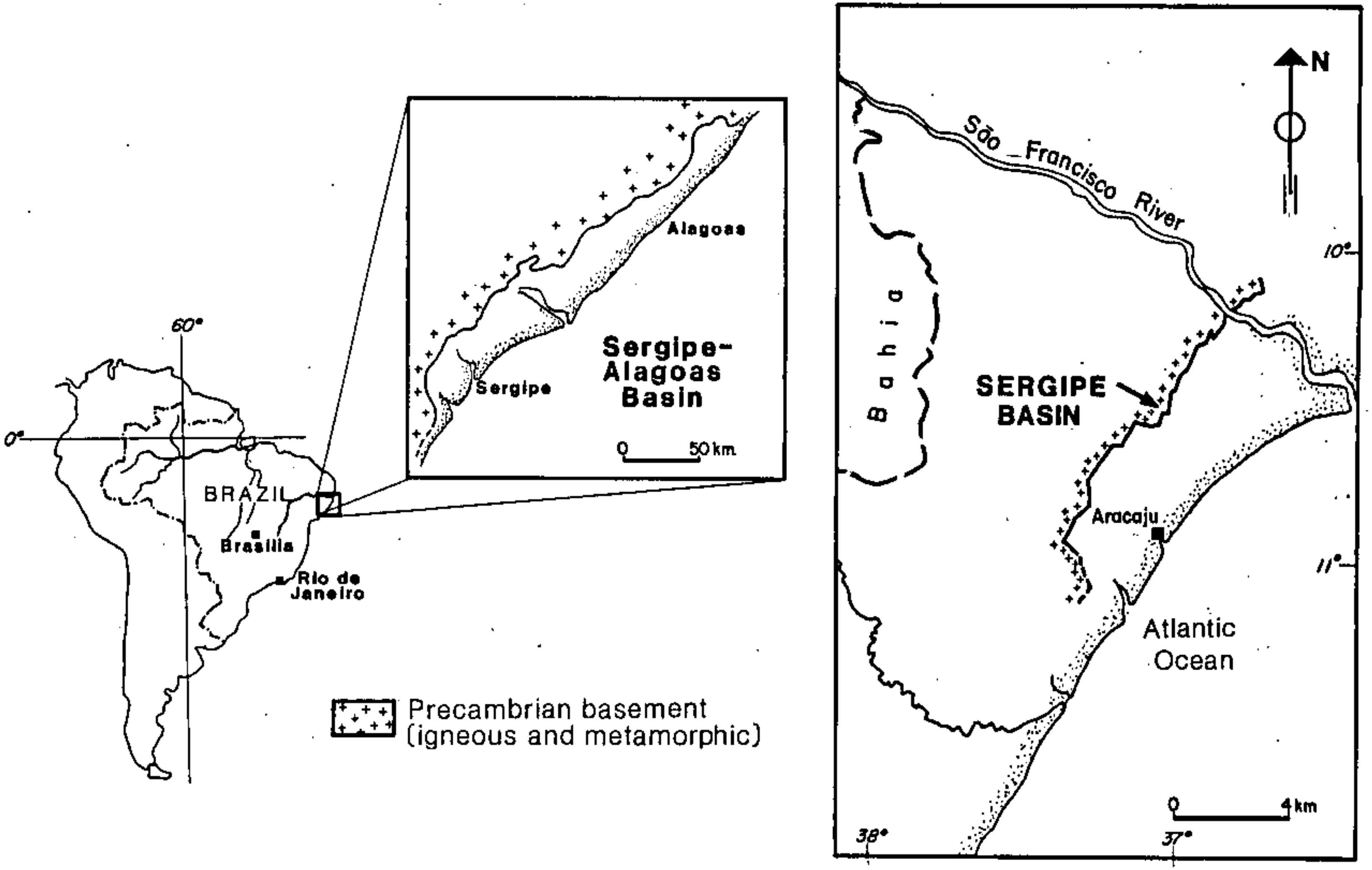


FIGURE 1.1 : Location map of the Sergipe Basin.

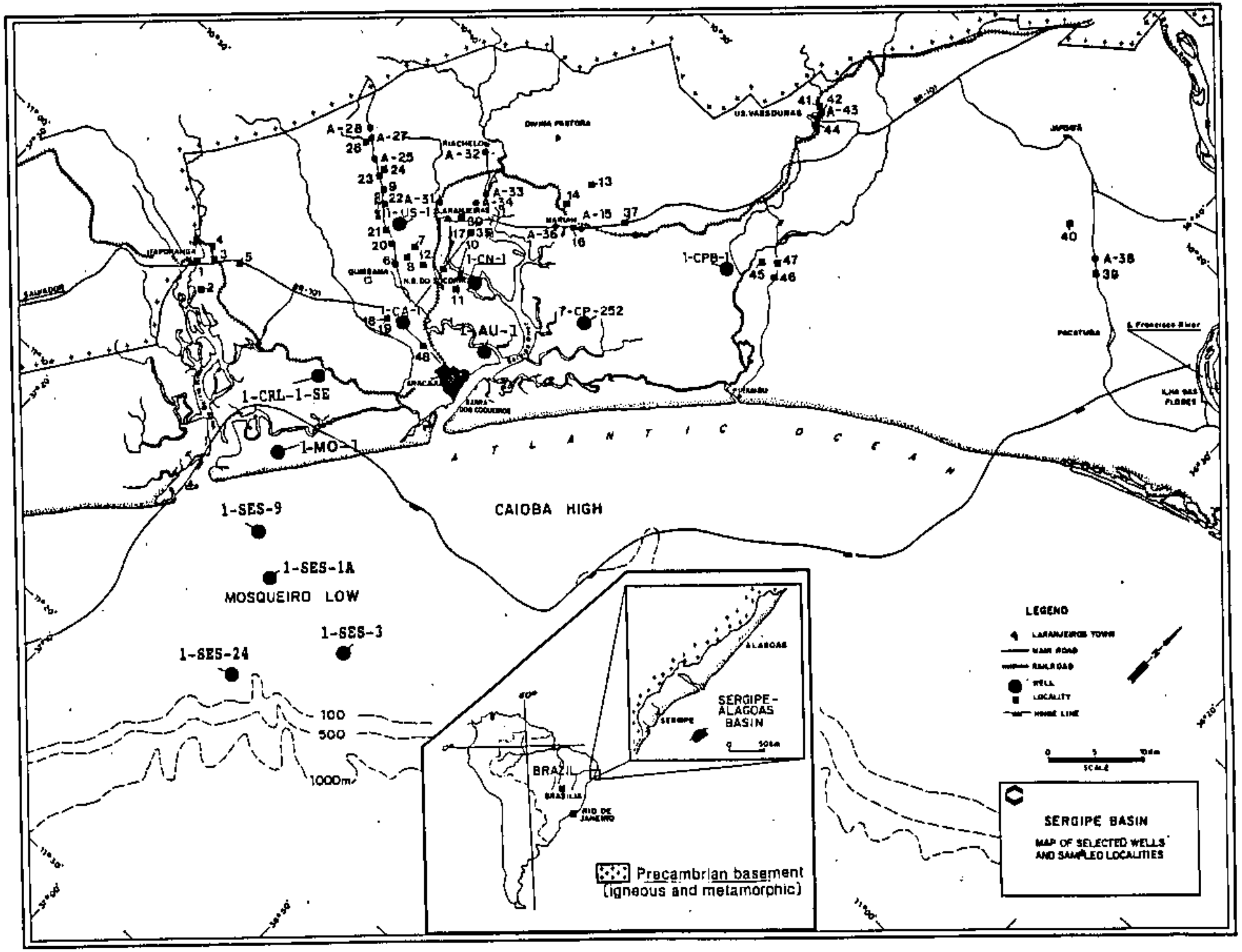


FIGURE 1.2: Location map of studied localities and well-sections.

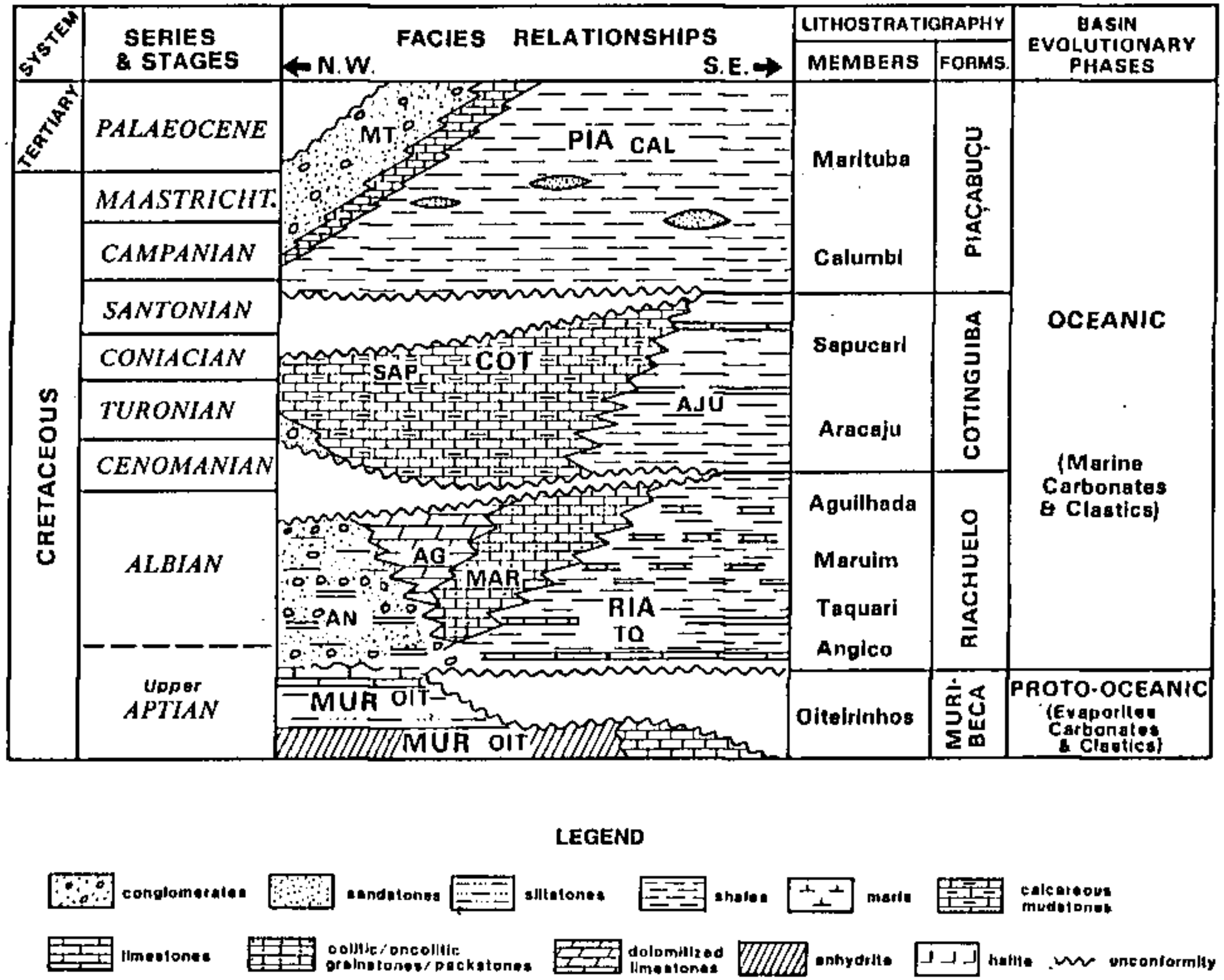


FIGURE 1.3 : Middle to Upper Cretaceous lithostratigraphy of the Sergipe Basin (based on Ojeda & Fugita, 1976, and Bengtson, 1983). Basin evolutionary phases after Asmus & Baisch (1983). Abbreviations refer to lithostratigraphic units.

1.2 - EXPERIMENTAL AND ANALYTICAL PROCEDURES

Part of this research has been carried out on field sampling the Cretaceous marine sediments of the Sergipe Basin. There, forty-eight outcroping localities were sampled, comprising 127 samples representative of all the mapped chrono-lithostratigraphical units in the basin. These samples were subsequently processed along with borehole material (ditch-cuttings and cores) from selected onshore and offshore well sections. A complementary sampling programme was carried out in November, 1987, from the sample collection of Cenomanian-early Coniacian ammonite-dated localities from Sergipe at the 'Paleontologiska Institutionen' of Uppsala University, Sweden.

All the samples from outcrops and well sections were submitted to micropalaeontological analyses (taxonomy and a quantitative evaluation of the relative abundances of the microfauna). An extensive type collection was curated for all the biochronostratigraphical units. The species and their variants were carefully selected to be photomicrographically recorded using the JEOL (JSM - T20) Scanning Electron Microscope in the Electron Microscopy Unit of Polytechnic South West. A total of 2550 photomicrographs have been taken. The figured specimens will be registered and deposited in the micropalaeontological collections of the PETROBRAS' Research Centre (CENPES), in Rio de Janeiro, Brazil.

1.2.1 - Field Work

The selection of the surface localities to be sampled was undertaken as follows. The geological guide 'Roteiro Geológico da Bacia Sergipe-Alagoas' of Schaller et al. (1980, 'Roteiro 1: Sergipe', PETROBRAS' Internal Report), with 13 plotted sections, gave a reasonable initial coverage to well-known localities of the Riachuelo and Cotinguiba Formations; the works of G. Beurlen (1967a, 1968) were particularly helpful in the location of the Albian strata (Riachuelo Formation). The ammonite-based biostratigraphical map and locality descriptions provided in the work of Bengtson (1983) was a further leading reference to the outcrops of the Cotinguiba Formation (Cenomanian to lower Coniacian). Finally, the field experience and assistance of geologists F.J. Feijó and A.J. Richter, in the planning and location of most of the localities, was essential for the success of the field work.

The typical tropical climate (humid and hot) of Sergipe acts as a stimulant to the rapid weathering processes, which contributed to the destruction of several old, well-known, localities (e.g., outcrops of the Calumbi Member, Piacabucu Formation, near Aracaju). However, the modern quarries of limestone beds (Riachuelo and Cotinguiba Formations) presented good opportunities of sampling virtually unweathered sections. In badly weathered localities a throughout cleaning of the surface was carried out in order to reach the less oxidized and decalcified levels. Usually around 0.5kg of sediment was taken for each sample. A brief lithological and stratigraphical description, photographic record and plotting on topographic maps (PETROBRAS' unpublished topographical maps, 'Bacia de Sergipe-Alagoas', 1:25000, produced by Servicos Aerofotogramétricos Cruzeiro do Sul S.A., 1964) were routinely undertaken for all sampled localities.

The location of sampled localities can be found in Fig. 1.2. Complete locality descriptions (UTM coordinates, local references and lithology) are referred to in Appendix 1. There are also additional brief descriptions of the locality data from the complementary outcrop samples (not plotted in Fig. 1.2) and studied well sections.

1.2.2 - Sample Preparation

The studied microfossil assemblages were collected as a result of conventional preparation of samples for foraminiferal analysis. Laboratory sample preparation was mostly carried out in the 'Setor de Bioestratigrafia e Paleoecologia' of the PETROBRAS Research Centre (CENPES), in Rio de Janeiro. All the indurated samples were crushed prior to processing. Representative cuts of 60g (ditch-cuttings) and 120g of sediment (cores and outcrops) were taken from each sample and then immersed in a solution of concentrated hydrogen peroxide (120 v/v), and allowed to sit for about 6-8 hours in a fume cupboard until breakdown. The disaggregated sediment was then washed through one fine-mesh sieves of 63μm to eliminate the clay. The residues were allowed to dry for 24 hours at 60° C and were, subsequently, dry-sieved with three screens of 125μm, 250μm and 500μm mesh. All the size fractions were examined and the microfossils (foraminifera, ostracods, radiolarians, micromolluscs), and any other significant fossil debris, were picked out on a gridded tray and collected into one-hole slides, until a minimum representative count of approximatelly 300 specimens was reached. The samples rich in microfossils were usually divided into two or more equivalent parts prior to picking. It is strongly emphasized the use of this small-size 63μm mesh, which increases specimen recovery and yields a more representative and palaeo-ecologically significant planktonic and benthonic foraminiferal assemblage (Leckie, 1987; Schroder _et al._, 1987). This is particularly important when an ontogenetic analysis is undertaken (Brummer _et al._, 1986) - see Chapter 6. About 30 samples from the complementary sampled localities were processed at the laboratories of the Department of Geological Sciences of Polytechnic South West, in a standard manner as follows. Samples were broken down into small-pieces using a mortar and pestle. Crushed samples were then dried and soaked in 'White Spirit' overnight. Excess solvent was decanted off and boiling water added (1h) until breakdown. Normal washing procedures and picking followed (as above).

Some of the processed samples (surface, ditch-cuttings and cores) did not succeed in yielding microfossils, because they were either too highly indurated or to non-preservation. In the case of the outcrop sections this is mostly due to the extremely weathered condition of some localities, from where all the microfossils have been probably dissolved.

1.2.3 - Scanning Electron Microscopy

All the selected specimens to be photographically recorded were mounted on standard copper stubs with double-sided tape, shadowcasted with approximately 13A° of gold, and observed on a JEOL (JSM-T20) Scanning Electron Microscope, operated at 20Kv. Elemental analysis of test composition were carried out under a JEOL (JSM-35C) S.E.M. with a Link System X-Ray Spectrometer (860B Series), operated at 25Kv.

1.2.4 - Microbiostratigraphy

The integration of the ammonite biostratigraphical framework (Beurlen, 1967a,b, 1968, 1970; Schaller, 1970; Bengtson, 1983) with the microfossil assemblages, for the upper Aptian to lower Coniacian outcrop succession, made possible the proposal of a preliminary composite microbiozonal scheme. This was subsequently applied to the drilled sections, improving the final proposed microbiostratigraphical zonation (Chapter 4).

The microfossil biozonations (for the planktonic and benthonic foraminiferal assemblages) proposed here are primarily defined for regional application. However, there are close analogies between the proposed foraminiferal zonal schemes and others established for coeval strata elsewhere. This makes it possible to assess their significance on a larger scale as well to allow correlation with, and identification of, worldwide palaeoceanographical events.

1.2.5 - Foraminiferal Palaeo-ecology

The palaeo-ecological study demonstrates an intimate relationship amongst the distribution of foraminiferal palaeocommunities, community trophic structures, palaeobathymetric niches (water-depth, inferred microhabitat and substrate type and stability) and pelagic conditions, depth-related in part, such as temperature, salinity, oxygen concentrations, calcium carbonate availability (Chapter 5).

Palaeobathymetric terms and general depth values may be summarised as follows (see Fig. 1.4) :
Paralic: hyper-/hyposaline marginal environments (lagoons, bays, tidal flats, estuaries, marshes and mangroves); c. 0-10m
Inner (shallow) neritic (shelf): c. 0-30/50m
Middle neritic: c. 30/50-100m
Outer (deep) neritic: c. 100-200m
Upper bathyal (slope): c. 200-500m
Middle bathyal: c. 500-1000m
Lower bathyal: c. 1000-2000m
Abyssal (oceanic deeps): >2000m

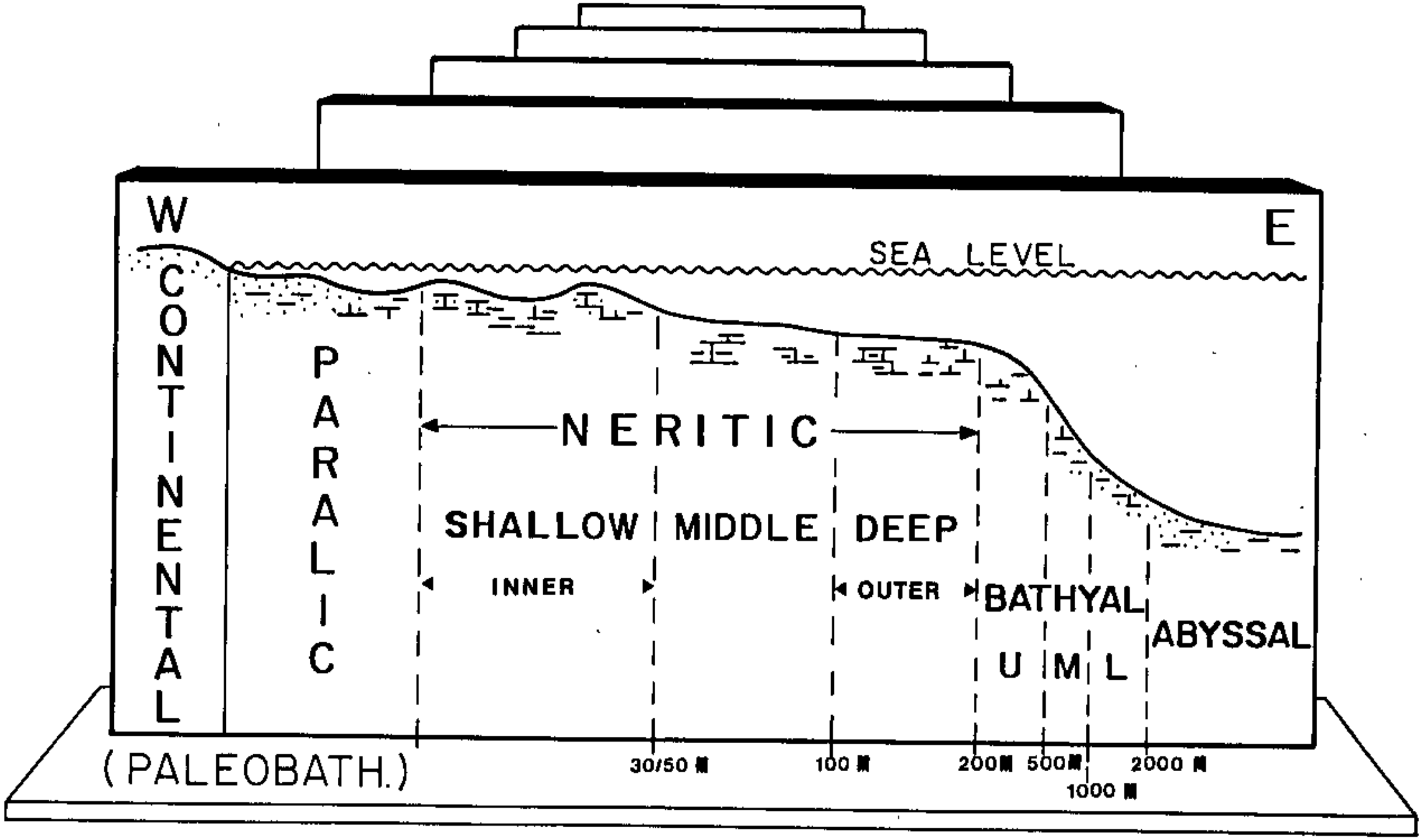


FIGURE 1.4: Palaeobathymetric zones and marine environments.

1.3 - PREVIOUS BIOSTRATIGRAPHIC STUDIES (post-1960)

Several studies have dealt with the palaeontology and biostratigraphy of the marine Cretaceous succession of Sergipe. The following review gives a summary account of the more recent (post-1960) contributions. The Cretaceous foraminiferal assemblages reported in the literature are listed and briefly discussed in Appendix 2.

The first attempt at an ammonite zonation was presented by K. Beurlen (1961) for the upper Aptian-Albian sediments, while Petri (1962) proposed a foraminiferal zonation for the Albian-Maastrichtian succession. The latter author also attempted to correlate the microbiostratigraphical scheme with the macrofossil zonation that was based, in part, on Maury (1937) and Beurlen's (1961) work. Ostracods were reported by Krommelbein (1964, 1966, 1975) from the mid-Cretaceous sequence. Muller (1966) proposed a palynological zonation for the Cretaceous of northeastern Brazil, with one palynozone defined for the Cotinguiba Formation. G. Beurlen (1967a, b, 1968, 1970) proposed ammonite ages for the upper Aptian to lower Coniacian succession, complementing K. Beurlen's (1961) Aptian-Albian zonation. Viana (1969) presented the foraminiferal zonation used by Petrobrás for the Cretaceous of the Sergipe. Schaller's (1970) work, on the stratigraphical revision of the Sergipe-Alagoas Basin, described the zonal schemes established by Petrobrás' biostratigraphers for the mid- to Upper Cretaceous, based on ammonites, foraminifera, ostracods and palynomorphs. A zonal scheme based on calcareous nannofosssils was later developed by Petrobrás for the Brazilian marginal basins, and presented in Troelsen & Quadros (1971) and Quadros & Gomide (1973). G. Beurlen (1972) presented palae-ecological studies of the foraminiferal microfauna from the Calumbi Member, Piacabucu Formation (Campanian-Miocene), in the area of the São Francisco low, mouth of the São Francisco River, between the states of Sergipe and Alagoas. Noguti & Santos (1973) erected a zonation based upon planktonic foraminifera, recognising five biozones for the Cretaceous. Regali et al. (1974, 1975) subsequently established a palynological zonation for the continental margin. At the same time Herngreen (1975), based on palynological studies of cored sections, recognised two pollen zones in the Cenomanian-Turonian and late Senonian of Sergipe-Alagoas. In an attempt to reconstruct the early history of the South Atlantic, Reyment & Tait

(1972) proposed further ammonite ages for the mid-Cretaceous succession. Late Cretaceous ostracod assemblages were described by Neufville (1979). Quadros (1981) presented a palaeo-ecological study of the upper Cretaceous from the Brejo Grande area, São Francisco low, based on statistical accounts of calcareous nannofossil populations. Bengtson & Berthou (1982) described, by means of microfacies studies, the microfossils, echinoderms and algal species from the upper Albian to lower Coniacian deposits. A major investigation was carried out by Bengtson (1983), who established a detailed ammonite biostratigraphical zonation for the Cenomanian-lower Coniacian succession. Freitas (1984) discussed the stratigraphy and distribution of the calcareous nannofossils in the basin. Kauffman & Bengtson (1985) distinguished three Turonian assemblage zones of inoceramids. Further biostratigraphic and palaeo-ecological studies on the area of the São Francisco Low were presented by G. Beurlen et al. (1986), for the Cretaceous marine succession. Lower Turonian inoceramid bivalves were later described by Hessel (1987) with a palaeo-ecological analysis of the region. More recently Berthou & Bengtson (1988) reported studies on the potential of microfacies analysis for stratigraphical correlation of the Cenomanian-lower Coniacian succession.

CHAPTER 2

GENERAL GEOLOGICAL SETTING

2.1 - GEOLOGY OF THE BRAZILIAN CONTINENTAL MARGIN

The Brazilian marginal basins (Fig. 2.1) are directly related to the rupture of the African-South American plates and occur on a typical divergent, rifted, Atlantic-type continental margin (Ponte & Asmus, 1978; Ojeda, 1982; Estrella et al., 1984) extending for almost 8000km. In general, they can be linked to a single evolutionary geological history (Fig. 2.2) and subdivided into three main tectono-sedimentary stages: pre-rift, rift and drift. The drift stage is subdivided into two distinct phases: a gulf proto-marine evaporitic phase, and a subsequent marine phase (Asmus, 1975, 1981; Asmus & Baisch, 1983).

The late Jurassic-early Cretaceous pre-rift stage is associated with stretching of the continental crust and lithosphere. Block faulting, subsidence and localised mafic volcanism occurred, associated with thinning of the underlying crust and mantle (Bott, 1976). The sedimentary succession is composed mainly of red beds of fine to coarse siliciclastic sediments deposited under highly oxygenated conditions in fluvial and delta-lacustrine environments, associated with aeolian sediments (Schaller, 1969; Medeiros et al., 1971; Mello, 1988).

The early Cretaceous rifting stage is generally associated with basement-involved block faulting on a subsiding crust, and widespread mafic volcanism (Bott, 1976; Mohriak & Dewey, 1987). It is represented by the deposition of a thick sedimentary succession comprising siliciclastic, carbonate and evaporitic sediments in fresh to saline water lacustrine environments (Bertani & Carozzi, 1985; Mello, 1988). In some areas, the section overlies, and is intercalated with, basic-volcanic rocks. After rifting, tectonic activity appears to have been restricted to subsidence and basinward tilting, with the development of gravity sliding features and localised reactivation of faults (Ojeda, 1982; Estrella et al., 1984).

The first marine incursions into the northern coastal basins occurred during the Aptian when the São Paulo Plateau-Walvis Ridge complex was bypassed and saline waters flooded the central rift-graben system from the south (proto-marine phase) - (Asmus, 1975). A narrow and elongated embayment was then formed between South America and Africa, extending northwards along the eastern marginal basins from Santos to Sergipe-

Alagoas (Figs 2.1, 2.2). Tectonic quiescence and isolation by topographical barriers, together with warm and arid climatic conditions, led to low clastic influx and restricted conditions appropriate for high evaporation. This allowed the cyclic deposition of a thick and widespread succession of evaporitic sediments (halite, anhydrite, dolomite, gypsum) intercallated with carbonate and siliciclastic sediments (Asmus, 1975; Ojeda, 1982). Two major restricted basins were then located in the Proto-South Atlantic; the Brazil-Angola Basin in the north and the Cape-Argentine Basin in the south, separated by the São Paulo Plateau-Walvis Ridge (Arthur & Natland, 1979; Reyment & Bengtson, 1986) - Fig. 2.3.

As a consequence of increased sea floor spreading and progressive subsidence, the environmental conditions became less restricted and near normal marine conditions were established by late Aptian times (see Chapters 4, 8 and 9), initiating the marine phase in the marginal basins. Local basalt flows, progressive basin subsidence, seaward tilting and large adiastrophic growth-faulting structures marked the tectono-sedimentary activity of the whole marine succession (Estrella et al., 1984).

The marine phase can be further characterised into three distinct depositional sequences:

(i) the late Aptian-Albian marine platform and slope sequence, mainly composed of fine to coarse carbonate sediments accumulated under the predominantly neritic environments of a narrow epicontinental sea (Koutsoukos & Dias-Brito, 1987). As a result of the dynamic balance between subsidence and sedimentation on the continental margin, the northern area maintained an almost uniform palaeogeographical setting during that time. The marine carbonates and subordinate siliciclastic sediments of the platform and slope were deposited mainly under conditions of tectonic quiescence, with the development of growth faults probably produced by progressive gravity sliding of carbonate rock slabs as the basins tilted seaward (Falkenhein, 1981; Ojeda, 1982). Geochemical and micropalaeontological evidence suggest deposition of organic-rich marls and calcareous mudstones in hypersaline (stratified water-masses) and intermittent oxygen-depleted bottom conditions (Mello, 1988; see also Chapter 5, section 5.5.1).

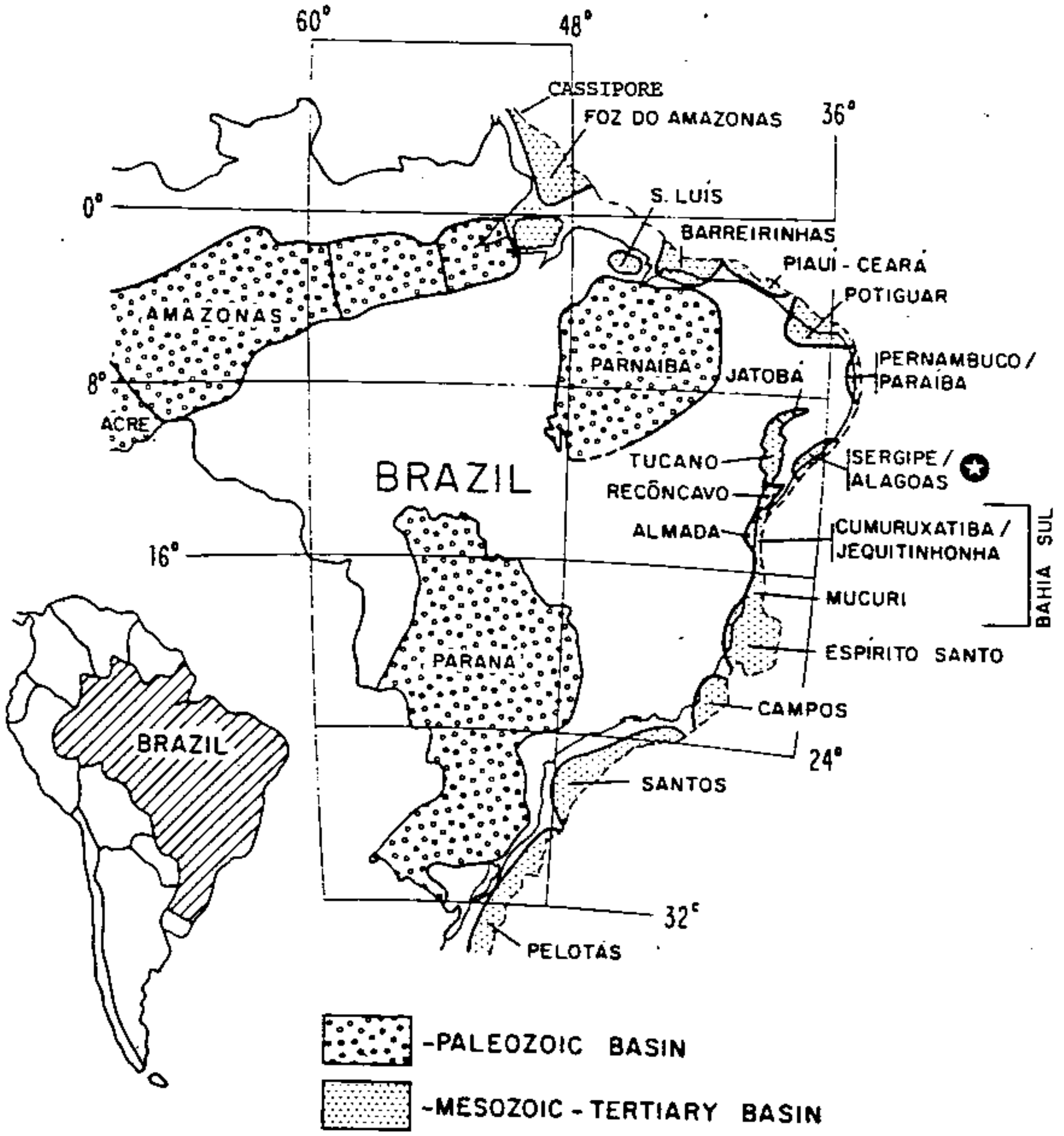
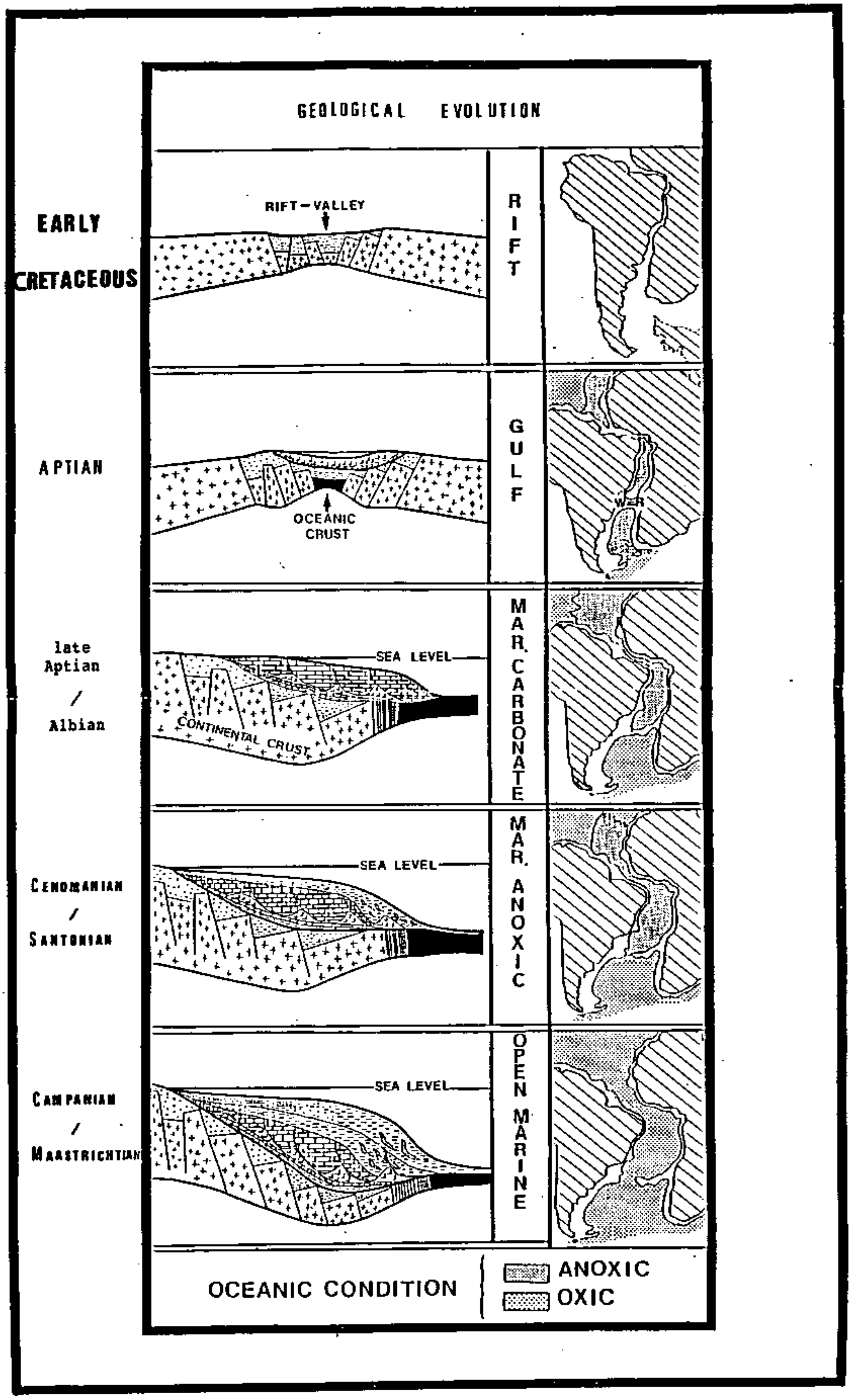


FIGURE 2.1: Location map of Brazilian marginal basins (from Ojeda, 1982, Fig. 1).

FIGURE 2.2: Evolutionary phases of the Brazilian continental margin (adapted after Mello, 1988).



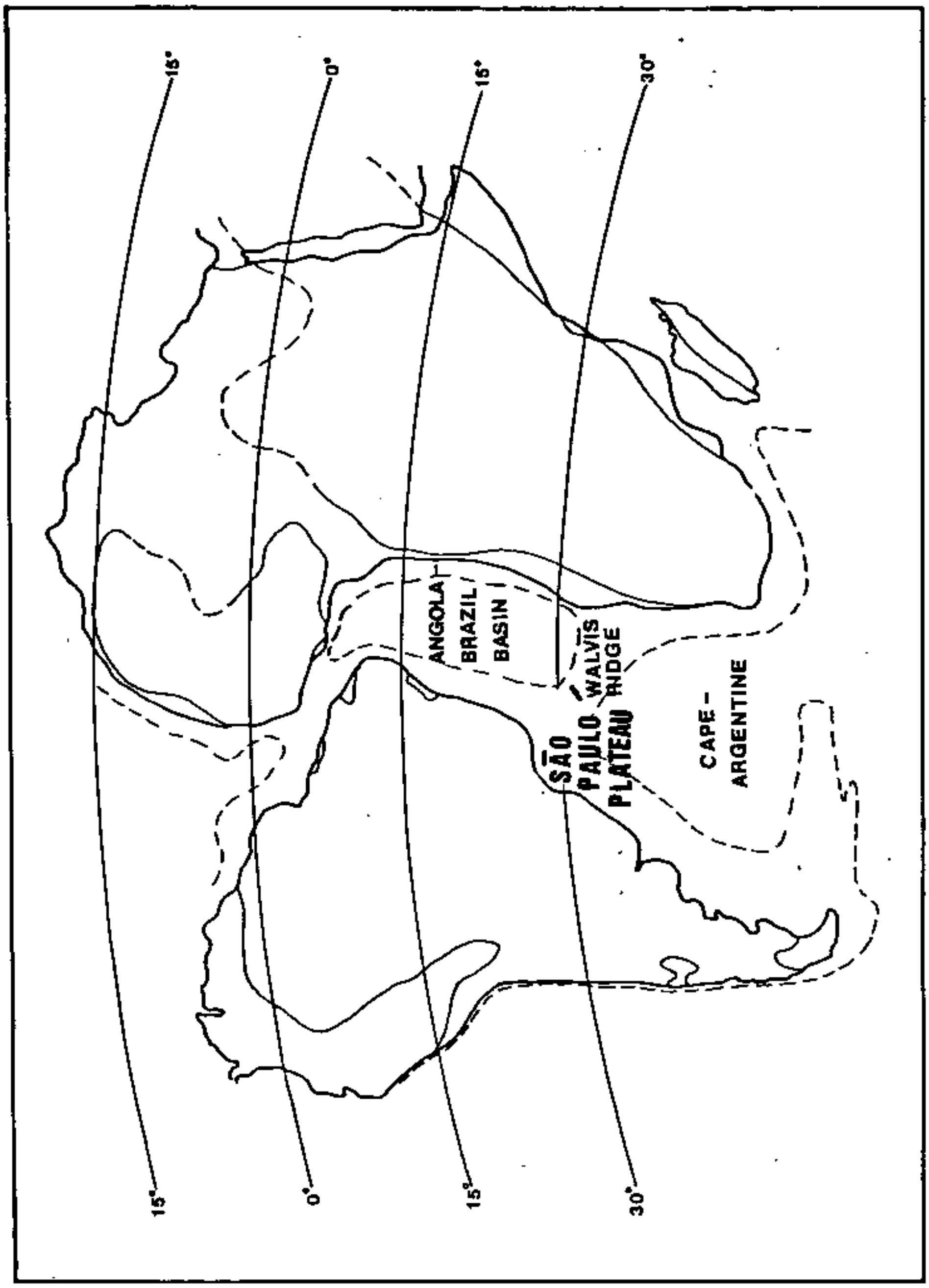


FIGURE 2.3: South Atlantic palaeogeographic reconstruction during the late Aptian-Albian showing the Walvis Ridge-São Paulo Plateau separating the Brazil-Angola Basin, to the North, from the Argentine-Cape Basin, to the South.

(ii) the Cenomanian to Palaeogene marine shelf-slope sedimentary system, is characterised by predominantly siliciclastic deposition in progressively deepening basins, which lead ultimately to bathyal/abyssal conditions in the more distal areas (sequence of coastal onlap; Beurlen, 1982). Widespread oxygen-depleted conditions were established from Cenomanian to Santonian times, with the deposition of organic-rich sediments, such as calcareous mudstones or black shales, in most of the Brazilian marginal basins (e.g., Arai, 1988, Mello et al., 1989, and references therein).

(iii) the Campanian-Maastrichtian to Holocene progradational sequence of the passive margin, is generally characterised by proximal coarse siliciclastic facies and distal pelitic and turbiditic deposits. Geochemical and micropalaeontological evidence suggests that during the late Cretaceous normal marine conditions with warm tropical and well oxygenated waters prevailed in the whole water column (Mello et al., 1989).

More recently published reviews have concentrated on the geological evolution, structural geology and palaeogeography of the Brazilian continental margin. These were discussed by Ojeda (1982), Asmus & Baisch (1983), Chang & Kowsmann (1987), Petri (1987), Francolin & Szatmari (1987), Szatmari et al. (1987), Zanotto & Szatmari (1987), Viviers & Azevedo (1988) and Spadini et al. (1988), among others.

2.2 - THE SERGIPE BASIN

2.2.1 - Mesozoic-Cenozoic Geological Setting

The basin is the southern part of the Sergipe-Alagoas sedimentary complex, a structurally-elongated marginal basin located between the latitudes 9° and 11°30'S, and the longitudes 37° and 35°30'W (Fig. 1.1). It has an area of approximately 6000km^2 onshore, extending to more than 5000km^2 offshore. Onshore, it covers a narrow coastal strip, approximately 16 to 50km wide and some 170km long, extending from near Indiaroba, at the mouth of the Real River, up to the São Francisco River, in the north. In this area, between the states of Sergipe and Alagoas, the basin is at its maximum width of 50km. It is limited, on the continent, by a boundary system of normal faults, constituting the topographic high called 'Serra de Itabaiana', and offshore by the continental slope. South of the Itaporanga fault, in the southwestern area, is the 'Estância Platform' where only a thin sedimentary record of mid-Cretaceous marine deposits is found (Schaller, 1970; Meister & Aurich, 1972; Ojeda & Fugita, 1976; Bengtson, 1983; Petri, 1987) - see Figs 2.4 and 2.5.

The Sergipe Basin forms a half-graben with a regional dip averaging 10-15° to the southeast (Ojeda & Fugita, 1976), which is the result of the continental drifting of South American and African continents in the Late Mesozoic. It is part of a group of Mesozoic-Cenozoic extensional basins formed along the western continental margin of the northern South Atlantic during that event and is, therefore, classified as an Atlantic-type basin (passive margin; Dickinson, 1974; Wilson & Williams, 1979; Asmus, 1981). Its probable counterpart in the African continent is offshore Gabon (Fernandes, 1966; Reyment & Tait, 1972; Castro Jr., 1987). It has a sedimentary thickness onshore which generally varies from 1000 to 3000 meters. In local areas offshore, the basin may contain 9000m of sediments, with a stratigraphic record spanning a time interval from the Carboniferous(?) to Recent (Asmus & Ponte, 1973; Ponte et al., 1980). This sequence is thought to be one of the most complete of the northern South Atlantic basins (cf. Bengtson, 1983), with virtually all the rift and post-rift succession represented.

The Sergipe Basin has been extensively drilled since 1963, when the first oil field was discovered near Carmópolis. It was also in Sergipe, in 1968, where the first oil field was found in the Brazilian continental platform, the Guaricema field (Aurich et al., 1972). The stratigraphy, sedimentology and geological history of the basin has been discussed in more detail in the works of Schaller (1970), Ojeda & Bisol (1972), Reyment & Tait (op. cit.), Meister & Aurich (1972), Ojeda & Fugita (1976), Bandeira Jr. (1978), Feijó (1980), Schaller et al. (1980), Bengtson (1983) and Berthou & Bengtson (1988). The middle to Upper Cretaceous lithostratigraphy and evolutionary phases of the Sergipe Basin are presented in Fig. 1.3.

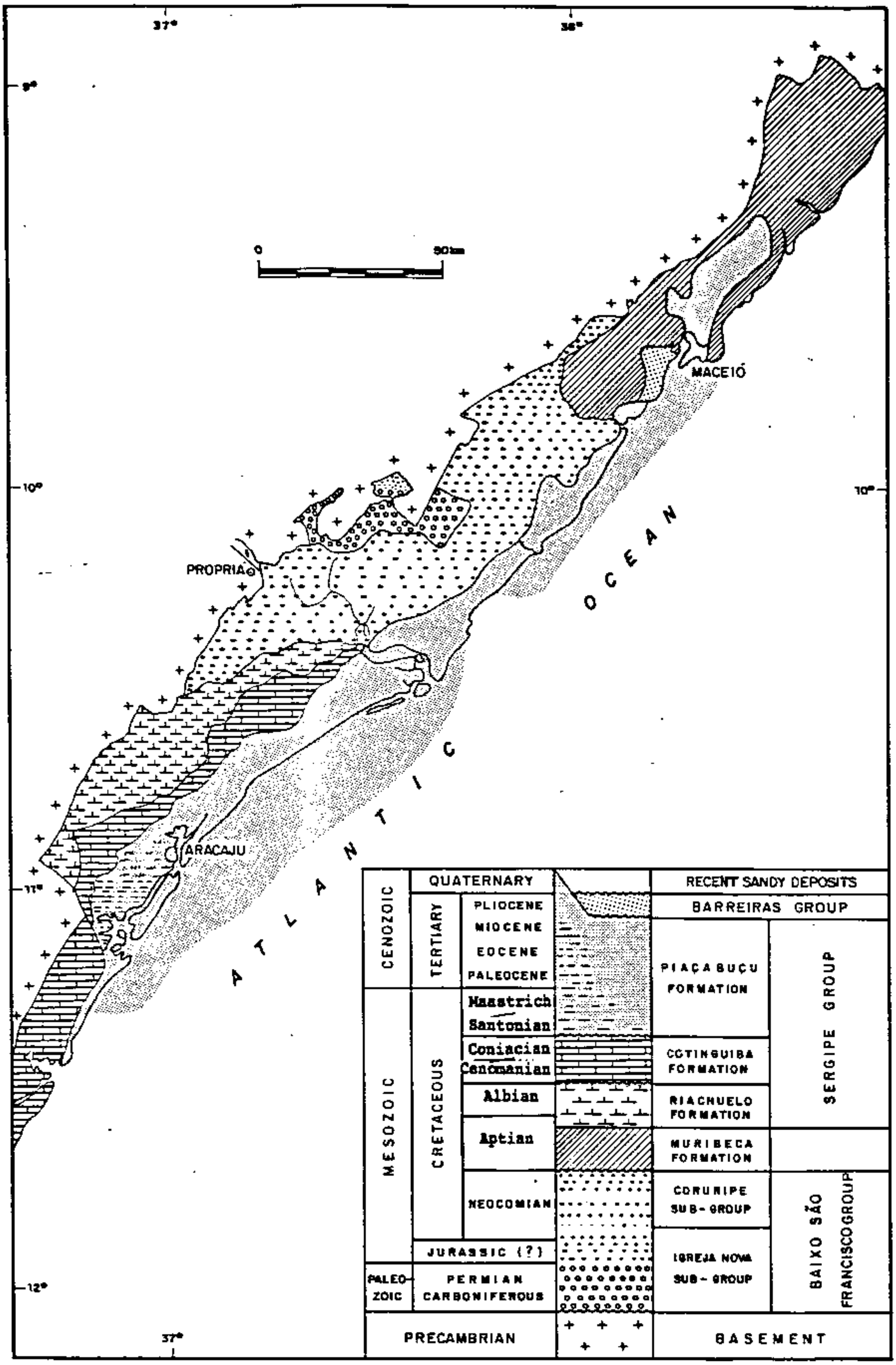


FIGURE 2.4: Geographic distribution of lithostratigraphic units in the Sergipe Basin (adapted after Asmus & Ponte, 1973, Fig. 6)

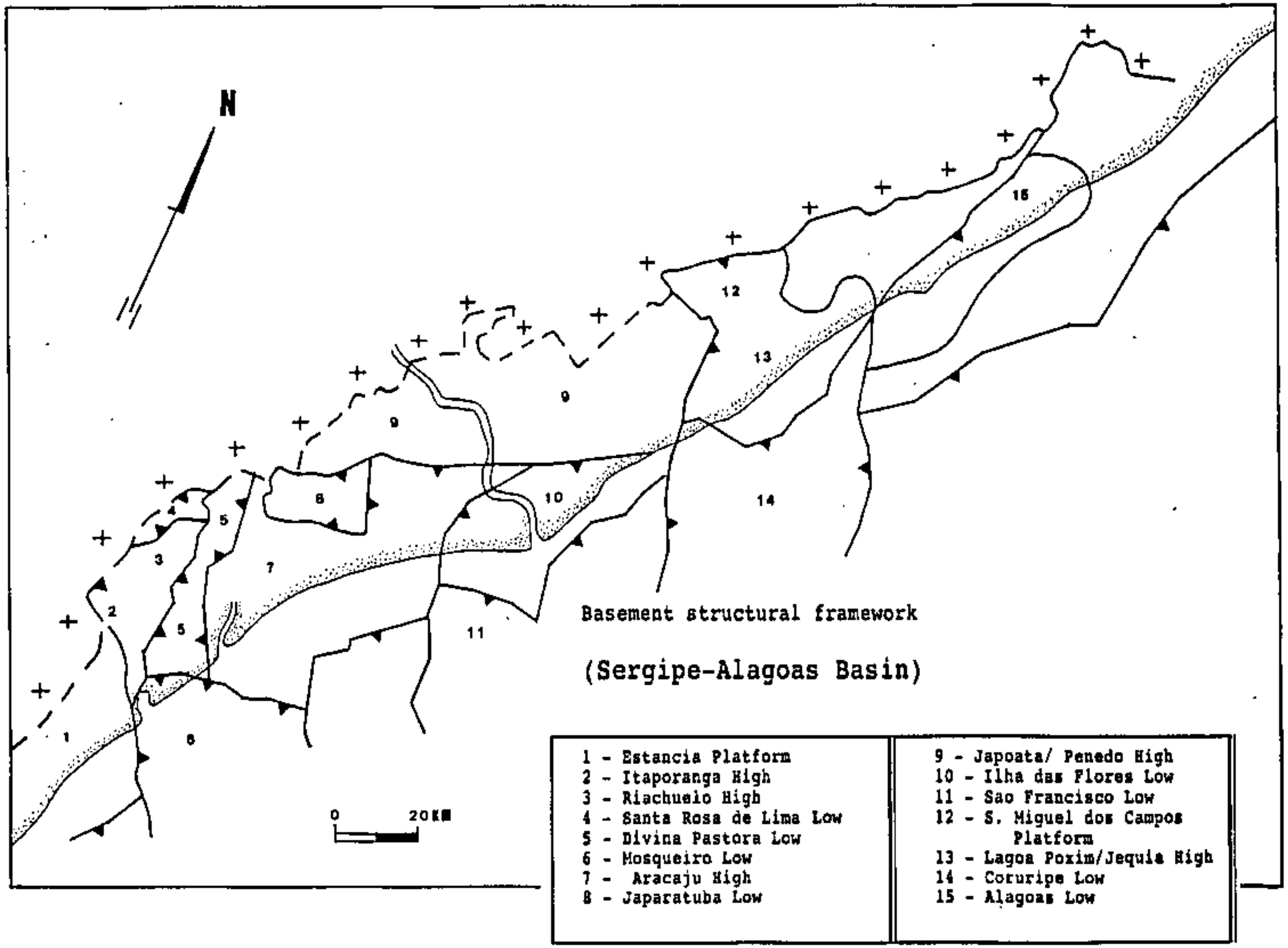


FIGURE 2.5: Basement structural framework of the Sergipe-Alagoas Basin (adapted after Cainelli et al., 1987, and Cunha, 1987).

2.2.2 - Geohistory and Lithostratigraphy

The Mesozoic succession of the Sergipe Basin is closely related to the rifting and drifting phases and exemplifies the early geological history of other northern South Atlantic marginal basins. The basement is characterised by local structural highs, lows and intermediate areas, these being evidence of the strong tectonic activity that has affected the basin since its formation. Normal faults, arranged in preferential trends along zones of weakness in the Precambrian basement, give rise to a system of horsts and grabens that constitute the more remarkable structural character of the basin - see Fig. 2.5.

Basically, five major tectono-sedimentary phases (adapted after Ojeda & Fugita, 1976; Ponte & Asmus, 1976; Figueiredo, 1978; Ponte et al., 1980; Ojeda, 1982) can be distinguished (Fig. 1.3): **intracratonic phase** (Permo-Carboniferous); **pre-rift phase** (late Jurassic(?)/earliest Cretaceous; Dom João local stage); **rift phase** (Neocomian to early(?) Aptian; Rio da Serra, Aratu, Buracica, Jiquiá and lowermost Alagoas local stages); **proto-marine evaporitic phase** (Aptian; Alagoas local stage), and; **marine phase** (late Aptian to Recent). These correspond to the general evolution of the Brazilian continental margin and have been identified, in whole or in part, in all northern South Atlantic basins.

2.2.2.(i) - Intracratonic Phase

The intacratonic phase is characterized by continental lacustrine deposits that once covered a large area of the Gondwana Continent, from the northeastern Brazilian to the central and western African basins. During this phase the sediments of the **Batinga Formation** (Carboniferous?); siltstones, paraconglomerates, ortoconglomerates and coarse arenites), of the **Aracaré Formation** (Permian; shales interbeded with bands of fine sandstone, siltstone and sporadic limestones, all associated with flint bands) and their lithostratigraphic African counterparts were deposited over metamorphic rocks of the Precambrian basement.

2.2.2.(ii) - Pre-Rift Phase

Phase of crustal uplift (intumescence) with continental sediments (fluvio-lacustrine clastics) being deposited in the peripheral intracratonic basin. During this phase, in late Jurassic-earliest Cretaceous times, the deposits of the **Bananeiras Formation** (red and green shales) and of the **Serraria Formation** (thick-bedded to massive, coarse-grained, poorly sorted, white to grey quartzitic sandstones) were extensively accumulated in a continuous and progressive subsiding system, the **Baixo São Francisco Group.**

2.2.2.(iii) - Rift Phase

This is a taphrogenic phase of intense tectonic activity with stretching of the crust. The breakup of the continental crust of the Gondwana continent in early Cretaceous times gave rise to the formation of a long central graben and rift-valley systems, where siliciclastic and carbonate sediments were being deposited in deltaic-lacustrine environments.

The Rift Phase is represented by the Barra de Itiúba, Penedo, Rio Pitanga and Morro do Chaves Formations. The **Barra de Itiúba** consists of a thick succession of greenish-grey shales with some intercalations of fine-grained sandstones and rare calcareous bands. The **Rio Pitanga and Penedo Formations** are considered to be laterally equivalent, i.e., facies variations (Schaller , 1970; Meister & Aurich, 1972). They are represented, respectively, by red to green coarse conglomerates and breccias mainly consisting of metamorphic rocks (Rio Pitanga Formation), and by poorly sorted, greyish white to yellow sandstones (Penedo Formation). The **Morro do Chaves Formation** has a restricted occurrence in the Sergipe Basin, where it consists of chalky, coquinoidal or dolomitic limestones, with intercalations of sandstones, shales and marls. The **Coqueiro Seco and Ponta Verde Formations** are predominantly siliciclastic units regarded as probably different facies variations of the Morro do Chaves Formation (Reyment & Tait, 1972) and only recorded in the northern part of the Sergipe-Alagoas sedimentary complex, the Alagoas Basin. Following the deposition in the basin of the Lower Cretaceous sediments occurred a widespread erosional event that removed major parts of the previous stratigraphic record (Ojeda & Fugita, 1976). This hiatus is known as the pre-Muribeca unconformity.

2.2.2.(iv) - Proto-Marine Evaporitic Phase

The proto-marine evaporitic phase, initiated in early Aptian times, corresponds to a terminal rift cycle with less pronounced tectonism. At that time were deposited the oil-productive beds of the **Muribeca Formation**, a hypersaline sedimentary sequence unconformably resting over older Morro do Chaves strata. It represents the record of the first marine advances that occurred in the northern proto-South Atlantic. The Muribeca Formation is represented in Sergipe by three superimposed members: Carmópolis, Ibura and Oiteirinhos. The **Carmópolis Member** sequence, deposited in a system of infilled palaeotopographic depressions and delta fans, begins at its base with a coarse conglomerate interbedded with grey and bituminous shales that gradually fines upwards, grading into the next unit. The overlying **Ibura Member**, deposited in a transitional evaporitic environment, is represented by a succession of bituminous shales, soluble salts (halite, tachyhydrite, carnalite and silvinite), dolomitic limestones, dolomites and anhydrites, reaching a considerable thickness in the basin (Szatmari et al., 1979; Ojeda, 1982). The uppermost **Oiteirinhos Member** consists of intercalations of grey to dark bituminous shales, limestones and siltstones, deposited on a carbonate and clastic platform system.

2.2.2.(v) - Marine Phase

Following a short erosional period that succeeded the Muribeca Formation, and as the South Atlantic rift progressively expanded, the sea transgressed over the southern part of the basin from late Aptian to Albian times . It reached as far north as the São Francisco River region and the southernmost part of the Alagoas Basin (near the 'Pontal de Coruripe' graben). At that time deposition of the first true marine carbonate sediments (the **Riachuelo Formation**) occurred, initiating the marine phase. However, in the present onshore region of the Alagoas Basin, there was, apparently, no further recorded sedimentation until the late Tertiary (Pliocene ?), although there are some scattered records of ammonite-bearing late Cenomanian beds (Beurlen, 1961; Muniz et al., 1975; Bengtson & Nordlund, 1987).

In the Sergipe Basin, the outcrops of the Riachuelo Formation extend along a band from Itaporanga, south of Aracaju, to the valley of the Poxim

River, north of Pacatuba, with a width of approximately 20km. The formation has an average thickness of 500m, but locally attains a maximum of 1700m. Four members can be distinguished (Figs 1.3, 2.4). The **Angico Member** occurs mainly near the base of the sequence, overlying the Muribeca Formation, close to the western interior margin of the basin, where it represents a syntectonic facies. It consists of conglomeratic to very fine-grained sandstones, interbedded with siltstones, shales and rare thin beds of limestones with bivalve shells (Chapter 8, Photos 8.4-6. Towards the east the Angico Member grades into the sediments of the **Taquari Member (Photo 8.7).** The latter consists of alternating deposits of shales, siltstones and, occasionally, thin beds of greyish limestones, which appear to have accumulated in a slightly deeper water environment. The overlying **Maruim Member** is mainly represented by oolitic/oncolitic and bioclastic limestones, and some red algal, patch reef structures (well preserved in outcrops - see Photo 8.11), with a few intercalations of siliciclastic material (Photos 8.8-9). It reaches a maximum thickness of 600m towards the east. The lithological characteristics of the Maruim Member indicate an environmental change from the relatively deep and quiet waters of the Taquari deposits to a shallower and more turbulent, higher-energy facies. The saccharoidal dolomites of the **Aquilhada Member** (Photo 8.10) commonly occur with some intercalations of fine to conglomeratic sandstones, shales and sporadic non-dolomitized limestones. It represents a dolomitic facies of the Maruim Member.

Overlying the Riachuelo Formation is the **Cotinguiba Formation** (Cenomanian to lower Coniacian), previously kown as the Sapucari-Laranjeiras Formation. It outcrops in Sergipe along a band of 5 to 10km wide, from the Real River, in the south, area of the Estância Platform (where it is known to lie directly over the Precambrian basement - Bengtson, 1983), to Japaratuba, in the north. The Cotinguiba Formation represents a time of sedimentation/subsidence balance on a tectonically stable platform with areas of low terrigenous influx, where thick sequences of calcareous mudstones are to be found (cf. Bengtson, op. cit.; Berthou & Bengtson, 1988). Two lithological units are identified: the Sapucari and Aracaju Members.

The **Sapucari Member** is composed of a very thick succession of calcareous mudstones (maximum thickness around 1000m) with occasional thin pelitic levels of marls or shales and some conglomeratic sandstones near the base (Photos 8.12, 8.15-26). The **Aracaju Member** is a pelagic facies with an average thickness of 100m (maximum around 300m in the subsurface) and consists of shales interbedded with thin calcareous mudstones and marls. It occurs predominantly in the subsurface sections (only one exposure has been studied in Sergipe; locality A-9, see Chapter 8, Photos 8.13-14).

Unconformably resting over the previous unit and closing the carbonate-dominated deposicional cycle are the siliciclastic deposits of the **Piacabucu Formation** (upper Coniacian/Santonian to Miocene/ Pliocene? - Asmus, 1981; Ojeda & Fugita, 1976) - (Photo 8.27). This event marks the reactivation of the source area with strong terrigenous input leading to a change in the sedimentary regime, from a carbonate-dominated (Cotinguiba Formation) to a siliciclastic depositional cycle. Two lithostratigraphic units are described: the Calumbi and Marituba Members.

The **Calumbi Member** occurs stratigraphically below and basinward of the Mosqueiro carbonate system, in the south, and represents deposition in middle/outer shelf and continental slope environments. It consists of a thick sequence of dark grey shales (maximum thickness around 3000m) with minor amounts of fine and coarse grained sandstones deposited as turbiditic submarine fans (Fisher et al., 1973). The shallower coeval deposits were probably eroded as a result of the progressive eastward tilting of the basin and consequent uplift of most of the present onshore area (Ojeda & Fugita, 1976).

The **Marituba Member** is chiefly composed of sandstones and calcarenites commonly occurring in the north, offshore the mouth of the São Francisco River. It comprises a major fan delta system that prograded over a narrow shelf on which were developed the Mosqueiro carbonates. These sediments were not studied during this research.

During the Pliocene the **Barreiras Formation** was deposited, consisting of fine to coarse grained continental clastics with a maximum thickness around 300m. Its deposits occur in a widespread area, passing over the borders of the basin and forming cliffs along the present coast. The Quaternary sediments consist mostly of continental alluvium and sands being extensively deposited along the valleys of the great rivers and along the present-day shoreline.

CHAPTER 3

SYSTEMATIC PALAEONTOLOGY

3.1 - FORAMINIFERA

A systematic record is given of the planktonic and benthonic foraminifera which have been recovered during this study from the upper Aptian to Maastrichtian succession of Sergipe. Each species is illustrated by scanning electron photomicrographs using specimens selected from the curated type collection. The taxa are arranged at suprageneric level chiefly according to the classifications of Haynes (1981) and Loeblich & Tappan (1988). The generic definitions used are mostly according to the diagnoses of Loeblich & Tappan (1988), for the benthonic foraminifera, and Masters (1977), Robaszynski & Caron (1979), Robaszynski et al. (1984) and Caron (1985), for the planktonic species, except where stated otherwise.

Entries for each species are brief giving only the author, date, plate and figure numbers. Each reference is restricted to the first original description of the species, subsequent generic name changes and to all relevant references used in this study. All are listed according to their year of publication. Since most of the species illustrated in this work have been described in detail in easily accessible literature, only brief taxonomic remarks are made within the text about pertinent, distinctive and diagnostic morphological features where these are necessary. More extensive taxonomic entries and remarks are given where original descriptions have beem emended, redefined and/or modified in any manner. The recorded biochronostratigraphic range, sites of occurrence and palaeo-environments (for the benthonic microfauna) are also reported. Several gaps were observed in the biostratigraphic record of long ranging benthonic species (e.g., Superfamily Astrorhizacea), in these cases reflecting exclusion due to major changes in palaeo-environmental conditions.

Phylum **PROTOZOA**
Subphylum **SARCODINA**
Class **RHIZOPODEA**
Subclass **GRANULORETICULOSIA**
Order **FORAMINIFERIDA**

Suborder **TEXTULARIINA**
Delage & Hérouard, 1896

Superfamily **ASTRORHIZACEA**
Brady, 1881

- Remarks on the taxonomy of the primitive types of agglutinated foraminifera -

The genera Bathysiphon, Dendrophrya, Hyperammina (Superfamily Hippocrepinacea), Rhabdammina and Rhizammina are referable to a morphogroup of long-ranging primitive elongate agglutinated foraminifera whose test is wholly or in part arenaceous, composed of single-chambered tubes, straight or branched, and regular or irregular in size and arrangement. In the northern hemisphere they are mostly known from the European flysch facies (Bavaria, southern Germany: Pflaumann, 1967; Gurnigel/Schlieren, Switzerland: Butt, 1980, Winkler & Van Stuijvenberg, 1982, Winkler, 1984; Solignano and Monte Cassio, northern Italian Apennines: Morloti, 1988; Moravia, Czechoslovakia: Hanzlíková, 1966, 1969; Nauss, 1947; Subbotina, 1950; Rumania: Neagu, 1970; Carpathian flysch, Poland: Ksiazkiewicz, 1975, Morgiel & Olszewska, 1981).

As regards the taxonomy of these specimens, the views of Bartenstein (1974, p. 684) are followed herein: "differences in test size (small, intermediate, giant); in wall material (smooth, coarse, fine grained, coarser grained); or in colour (white, reddish-brown, or differently colored), do not justify the erection of new species or even genera". Furthermore, because of the fragmentation of tests and common post-depositional deformation, no decision could be made on specific attribution of several morphotypes. Such forms were lumped in single species-groups, each regarded with broad morphological variability.

Family **BATHYSIPHONIDAE** Avnimelech, 1881

Genus **BATHYSIPHON** M. Sars, 1872
Type species: Bathysiphon filiformis M. Sars, 1872

Bathysiphon ex gr. vitta Nauss

(Pl. 1, Figs 1-3)

Bathysiphon vitta Nauss, 1947, p. 334, pl. 48, fig. 4.

Bathysiphon vitta Nauss. Trujillo, 1960, p.302-303, pl.43, fig.2a-b.

Bathysiphon brosgei Tappan. Sliter, 1968, p. 39-40, pl. 1, fig. 1.

Bathysiphon vitta Nauss. Sliter, 1968, p. 40-41, pl. 1, fig. 3.

Bathysiphon sp., Bartenstein, 1974, p. 684-685, pl. 1, figs 1-4.

Bathysiphon brosgei Tappan. Haig, 1980, p. 91, pl. 1, figs 1-2, pl. 9, fig. 1.

Bathysiphon vitta Nauss. Haig, 1980, p. 91-92, pl. 1, fig. 3, pl. 9, fig. 2.

Bathysiphon microrhaphidus Samuel. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988 p. 182, pl. 1, figs 1a-b.

Bathysiphon sp., Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988 p. 182, pl. 1, figs 2-3.

Remarks: Morphotypes assigned to this species-group occur as only fragmental unilocular chambers of a straight, or slightly curved, unbranched elongate tubular shape, open at both ends (fragments varying from c. 760μm to 1900μm in maximum length); wall structure thick and fine-grained; cement of organic and/or siliceous origin; test surface typically smooth, homogeneous, sometimes showing annular constrictions at irregular intervals; test usually compressed by post-mortem compaction.

Range: late Aptian to Albian, late Coniacian to Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: deep neritic to upper bathyal (late Aptian to late Albian biotopes); middle to lower bathyal (late Coniacian to Maastrichtian biotopes).

Family **RHABDAMMINIDAE** Brady, 1884

Subfamily **RHABDAMMININAE** Brady, 1884

Genus **RHABDAMMINA** M. Sars, 1869

Type species: Rhabdammina abyssorum M. Sars, in Carpenter, 1869

Rhabdammina ex gr. discreta Brady
(Pl. 1, Figs 4-5)

Rhabdammina discreta Brady, 1881, p. 48, pl. 22, figs 7-10.
Rhabdammina discreta Brady. Cushman, 1946, p. 14, pl. 1, figs 1-2.
Rhabdammina sp., Hofling, 1988, p. 135, pl. 1, figs 1-2.
Rhabdammina ex gr. discreta Brady. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988 p. 183, pl. 1, figs 8-9.
Rhabdammina sp. aff. abyssorum Sars. Moullade, Kuhnt & Thurow, 1988, pl. 1, fig. 1.

Remarks: Rhabdammina ex gr. discreta morphotypes are represented by short, rarely branched (Pl. 1, Fig. 4) or single fragments of straight cylindrical tubes (c. 1010-1640μm in maximum length), of nearly constant diameter, mostly without annular constrictions, open at both ends; thick-walled and coarsely agglutinated; rough test surface, with little cement, of organic and/or siliceous origin; test usually circular in cross section, but may be compressed by post-mortem compaction.

Range: late Campanian.

Occurrence: 1-SES-9.

Palaeo-environments: middle to lower bathyal.

Genus **RHIZAMMINA** Brady, 1879

Type species: Rhizammina algaeformis Brady, 1879

Rhizammina ex gr. indivisa Brady
(Pl. 1, Figs 6-8)

Rhizammina indivisa Brady, 1884, p. 277, pl. 29, figs 5-7.
Rhizammina indivisa Brady. Sliter, 1980, p. 368, pl. 1, fig. 1.
Rhizammina indyvisa Brady. Morgiel & Olszewska, 1981, p. 7, pl. 1, fig. 2.
Rhizammina indivisa Brady. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988 p. 183, pl. 1, figs 10-13.

Remarks: Rhizammina ex gr. indivisa morphotypes are characterised by narrow, elongate and cylindrical test fragments (varying from c. 580µm to 1400µm in maximum length), commonly flattened and distorted; thin-walled and flexible test, with little cement, of organic and/or siliceous origin; coarsely agglutinated. Fragments of Rhizammina are distinguished from those of Hyperammina gaultina ten Dam by their coarser agglutinated and slender test, commonly distorted, with less cement and a rougher surface (cf. Sliter, 1980, p. 368).

Range: Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Subfamily **DENDROPHRYINAE** Haeckel, 1894

Genus **DENDROPHRYA** T.S. Wright, 1861

Type species: Dendrophrya erecta T.S. Wright, 1861

Dendrophrya ex gr. excelsa Grzybowski

(Pl. 1, Figs 9-10)

Dendrophya excelsa Grzybowski, 1898, p. 272, pl. 10, figs 1-4.

Dendrophrya excelsa Grzybowski. Hanzlíková, 1972, p. 32, pl. 2, fig. 6.

Hyperammina gaultina ten Dam. Bartenstein, 1974, p. 685, pl. 2, fig. 4 (?).

Kalamopsis grzybowskii (Dylazanka). Bartenstein, 1974, p.685, pl. 1, fig. 34, pl. 2, fig. 35.

Dendrophrya excelsa Grzybowski. Morgiel & Olszewska, 1981, p. 7, pl. 1, figs 5-6.

Dendrophrya ex gr. excelsa Grzybowski. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 182, pl. 1, figs 4-5.

Dendrophrya latissima Grzybowski. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988 p. 182, pl. 1, fig. 6.

Dendrophrya sp., Hofling, 1988, p. 135-136, pl. 1, figs 11-12.

Remarks: Dendrophrya ex gr. excelsa morphotypes are characterised by large-sized, elongate, tubular test fragments (c. 2220-2230µm in maximum length); wide tube, usually compressed, with a longitudinal groove; fine-grained agglutinated wall; smooth, even surface; non-constricted and parallel-sided chamber. No branched specimens have been found.

Range: Maastrichtian.

Occurrence: well 1-SES-1A.

Palaeo-environments: middle to lower bathyal.

Family **PSAMMOSPHAERIDAE** Haeckel, 1894

Subfamily **PSAMMOSPHAERINAE** Haeckel, 1894

Genus **PSAMMOSPHAERA** Schulze, 1875

Type species: Psammosphaera fusca Schulze, 1875

Psammosphaera scruposa (Berthelin)

(Pl. 1, Figs 11-13)

Haplophragmium scruposum Berthelin, 1880, p. 21, pl. 1, fig. 1.

Psammosphaera laevigata White, 1928 a, p. 183-184, pl. 27, fig. 1a-b.

Psammosphaera laevigata White. Hanzlíková, 1972, p. 33, pl. 1, figs 7-8.

Psammosphaera scruposa (Berthelin). Hanzlíková, 1973, p.136, pl. 1, fig.4a-b.

Psammosphaera scruposa (Berthelin). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 182, pl. 2, fig. 5.

Remarks: P. scruposa comprises specimens with a large spherical test (c. 1470-1530µm in maximum diameter), commonly compressed by post-mortem compaction; non-septate; wall thick and rather coarsely agglutinated. The morphotypes differ from Saccammina sphaerica Sars in having a larger test with agglutinated grains that are finer and more uniform.

Range: late Coniacian to Maastrichtian

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Family **SACCAMMINIDAE** Brady, 1884

Subfamily **SACCAMMININAE** Brady, 1884

Genus **SACCAMMINA** Carpenter, 1869

Type species: Saccammina sphaerica Brady, 1871

Saccammina sphaerica Sars

(Pl. 1, Fig. 14)

Saccammina sphaerica Sars, 1872, p. 250.
Saccammina complanata (Franke). Sliter, 1968, p. 42, pl. 1, fig. 7.
Saccammina placenta (Grzybowski). Hanzlíková, 1972, p. 33, pl. 1, fig. 9.
Saccammina complanata (Franke). Krasheninnikov, 1974, p. 644, pl. 7, figs 10a-b.
Saccammina sphaerica Sars. Moullade, Kuhnt & Thurow, 1988, pl. 2, fig. 12.

Remarks: S. sphaerica is characterised by having a large spherical test (c. 840-850µm in maximum diameter), commonly compressed by post-mortem compaction; small, rounded, terminal aperture, often obscured [which makes it difficult to be distinguished from specimens of Psammosphaera scruposa (Berthelin)]; thick-walled and coarsely agglutinated, with a rough test surface.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Subfamily **PILULININAE** Brady, 1884

Genus **PILULINA** Carpenter, 1870

Type species: Pilulina jeffreysii Carpenter, 1875

Pilulina sp. A

(Pl. 1, Figs 15-16)

Remarks: Specimens of Pilulina sp. A have a large single-chambered spherical test (c. 1020-1240µm in maximum diameter), usually compressed by compaction; long oval, slit-like, terminal aperture; rather fine-grained agglutinated wall. It is similar to Saccammina from which it differs in possessing an elongate slit-like aperture. The species has affinities with Pilulina antiqua described by Krasheninnikov (1974) from the Upper Cretaceous of the NE part of the Indian Ocean, but differs in its much larger size, depressed terminal aperture and coarser-grained agglutinated wall.

Range: late Campanian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: middle to lower bathyal.

Superfamily **HIPPOCRECEPINACEA**
Rhumbler, 1895

Family **HIPPOCREPINIDAE** Rhumbler, 1895

Genus **HYPERAMMINA** Brady, 1878
Type species: *Hyperammina* *elongata* Brady, 1878

Hyperammina* ex gr. *gaultina ten Dam
(Pl. 1, Figs 17-20)

Hyperammina *gaultina* ten Dam, 1950, p. 5, pl. 1, fig. 8.

Hyperammina *gaultina* ten Dam. Bartenstein, 1974, p. 685, pl. 1, figs 5-30, 35-36, pl. 2, figs 1-4.

Hyperammina sp. 1, Bartenstein, 1974, p. 685, pl. 2, figs 5-14.

Hyperammina ex gr. *subnodosiformis* Grzybowski. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 184, pl. 1, figs 16-17.

Remarks: *Hyperammina* ex gr. *gaultina* specimens are distinguished by their simple, elongate tubular test fragments (varying from c. 660µm to 1350µm in maximum length), usually compressed, with an irregular growth; slender or large long tests, of constant diameter but tapering slightly at one end; annular constrictions at irregular intervals may be present; finely agglutinated wall, with abundant cement of organic and/or siliceous origin; smooth test surface. *Hyperammina* ex gr. *gaultina* and *Bathysiphon* ex gr. *vitta* Nauss morphotypes are closely related, based only on simple morphological characteristics, and it is not always possible to differentiate one from the other.

Range: late Aptian to middle-late Albian, Maastrichtian.

Occurrence: 1-US-1-SE, 1-CN-1-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: deep neritic to upper bathyal (late Aptian to middle-late Albian biotopes), middle to lower bathyal (Maastrichtian).

Superfamily **AMMODISCACEA**
Reuss, 1862

Family **AMMODISCIDAE** Reuss, 1862

Subfamily **AMMODISCINAE** Reuss, 1862

Genus **AMMODISCUS** Reuss, 1862

Type species; *Ammodiscus infimus* L. G. Bornemann, 1874

Remarks: In the studied samples specimens belonging to this genus commonly show post-mortem deformation.

Ammodiscus cretaceus (Reuss)
(Pl. 1, Fig. 21)

Operculina cretacea Reuss, 1845, p. 35, pl. 13, figs 64-65.

Ammodiscus cretaceus (Reuss). Cushman, 1946, p. 17, pl. 1, fig. 35.

Ammodiscus cretaceus (Reuss). Tappan, 1962, p.130, pl.30, figs 1-2.

Ammodiscus cretaceus (Reuss). Sliter, 1968, p. 42, pl. 1, fig. 8.

Ammodiscus cretaceus (Reuss). Hanzlíková, 1972, p. 34, pl. 3, figs 1, 9.

Ammodiscus cretaceus (Reuss). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 184, pl. 3, fig.7.

Ammodiscus glabratus Cushman & Jarvis. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 184, pl. 3, fig. 8a-b.

Ammodiscus cretaceus (Reuss). Moullade, Kuhnt & Thurow, 1988, pl. 1, fig.7.

Remarks: This species is distinguished by having a large discoidal test (c. 800μm in maximum diameter); biconcave; an undivided, planispiral, wide tubular chamber, partially overlapping preceeding whorls; finely agglutinated wall, surface smooth.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Ammodiscus glabratus Cushman & Jarvis

(Pl. 1, Fig. 22)

Ammodiscus glabratus Cushman & Jarvis, 1928, p. 86, pl. 12, fig. 6.
Ammodiscus glabratus Cushman & Jarvis. Hanzlíková, 1972, p. 35, pl. 3, fig. 7.
Ammodiscus cretaceus (Reuss). Scheibnerová, 1976, pl.2, figs 3–4.

Remarks: A. glabratus is characterised by its small discoidal test (c. 230–240µm in maximum diameter), biconcave, involute; wall very finely agglutinated, with cement of organic and/or siliceous origin; homogeneous and smooth test surface. This species differs from A. cretaceus (Reuss) by its smaller size and more compressed test, usually more involute.

Range: late Campanian to Maastrichtian.

Occurrence: locality A-18, wells 1-SES-1A, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Ammodiscus incertus (d'Orbigny)

(Pl. 1, Fig. 23)

Operculina incerta d'Orbigny, 1839, p. 49, pl. 6, figs 16, 17.
Ammodiscus incertus (d'Orbigny). Bartenstein, 1974, p. 687, pl. 3, figs 14–17.
Ammodiscus rotalarius Loeblich & Tappan, 1949, p. 247, pl. 46, fig. 1.
Ammodiscus rotalarius Loeblich & Tappan. Haig, 1980, p. 96–97, pl. 2, figs 3–4, pl. 9, fig. 5.

Remarks: A. incertus is distinguished by its small, compressed, discoidal test (c. 320µm in maximum diameter), involute, with radiate constrictions. The specimens differ from Glomospirella gaultina (Berthelin) in having a more regular, planispiral coiling throughout.

Range: late Aptian to middle–late Albian.

Occurrence: wells 1-US-1-SE, 1-SES-9.

Palaeo-environments: deep neritic to upper bathyal.

Ammodiscus planus Loeblich

(Pl. 1, Fig. 24)

Ammodiscus planus Loeblich, 1946, p. 133, pl. 22, fig. 2.

Ammodiscus planus Loeblich. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 185, pl. 3, fig. 13.

Remarks: A. planus is distinguished by having a small, very thin-walled, compressed, discoidal test (c. 220-300μm in maximum diameter); finely agglutinated, with cement, of organic and/or siliceous origin; smooth test surface. It differs from A. glabratus Cushman & Jarvis by its more compressed and regular test.

Range: late Maastrichtian.

Occurrence: wells 1-SES-9, 1-SES-24 (rare occurrence).

Palaeo-environments: middle to lower bathyal.

Ammodiscus tenuissimus (Guembel)

(Pl. 1, Fig. 25)

Spirillina tenuissima Guembel, 1862, p. 214, pl. 13, fig. 2.

Ammodiscus tenuissimus (Guembel). Bartenstein, 1974, p. 687, pl. 3, figs 7-13.

Remarks: Specimens of A. tenuissimus are characterised by their slender, very compressed, discoidal test (c. 450μm in maximum diameter), involute.

Range: late Aptian.

Occurrence: well 1-US-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Subfamily **AMMOVERTELLININAE** Saidova, 1981

Genus **AMMOVERTELLINA** Suleymanov, 1959

Type species: Ammovertellina prima Suleymanov, 1959

Ammovertellina sp. A

(Pl. 1, Figs 26–27)

Remarks: A single specimen referable to Ammovertellina sp. A was recovered from the lower to middle Campanian. It is characterised by having a tubular chamber with an early stage planispirally enrolled in an evolute pattern, as in Ammodiscus Reuss, later uncoiling with irregular growth (c. 640μm in maximum length); wall somewhat finely agglutinated, compressed by compaction. The early streptospiral stage, as in the description of the genus (cf. Loeblich & Tappan, 1988, p. 50), is not observed in this single specimen. This feature may actually be absent or rather masked by post-depositional deformation.

Range: late Campanian.

Occurrence: well 1-SES-1A (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **GLOMOSPIRA** Rzehak, 1885

Type species: Trochammina squamata Jones & Parker
var. gordialis Jones & Parker, 1860

Glomospira charoides (Jones & Parker)

(Pl. 1, Figs 28–30)

Trochammina squamata var. charoides Jones & Parker, 1860, p.304.

Glomospira charoides (Jones & Parker) var. corona Cushman & Jarvis, 1928, p. 89, pl. 12, figs 9–11.

Glomospira charoides (Jones & Parker). Hanzlíková, 1966, p. 101, pl. 1, fig. 6.

Glomospira charoides (Jones & Parker). Bartenstein, 1974, p. 686, pl. 2, figs 45–50.

Glomospira charoides (Jones & Parker). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 185, pl. 3, figs 14–15.

Glomospira charoides (Jones & Parker). Moullade, Kuhnt & Thurow, 1988, pl. 1, fig. 6.

Remarks: G. charoides is characterised by a fairly regular cylindrical test (varying from c. 250/240µm to 600/400µm in maximum diameter/height ratio), with almost parallel lateral sides; a thin tube in a near trochospiral coil in horizontal planes; the last one or two whorls irregularly coiled; finely-grained agglutinated wall, with cement of organic and/or siliceous origin; smooth and homogeneous test surface.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Glomospira gordialis (Jones & Parker)

(Pl. 1, Fig. 31)

Trochammina squamata Jones & Parker var. gordialis Jones & Parker, 1860, p. 304.

Glomospira gordialis Jones & Parker. Bartenstein, 1974, p. 686, pl. 2, figs 51-53 (not fig. 54 and pl. 3, figs 1-3.

Glomospira gordialis (Jones & Parker). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 185, pl. 3, fig. 17.

Glomospira gordialis Jones & Parker. Moullade, Kuhnt & Thurow, 1988, pl. 1, fig. 4.

Remarks: G. gordialis is characterised by having a moderately large, subglobular test with an irregularly coiled tube (c. 410/200µm in maximum diameter/height ratio); finely agglutinated wall, with cement of organic and/or siliceous origin; smooth and even test surface.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-24 (rare ocurrence).

Palaeo-environments: middle to lower bathyal.

Genus **GLOMOSPIRELLA** Plummer, 1945

Type species: Glomospira umbilicata Cushman & Waters, 1927

Glomospirella gaultina (Berthelin)

(Pl. 1, Figs 32-35)

Ammodiscus gaultinus Berthelini, 1880, p. 19, pl. 1, fig. 3a-b.

Glomospira gordialis (Jones & Parker) var. diffundens Cushman & Renz, 1946, p. 15, pl. 1, fig. 30.

Glomospira gordialis Jones & Parker. Bartenstein, 1974, p. 686, pl. 2, fig. 54, pl. 3, figs 1-3.

Glomospira sp., Bartenstein, 1974, p. 687, pl. 3, fig. 4.

Glomospirella gaultina (Berthelin). Krasheninnikov, 1974, p. 643, pl. 7, figs 6-7.

Glomospirella gaultina (Berthelin). Magniez-Jannin, 1975, p. 26-27, pl. 1, figs 2-4.

Glomospirella gaultina (Berthelin). Haig, 1980, p. 97-99, pl. 2, figs 5-7, pl. 9, fig. 4.

Glomospirella gaultina (Berthelin). Sliter, 1980, p. 368, pl. 1, figs 11-13(?).

Glomospirella gaultina (Berthelin). Crittenden, 1983a, p. 17, pl. 1, figs 8-9.

Glomospira diffundens (Cushman & Renz). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 185, pl. 3, figs 18-19.

Glomospirella gaultina (Berthelin). Moullade, Kuhnt & Thurow, 1988, pl. 1, fig. 5.

Remarks: This species is characterised by having a compressed discoidal test (varying from c. 310-320µm in maximum diameter, in the lower Albian, to c. 720-730µm, in the upper Campanian-lower Maastrichtian); thin tubular chamber arranged in an initial streptospiral coil, later becoming planispirally coiled, overlapping previous whorls; wall very finely agglutinated, with organic and/or siliceous cement; smooth test surface.

Range: Albian, late Campanian to early Maastrichtian.

Occurrence: wells 1-US-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: deep neritic to upper bathyal (Albian biotopes), middle to lower bathyal (Campanian-Maastrichtian biotopes).

Superfamily **RZEHAKINACEA**

Cushman, 1933

Family **RZEHAKINIDAE** Cushman, 1933

Genus **RZEHAKINA** Cushman, 1927

Type species: Silicina epigona Rzehak, 1895

Rzehakina epigona (Rzehak)

(Pl. 2, Fig. 1)

Silicina epigona Rzehak, 1895, p. 214, pl. 6, fig. 1.

Rzehakina epigona (Rzehak). Cushman, 1927a, p. 115, pl. 23, fig. 4.

Rzehakina epigona (Rzehak). Sliter, 1968, p. 43, pl. 1, fig. 18.

Rzehakina epigona (Rzmhak). Hanzlíková, 1972, p. 38, pl. 4, figs 1-4.

Rzehakina epigona (Rzehak). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 186, pl. 7, figs 6-7.

Remarks: Rzeh. epigona is characterised by an oval to nearly spherical (subcircular) test, fusiform shaped (c. 750/600μm in maxiumum length/width ratio); compressed, with central depression; periphery subacute; two chambers per whorl, planispiral, involute; wall finely agglutinated. with cement of organic and/or siliceous origin.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Rzehakina fissistomata (Grzybowski)

(Pl. 2, Figs 2-4)

Spiroloculina fissistomata Grzybowski, 1901, p.261,pl.7, figs 22-24.

Rzehakina fissistomata (Grzybowski). Hanzlíková, 1972, p. 39, pl. 4, figs 6-10.

Rzehakina fissistomata (Grzybowski). Morgiel & Olszewska, 1981, p.9, pl. 2, fig. 12.

Remarks: This species is distinguished by having a flattened elliptical test (varying from c. 480/340µm to 520/380µm in maximum length/width ratio) , almost planispiral, depressed on both sides; slightly evolute; several coils, of 2 tubular chambers per whorl, partially overlapping previous ones; finely agglutinated wall, with cement of organic and/or siliceous origin. It differs from Spirolocammina sp. A in having an elliptical test with a more symmetrical planispiral coil pattern.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Genus **SILICOSIGMOILINA** Cushman & Church, 1929

Type species: Silicosigmoilina californica Cushman & Church, 1929

Silicosigmoilina californica Cushman & Church

(Pl. 2, Figs 5-6)

Siligosigmoilina californica Cushman & Church, 1929, p. 502, pl. 36, figs 10-12.

Silicosigmoilina californica Cushman & Church. Sliter, 1968, p. 43, pl. 1, figs 13-15.

Silicosigmoilina futabaensis Asano. Beckmann, 1978, p. 769, pl. 1, fig. 2.

Remarks: The species is distinguished by its oval, compressed test (c. 610/270µm in maximum length/width ratio), with sigmoidal chambers; wall finely agglutinated, with organic and/or siliceous cement; smooth surface.

Range: late Campanian to early Maastrichtian.

Occurrence: well 1-SES-24 (rare occurrence).

Palaeo-environments: middle to lower bathyal.

Genus **SPIROLOCAMMINA** Earland, 1934

Type species: Spirolocammina tenuis Earland, 1934

Spirolocammina sp. A

(Pl. 2, Figs 7-8)

Remarks: Spirolocammina sp. A is characterised by an elongate and flattened test (varying from c. 540/240μm to 590/280μm in maximum length/width ratio), sigmoid in outline; coiling nearly planispiral, two tubular chambers per whorl, with a slight sigmoid curve in the long axis; wall thin, very finely aggultinated; smooth test surface.

Range: late Campanian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Superfamily **HORMOSINACEA**

Haeckel, 1894

Family **ASCHEMOCELLIDAE** Vyalov, 1966

Genus **KALAMOPSIS** de Folin, 1883

Type species: Kalamopsis vaillanti de Follin, 1883

Kalamopsis grzybowskii (Dylazanka)

(Pl. 2, Figs 9-10)

Hyperammina grzybowskii Dylazanka, 1923, p. 65-66 (nomen nudum).

Kalamopsis grzybowskii (Dylazanka). Hazlìkovà, 1972, p. 36, pl. 2, fig. 8.

Hyperammina gaultina ten Dam. Bartenstein, 1974, p. 685, pl. 1, figs 9-10, 35-36, pl. 2, fig. 4.

Kalamopsis grzybowskii (Dylazanka). Bartenstein, 1974, p.685, pl. 1, figs 31-34, pl. 2, figs 27-35.

Kalamopsis grzybowskii (Dylazanka). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 1, figs 18-20.

Remarks: K. grzybowskii morphotypes are characterised by large, single-chambered, flattened, elongate fragments (c. 1510-1520μm in maximum length), usually displaying constrictions at one end; very finely agglutinated wall with abundant cement, of organic and/or siliceous origin; smooth and even test surface.

Range: late Coniacian to early-late Santonian.

Occurrence: well 1-SES-24 (rare occurrence).

Palaeo-environments: middle to lower bathyal.

Family **HORMOSINIDAE**
Haeckel, 1894

Subfamily **HORMOSININAE**
Haeckel, 1894

Genus **HORMOSINA** Brady, 1879
Type species: Hormosina globulifera Brady, 1879

Hormosina ex gr. globulifera Brady
(Pl. 2, Figs 11-13)

Hormosina globulifera Brady, 1879, p. 60, pl. 4, figs 4-5.

Hormosina globulifera Brady var. trinitatensis Cushman & Renz, 1946, p. 14, pl. 1, figs 15-19.

Reophax globosus Sliter, 1968, p. 43, pl. 1, fig. 12.

Reophax trinitatensis (Cushman & Renz). Hanzlíková, 1972, p. 37, pl. 3, fig. 10.

Hormosina trinitatensis Cushman & Renz. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 3, fig. 1.

Reophax globosus Sliter. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 3, fig. 4.

Remarks: Specimens of Hormosina ex gr. globulifera are characterised by their uniserial test (varying from c. 1290µm to 2550µm, in maximum length), straight to slightly arcuate; large globular chambers increasing rapidly in size, commonly compressed by compaction, partially overlapping the previous ones; terminal aperture, produced at the end of a distinct tubular neck; wall thick, moderately to coarsely agglutinated, with abundant cement, of organic and/or siliceous origin.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Hormosina ovulum (Grzybowski)

(Pl. 2, Figs 14-16)

Reophax ovulum Grzybowski, 1896, p. 276, pl. 8, figs 19-20.

Hormosina ovulum (Grzybowski). Maslakova, 1955, p. 41, pl. 1, fig. 9.

Hormosina ovulum (Grzybowski) var. *gigantea* Geroch, 1960, p. 43, pl. 2, figs 18-19.

Pelosina caudata (Montanaro-Gallitelli). Hazlíková, 1972, p. 34, pl. 1, figs 2-6.

Hormosina ovulum ovulum (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 186, pl. 2, fig. 10.

Hormosina gigantea Geroch. Moullade, Kuhnt & Thurow, 1988, pl. 2, fig. 11.

Hormosina ovulum (Grzybowski). Moullade, Kuhnt & Thurow, 1988, pl. 2, figs 7-9.

Remarks: This species is characterised by a thick-walled, finely agglutinated test, with subspherical chamber-shape. The specimens are mostly found in unilocular fragments of large size (varying from c. 350µm to 750µm in maximum length, morphotypes of *Hormosina ovulum* var. *gigantea* Geroch).

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-SES-3, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Subfamily **REOPHACINAE** Cushman, 1910

Genus **REOPHAX** de Montfort, 1808

Type species: Reophax scorpiurus de Montfort, 1808

Reophax texanus Cushman & Waters
(Pl. 2, Figs 17-18)

Reophax texanus Cushman & Waters, 1927, p. 82, pl. 10, fig. 2.

Reophax texanus Cushman & Waters. Cushman, 1946, p. 16, pl. 1, figs 18-20.

Reophax hyatti Petri, 1962, p. 44-45, pl. 1, fig. 2.

Reophax sp. 2, Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 187, pl. 3, figs 2-3.

Remarks: Rephax texanus is characterised by having an elongate, straight, uniserial test (varying from c. 1600μm to 2230μm in maximum length); globular embracing chambers, gradually increasing in size; terminal aperture, on a short neck; thick, rather coarsely agglutinated wall. This form resembles specimens of Hormosina ex gr. globulifera Brady, but differs in possessing globular chambers that are smaller, less inflated, more embrancing and increasing gradually in size.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to lower bathyal.

Superfamily **LITUOLACEA**
de Blainville, 1827

Family **HAPLOPHRAGMOIDIDAE** Maync, 1952

Genus **ASANOSPIRA** Takayanagi, 1960

Type species: Lenticulina? teshioensis Asano, 1950

Remarks: This genus differs from Haplophragmoides in its lenticular form, subangular marginal periphery, and rounded rather than lobate equatorial periphery (cf. Loeblich & Tappan, 1988, p. 65).

Asanospira ex gr. glabra (Cushman & Waters), emended
(Pl. 2, Figs 19-22)

Haplophragmoides glabra Cushman & Waters, 1927, p. 83, pl. 10, fig. 6a-b.
Haplophragmoides glabra Cushman & Waters. Cushman, 1946, p. 20, pl. 2, figs 16-17.
Haplophragmoides wilgunyaensis Crespin. Scheibnerová, 1976, p. 39, pl. 4, figs 2, 7, text-fig. 5.
Haplophragmoides(?) jarvisi (Thalmann). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 190, pl. 7, figs 1-2, pl. 10, figs 8-9.

Remarks: Asanospira ex gr. glabra specimens are characterised by having a large, somewhat compressed, lenticular test (varying from c. 800µm to 1490µm in maximum diameter); planispiral and involute; marginal periphery subacute; 8 to 15 chambers (the greatest number of chambers in the largest specimens) in the last whorl, increasing slowly in size; circular equatorial periphery; wall finely agglutinated; smooth test surface. The species' original description is emended here to include specimens with larger size and more chambers than the holotype and paratypes. The morphotypes are similar to Cyclammina Brady and Daxia Cuvillier & Szakall, but there is no evidence of the alveolar subepidermal meshwork of the former. They have less numerous chambers in the last whorl than Daxia and the apertural face, although somewhat obscured, appears to be a simple low interiomarginal arch.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Asanospira walteri (Grzybowski)
(Pl. 2, Figs 23-24)

Trochammina walteri Grzybowski, 1898b, p. 290, pl. 11, fig. 31.
Haplophragmoides excavata Cushman & Waters. Cushman, 1946, p. 21, pl. 2, figs 13-15.

Haplophragmoides walteri (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 190, pl. 5, figs 14-15.

Remarks: Asan. walteri is distinguished by having a very compressed lenticular test (c. 630μm in maximum diameter); planispiral and involute; acute marginal periphery; 7 to 9 chambers in the last whorl, increasing gradually in size; nearly circular equatorial periphery; finely agglutinated wall. It is morphologically similar to Asanospira ex gr. glabra (Cushman & Waters), from which it differs in possessing a smaller test that is more laterally compressed and with fewer chambers in the last whorl. The specimens may eventually be shown to be early ontogenetic stages of the A. glabra species-group, but this could not be properly assessed in this study because of the scarcity of specimens referable to this taxon.

Range: late Santonian.

Occurrence: well 1-CA-1-SE (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **CRIBROSTOMOIDES** Cushman, 1910

Type species: Cribrostomoides bradyi Cushman, 1910

Cribrostomoides ex gr. trinitatensis Cushman & Jarvis

(Pl. 2, Figs 25-27)

Cribrostomoides trinitatensis Cushman & Jarvis, 1928, p.91, pl. 12, fig. 12.

Cribrostomoides cretacea Cushman & Goudkoff, 1944, p. 54, pl. 9, fig. 4.

Cribrostomoides trinitatensis Cushman & Jarvis. Cushman, 1946, p. 22, pl. 3, fig. 3.

Cribrostomoides trinitatensis Cushman & Jarvis. Hanzlíková, 1972, p. 42, pl. 6, figs 2-3.

Cribrostomoides trinitatensis Cushman & Jarvis. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 188, pl. 6, figs 1-2.

Remarks: Specimens of Cribrostomoides ex gr. trinitatensis have a large, involute planispiral test (varying from c. 370/310μm to 710/690μm in maximum diameter/width ratio), sometimes deformed by post-mortem compaction; 5 to 7 chambers in the last whorl, gradually increasing in size; low apertural face, with an areal dentate aperture, usually obscured; rather coarsely agglutinated wall. Larger specimens display a slight tendency towards a spreptospiral coil. Distorted or poorly preserved specimens, with obscured apertural characteristics, are morphologically similar to Haplophragmoides ex gr. bulloides (Beissel) and difficult to distinguish from each other.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Genus **HAPLOPHRAGMOIDES** Cushman, 1910

Type species: Nonionina canariensis d'Orbigny, 1839

Haplophragmoides ex gr. bulloides (Beissel), emended

(Pl. 2, Figs 28-31)

Haplophragmium bulloides Beissel, 1891, p. 17, pl. 2, figs 1-3, pl. 4, figs 24-30.

Haplophragmoides kirki Wickenden. Sliter, 1968, p. 44, pl. 2, fig. 2.

Haplophragmoides eggeri Cushman. Hanzlíková, 1972, p. 40, pl. 5, figs 1-2.

Haplophragmoides impensus Martin. Hanzlíková, 1972, p. 40-41, pl. 5, figs 6-7.

Haplophragmoides kirki Wickenden. Hanzlíková, 1972, p. 41, pl. 5, fig. 4.

Haplophragmoides bulloides (Beissel). Krasheninnikov, 1974, p. 636, pl. 1, figs 9-11.

Haplophragmoides pseudokirki Krasheninnikov, 1974, p. 635-636, pl. 1, fig. 8a-b.

Haplophragmoides sp. cf. bulloides (Beissel). Malumián & Proserpio, 1978, p. 439, pl. 2, figs 1-2.

Haplophragmoides ex gr. suborbicularis (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 189, pl. 5, figs 12-13.

Haplophragmoides bulloides (Beissel). Moullade, Kuhnt & Thurow,1988, pl. 6, figs 3, 7-8.

Remarks: Haplophragmoides ex gr. bulloides is here considered to comprise several morphotypes of common origin (ecophenotypes and ontogenetic polymorphs), which have have been ascribed to several different species by previous authors and are, henceforth, included in the synonomy list of this species-group. The specimens are characterised by large, inflated, nearly spherical planispiral tests (varying from c. 380μm to 910μm in maximum diameter); involute; 5 to 8 chambers in the last whorl, gradually increasing in size; marginal periphery broadly rounded; apertural face low and broadly arched; wall finely or somewhat coarsely agglutinated; post-depositional deformation commonly observed.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Haplophragmoides rugosa Cushman & Waters

(Pl. 2, Figs 32-35)

Haplophragmoides rugosa Cushman & Waters, 1927, p. 83, pl. 10, fig. 4a-b.

Haplophragmoides rugosa Cushman & Waters. Cushman, 1946, p. 20-21, pl. 2, figs 18-19.

Haplophragmoides topagorukensis Tappan. Eicher & Worstell, 1970, p. 280, pl. 1, fig. 12a-b.

Haplophragmoides rugosus Cushman & Waters. Hanzlíková, 1972, p. 41, pl. 5, fig. 8.

Remarks: Hapl'des rugosa is distinguished by having a moderately small, closely coiled, planispiral test (c. 300-320μm in maximum diameter); rounded marginal periphery; 5 to 6 subspherical chambers in the last whorl, rapidly increasing in size; circular equatorial periphery; coarsely agglutinated wall. It differs from Haplophragmoides ex gr. bulloides (Beissel) by its smaller size, more compressed laterally, less numerous chambers in the last whorl, more rapidly increasing in size, and more coarsely agglutinated wall.

Range: late Santonian to Campanian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: upper to middle bathyal.

Family **DISCAMMINIDAE** Mikhalevich, 1980

Genus **DISCAMMINA** Lacroix, 1932

Type species: Discammina fallax Lacroix, 1932

Discammina sp. A

(Pl. 3, Figs 1-5)

Remarks: Specimens of Discammina sp. A are characterised by having a moderately large, planispiral test (varying from c. 360μm to 530μm in maximum diameter), slightly evolute, strongly compressed; aperture a broad low interiomarginal equatorial arch; finely to moderately agglutinated wall. They are similar to morphotypes described by Scheibnerovà (1976) as Ammomarginulina paterella Eicher (p. 46, pl. 6, fig. 2, pl. 7, fig. 1, text-fig. 18), Discammina sp. (p. 41, pl. 5, fig. 5, pl. 6, fig. 1, text-fig. 9) and Haplophragmoides sp. (pl. 4, figs 5-6), and to specimens described as Haplophragmoides collyra Nauss by Eicher (1967, p. 180-181, pl. 17, fig. 9, not fig. 7).

Range: latest Cenomanian.

Occurrence: localities A-9, A-45.

Palaeo-environments: shallow-middle neritic to upper bathyal.

Genus **GLAPHYRAMMINA** Loeblich & Tappan, 1984

Type species: Ammobaculites americanus Cushman, 1910

Glaphyrammina sp. A

(Pl. 3, Figs 6-11)

Remarks: Specimens of Glaphyrammina sp. A are distinguished by having a large, planispiral, discoidal test (c. 520-630μm in maximum diameter), laterally compressed, partially evolute and tending to uncoil in the later stage; 5 to 6 chambers in the last whorl; terminal aperture an elongate narrow, slit-like opening; coarsely agglutinated wall. They are similar to Discammina sp. A morphotypes, but differ in the apertural characteristics and in having coarser agglutinated tests.

Range: late Campanian.

Occurrence: well 1-CA-1-SE (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Family **LITUOTUBIDAE** Loeblich & Tappan, 1984

Genus **TROCHAMMINOIDES** Cushman, 1910

Type species: *Trochammina proteus* Karrer, 1866

Trochamminoides* ex gr. *dubia (Grzybowski)

(Pl. 3, Figs 12-15)

Ammodiscus dubius Grzybowski, 1901, p. 274, pl. 8, figs 12, 14.
Trochamminoides velascoensis Cushman. Hanzliková, 1972, p.44, pl.8, fig. 3.
Trochamminoides dubius (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191, pl. 4, figs 16-17.

Remarks: *Trochamminoides* ex gr. *dubia* morphotypes are characterised by having a large, somewhat compressed, planispiral, evolute test (varying from c. 550µm in maximum diameter, in the lowermost Albian, to c. 1060-1070µm in the upper Santonian), with a circular equatorial periphery; rounded to subacute peripheral margin; moderately to coarsely agglutinated.

Range: earliest Albian, late Santonian.

Occurrence: wells 1-CA-1-SE, 1-US-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Trochamminoides flagleri Cushman & Hedberg

(Pl. 3, Figs 16-21)

Haplophragmoides flagleri Cushman & Hedberg, 1941, p. 82-83, pl. 21, fig. 2a-b.
Haplophragmoides fraseri Wickenden. Trujillo, 1960, p. 305, pl. 43, fig. 6a-b.

Remarks: Specimens of *Trochamminoidesdes flagleri* are distinguished by having a large, planispiral and evolute, discoidal test (varying from c. 520/230µm to 1160/540µm in maximum diameter/width ratio), commonly distorted by compaction; 7 to 9 chambers in the last whorl, increasing gradually in size; marginal periphery broadly rounded; wall finely to coarsely agglutinated. They differ from Trochamminoides dubius (Grzybowski) in possessing more chambers in the last whorl and a discoidal test; from Trochamminoides proteus (Karrer) (Trochamminoides velascoensis Cushman, probably a junior synonym) in their broadly rounded marginal periphery.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: middle to lower bathyal.

Trochamminoides sp. cf. T. subcoronata (Grzybowski)

(Pl. 3, Figs 22-23)

cf. Trochammina subcoronata Grzybowski, 1898b, p. 283-284, pl. 9, fig. 3a-c.

Haplophragmoides coronata Brady. Cushman, 1946, p. 20, pl. 2, figs 20-22.

Trochamminoides irregularis White. Hanzlìková, 1972, p. 44, pl. 8, figs 1-2, pl. 9, fig. 1.

Trochamminoides irregularis White. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191-192, pl. 4, fig. 18.

cf. Trochamminoides subcoronatus (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 192, pl. 4, fig. 19.

Remarks: Rare specimens tentatively assigned to Trochamminoides sp. cf. T. subcoronata were recovered from the Albian. They are characterised by having a large test (varying from c. 600μm to 1010μm in maximum diameter), commonly crushed and distorted by compaction; 5 to 7 flattened globular chambers, in an irregular coiling; rather finely agglutinated wall. The morphotypes differ from Trochamminoides flagleri Cushman & Hedberg in possessing a test strongly distorted, with fewer globular chambers in the last whorl.

Range: Albian.

Occurrence: wells 1-CA-1-SE, 1-US-1-SE.

Palaeo-environment: deep neritic to upper bathyal.

Family **LITUOLIDAE** de Blainville, 1827

Subfamily **AMMOMARGINULININAE** Podobina, 1978

Genus **AMMOBACULITES** Cushman, 1910

Type species: *Spirolina agglutinans* d'Orbigny, 1846

Remarks: The genus is characterised by having an elongate test, rounded in section; planispiral early stage, closely coiled, later uncoiled and straight to somewhat curved; aperture terminal, rounded to slit-like, partially due to post-depositional distortion of tests; wall finely to coarsely agglutinated.

A great variation in test size and shape, number of chambers of the uniserial stage, depression of sutures, and coarseness of the wall texture is found in the assemblages of the area studied. Because of this, broad specific definitions are accepted herein for the genera *Ammobaculites* and *Haplophragmium* Reuss (family Haplophragmiidae).

Ammobaculites* ex gr. *coprolithiformis (Schwager), emended

(Pl. 3, Figs 24-26)

Haplophragmium coprolithiforme Schwager, 1867, p. 654, pl. 34, fig. 3.

Ammobaculites coprolithiformis (Schwager). Cushman, 1946, p. 22-23, pl. 3, figs 7-9.

Ammobaculites junceus Cushman & Applin. Eicher, 1967, p. 181-182, pl. 17, figs 11-12.

Ammobaculites alexanderi Cushman. Hanzlíková, 1972, p. 45, pl. 9, fig. 4.

Ammobaculites coprolithiformis (Schwager). Hanzlíková, 1972, p. 46, pl. 9, fig. 5.

Ammobaculites compositus Magniez-Jannin, 1976, p. 44-45, pl. 1, fig. 27a-b.

Ammobaculites erectus Crespin. Scheibnerová, 1976, p. 44, pl. 7, figs 4-5, text-figs 14-15.

Ammobaculites fisheri Crespin. Scheibnerová, 1976, p. 42, pl. 7, figs 8-10, text-figs 11-12.

Ammobaculites fragmentarius Cushman. Scheibnerová, 1976, p. 45, pl. 7, fig. 11.

Ammobaculites minimus Crespin. Scheibnerová, 1976, p. 44, pl. 6, fig. 6, pl. 7, figs 2-3.

Ammobaculites humei Nauss. Haig, 1980, p. 106-108, pl. 4, figs 4-10, pl. 10, fig. 2.

Ammobaculites obscurus Loeblich. Stelck & Hedinger, 1983, pl. 1, fig. 37, pl. 2, figs 5, 11-12.

Ammobaculites pacalis pattersoni Sutherland & Stelck. Stelck & Hedinger, 1983, pl. 2, fig. 13.

Remarks: Specimens of *Ammobaculites* ex gr. *coprolithiformis* are characterised by having a large elongate test (varying from c. 1300μm to 2880μm in maximum length), sometimes compressed and distorted by compaction; globular, inflated chambers, of uniform width in the uncoiled uniserial stage; coarsely agglutinated wall, with organic and siliceous cement. The synomymy list exemplifies the broad variability of morphotypes here considered to belong to this species group.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to lower bathyal.

Ammobaculites* sp. cf. *A. coprolithiformis (Schwager)

(Pl. 3, Figs 27-28)

cf. *Haplophragmium coprolithiforme* Schwager, 1868, p. 654, pl. 34, fig. 3.

cf. *Ammobaculites fragmentarius* Cushman. Stelck & Hedinger, 1983, pl. 1, figs 33-36, 38-40.

Remarks: Specimens tentatively assigned to *Ammobaculites* sp. cf. *A. coprolithiformis* were recovered from paralic (lagoonal) environments of the uppermost Aptian. The morphotypes are distinguished by having a very large and robust test (c. 1450μm in maximum length); few chambers in the early coiled stage and 3 to 4 much larger inflated globular chambers in the uniserial portion; finely agglutinated wall with organic and calcareous cement.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE.

Palaeo-environments: paralic (lagoonal environments).

Ammobaculites sp. cf. A. fragmentaria Cushman

(Pl. 3, Figs 29–32)

Ammobaculites fragmentaria Cushman, 1927b, p. 130, pl. 1, fig. 8.
Ammobaculites fragmentarius Cushman. Cushman, 1946, p. 23, pl. 3, figs 10–13, 16 (not figs 14–15).

Remarks: Specimens referable to Ammobaculites sp. cf. A. fragmentaria are distinguished by having a large, elongate test, of variable size (varying from c. 630µm to 1070µm in maximum length), commonly compressed by compaction; uniserial stage with chambers increasing gradually or irregularly in size; sutures distinct, depressed; wall coarsely agglutinated; very rough test surface. They differ from A. ex gr. coprolithiformis (Schwager) morphotypes in possessing an irregular chamber growth in the uniserial stage and coarser wall texture.

Range: latest Campanian to early-late Maastrichtian

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Ammobaculites impexus Eicher

(Pl. 3, Figs 33–34)

Ammobaculites impexus Eicher, 1965, p. 895–896, pl. 104, figs 3–5.
Ammobaculites impexus Eicher. Eicher, 1967, p. 181, pl. 17, fig.6a–b.
Ammobaculites impexus Eicher. Abdel-Kireem & Sultan, 1988, p. 265, pl. 2, figs 6, 8–10.

Remarks: Specimens of Ammobaculites impexus are characterised by having a large, elongate test (c. 490–680µm in maximum length); planispiral and evolute early stage, later uncoiled and straight, usually distorted by compaction; early coiled portion greater in width than the later uniserial stage; coarsely agglutinated wall.

Range: latest Cenomanian.

Occurrence: localities A-9, A-46.

Palaeo-environments: shallow-middle neritic to upper bathyal.

Ammobaculites reophacoides Bartenstein

(Pl. 3, Figs 35-36)

Ammobaculites reophacoides Bartenstein, 1952, p. 307, fig. 1.

Ammobaculites reophacoides Bartenstein. Flandrin, Moullade & Porthault, 1961, p. 215-216, pl. 1, fig. 3.

Ammobaculites reophacoides Bartenstein. Bartenstein & Bolli, 1977, p. 546, pl. 1, figs 10-13.

Ammobaculites aff. *reophacoides* Bartenstein. Crittenden, 1983a, p. 20, pl. 2, figs 7-8.

cf. *Ammobaculites subcretaceus* Cushman & Alexander. Crittenden, 1983a, p. 19-20, pl. 2, figs 2-3.

Remarks: *Ammobaculites reophacoides* is characterised by having a large, elongate test (c. 590µm in maximum length), somewhat compressed, with a short early planispiral stage, of about 3 chambers, followed by a high uniserial stage of equal-sized chambers; coarsely agglutinated wall.

Range: late Aptian.

Occurrence: well 7-CP-252-SE (rare occurrence).

Palaeo-environments: shallow to middle neritic.

***Ammobaculites* sp. A**

(Pl. 3, Figs 37-39)

Remarks: *Ammobaculites* sp. A is characterised by having a large, elongate test (c. 460-630µm in maximum length); 4 to 5 chambers in the coil stage, and 3 globular chambers in the uniserial portion, increasing gradually to rapidly in size; wall finely to coarsely agglutinated. The specimens of smaller test size have a more regular chamber growth in the uniserial stage and resemble *Ammobaculites* sp. cf. *A. corprolithiformis* morphotypes.

Range: earliest Albian.

Occurrence: locality A-32.

Palaeo-environment: paralic (lagoonal environment).

Genus **AMMOMARGINULINA** Wiesner, 1931

Type species: Ammomarginulina ensis Wiesner, 1931

Ammomarginulina paterella Eicher

(Pl. 3, Figs 40-41)

Ammomarginulina paterella Eicher, 1967, p. 182, pl. 17, figs 15-16.

Ammomarginulina paterella Eicher. Scheibnerová, 1976, p. 46, text-fig. 18, pl. 7, fig. 1.

Ammomarginulina paterella Eicher. Abdel-Kireem & Sultan, 1988, p. 266, pl. 1, figs 17-18, 20.

Remarks: The species is characterised by having a moderately large, planispiral, evolute, strongly compressed test (c. 310-500μm in maximum diameter); coarsely agglutinated wall.

Range: latest Cenomanian.

Occurrence: locality A-9.

Palaeo-environments: upper bathyal.

Superfamily **HAPLOPHRAGMIACEA**

Eimer & Fickert, 1899

Family **AMMOSPHAEROIDINIDAE** Cushman, 1927

Subfamily **RECURVOIDINAE** Alekseychik-Mitskevich, 1973

Genus **BUDASHEVAELLA** Loeblich & Tappan, 1964

Type species: Circus multicameratus Voloshinova & Budasheva, 1961

Budashevaella nonioninoides (Reuss)

(Pl. 4, Figs 1-3)

Haplophragmium nonioninoides Reuss, 1863, p. 30, pl. 1, fig. 8a-b.

Haplophragmoides nonioninoides (Reuss). Magniez-Jannin, 1976, p. 30-37, pl. 2, figs 9-18, text-fig. 11-12.

Labrospira nonioninoides (Reuss). Haig, 1980, p. 104, pl. 3, figs 12-19.
Haplophragmoides nonioninoides (Reuss). Sliter, 1980, pl. 2, figs 5-6.
Haplophragmoides nonioninoides (Reuss). Crittenden, 1983a, p. 18, pl. 1, figs 17-18.

Remarks: Specimens of Budashevaella nonioninoides are characterised by having a large test (c. 410-430μm in maximum diameter) with an involute streptospiral initial coil, later stage partly evolute and nearly planispiral; 4 to 5 chambers in the last whorl; finely or coarsely agglutinated wall.

Range: late Aptian to early Albian.

Occurrence: wells 1-CA-1-SE, 1-US-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Budashevaella trinitatensis (Cushman & Renz)
(Pl. 4, Figs 4-5)

Haplophragmoides flagleri Cushman & Hedberg var. trinitatensis Cushman & Renz, 1946, p. 18, pl. 2, figs 2-3.
Recurvoides gerochi Hanzlíková, 1972, p. 43, pl. 6, figs 4(holotype)-6.
Budashevaella trinitatensis (Cushman & Renz). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 188-189, pl. 5, fig. 2, pl. 10, figs 2-3.

Remarks: Budashevaella trinitatensis is distinguished by its larger test (c. 900um in maxiumum diameter), with a somewhat more evolute later planispiral stage than B. nonioninoides (Reuss); 6.5 chambers in the last whorl; coarsely agglutinated wall.

Range: late Campanian.

Occurrence: well 1-SES-1A (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **RECURVOIDES** Earland, 1934
Type species: Recurvoides contortus Earland, 1934

Recurvoides ex gr. globulosa (Grzybowski), emended
(Pl. 4, Figs 6-8)

Cyclammina globulosa Grzybowski, 1896b, p. 285, pl. 9, fig. 10a-b.
Cribrostomoides cretaceus Cushman & Goudkoff. Hanzlíková, 1972, p. 42, pl. 6, fig. 1.

Haplophragmoides retroseptus (Grzybowski). Hanzlíková, 1972, p. 41, pl. 5, fig. 5.
Recurvoides deflexiformis (Noth). Hanzlíková, 1972, p. 42, pl. 6, figs 2-3
Recurvoides globulosus (Grzybowski). Hanzlíková, 1972, p. 43, pl.6, fig. 7, pl. 7, figs 1-4.
Recurvoides sp. 1, Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191, pl. 6, fig. 4a-b.
Recurvoides sp. 2, Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191, pl. 6, figs 10-11.
Recurvoides imperfectus Hanzlíková. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191, pl. 6, figs 5-6, pl. 10, fig. 4a-c.

Remarks: Specimens of Recurvoides ex gr. globulosa are characterised by having a spherical to subspherical test, of variable size (varying from c. 520µm to 800µm in maximum diameter), sometimes distorted by compaction; 4 to 7 chambers in the last whorl, arranged in a streptospiral coil; wall moderately to coarsely agglutinated.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Recurvoides sp. cf. R. subturbinata (Grzybowski)

(Pl. 4, Figs 9-10)

Haplophragmium subturbinatum Grzybowski, 1898b, p. 280, pl. 10, fig. 23.
Thalmannammina subturbinata (Grzybowski). Kanzlíková, 1972, p. 43-44, pl. 7, fig. 5.
Thalmannammina walteri (Grzabowski). Hanzlíková, 1972, p. 44, pl. 7, fig. 6.
Recurvoides cf. subturbinatus (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 191, pl. 6, figs 8-9.

Remarks: Specimens of Recurvoides sp. cf. R. subturbinata have a large subspherical test (c. 940/720µm in maximum diameter/breadth ratio); involute streptospiral coiling; 3 to 5 chambers in the last whorl; finely to moderately coarse agglutinated wall. They differ from Recurvoides ex gr.

globulosa (Grzybowski) morphotypes by their large irregular spherical test, with fewer chambers in the last whorl and smoother surface. The species was designated the genotype of Thalmannammina Pokorný, which is probable synonymous with Recurvoides (cf. Kaminski et al., 1988, p. 191).

Range: Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3.

Palaeo-environments: middle to lower bathyal.

Family **HAPLOPHRAGMIIDAE** Eimer & Fickert, 1899

Genus **HAPLOPHRAGMIUM** Reuss, 1860

Type species: Spirolina aequalis Roemer, 1841

Remarks: Haplophragmium is morphologically similar to Ammobaculites Cushman, from which it differs in having an initial streptospiral to trochospiral coil rather than planispiral.

Haplophragmium ex gr. foedissimum (Reuss)

(Pl. 4, Figs 11-13)

Dentalina foedissima Reuss, 1860, p. 45, pl. 3, fig. 23 (fide Hofker, 1957).

Haplophragmium foedissimum (Reuss). Hofker, 1957, p. 25-27, text-figs 9a-c, 10a-c.

Ammobaculites irregulariformis Bartenstein & Brand. Scheibnerová, 1976, p. 43, pl. 6, fig. 5, text-fig. 13.

Haplophragmium swareni Stelck & Hedinger, 1976, p. 135-136, 139-140, pl. 1, figs 8-10, 21-22, pl. 2, figs 2-3.

Haplophragmium swareni Stelck & Hedinger. Stelck & Hedinger, 1983, pl. 2, figs 7-8, 16-18.

Remarks: The morphotypes belonging to the Haplophragmium foedissimum species-group are characterised by having a large, rather elongate test (c. 470-540μm in maximum length); an earlier irregular, streptospiral to trochospiral/nearly planispiral coil, followed by an uniserial stage, straight rectilinear to slightly curved, somewhat distorted by compaction; outline slightly lobate as chambers are somewhat inflated and sutures, on the rectilinear stage, are slightly depressed; initial coiled portion is very low;

aperture a single terminal opening, sometimes producted on an incipient neck; wall rather coarsely agglutinated, with calcareous and organic cement.

Range: earliest Albian.

Occurrence: locality A-32.

Palaeo-environment: paralic (lagoonal environment).

Haplophragmium lueckei (Cushman & Hedberg)

(Pl. 4, Figs 14-16)

Ammobaculites lueckei Cushman & Hedberg, 1941, p. 83, pl.21, fig. 4.

Haplophragmium foedissimum (Reuss), megalospheric form. Hofker, 1957, p. 25-27, text-fig. 11a (?).

Haplophragmium lueckei (Cushman & Hedberg). Hanzlíková, 1972, p. 46, pl. 9, fig. 8.

Haplophragmium engleri Stelck & Hedinger, 1976, p. 140-141, pl. 1, figs 1-5.

Haplophragmium swareni Stelck & Hedinger, 1976, p. 135-136, 139-140, pl. 1, figs 25-26.

Haplophragmium sp. cf. *H. swareni* Stelck & Hedinger, 1976, p. 140, pl. 1, figs 15-16, 23-24, 27-28, pl. 2, fig. 6.

Haplophragmium engleri Stelck & Hedinger. Stelck & Hedinger, 1983, pl. 2, figs 3-4, 6, 14-15.

Haplophragmium swareni Stelck & Hedinger. Stelck & Hedinger, 1983, pl. 1, figs 31-32.

Bulbobaculites lueckei (Cushman & Hedberg). Loeblich & Tappan, 1988, p. 83-84, pl. 70, figs 14-16.

Remarks: Specimens of *Haplophragmium lueckei* are characterised by having a very large test (varying from c. 2140µm to 2810µm in maximum length), with few chambers in the coiled portion and inflated globular chambers in the uniserial stage; finely agglutinated wall, with calcareous and organic cement.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE.

Palaeo-environment: paralic (lagoonal environment).

Family **NEZZAZATIDAE** Hamaoui & Saint-Marc, 1970

Subfamily **NEZZAZATINAE** Hamaoui & Saint-Marc, 1970

Genus **TROCHOSPIRA** Hamaoui, 1965

Type species: Trochospira avnimelechi Hamaoui, 1965

Remarks: Genus known from the Cenomanian of the Middle East (Lebanon, Israel, Iran) - (cf. Loeblich & Tappan, 1988, p. 87).

Trochospira(?) sp. A

(Pl. 4, Figs 17-19)

Remarks: Rare specimens tentatively assigned to Trochospira (?) sp. A were recovered from the upper Santonian-lower Campanian section. They are characterised by having a large, plano-convex, trochospiral test (c. 520-630μm in maximum diameter); flattened trochospire and slightly convex ventral side; numerous chambers in the last whorl; digitate chamber interior; very finely agglutinated wall.

Range: late Santonian to early Campanian.

Occurrence: well 1-SES-9 (rare ocurence).

Palaeo-environments: upper to middle bathyal.

Superfamily **CYCLOLINACEA**
Loeblich & Tappan, 1964

Family **CYCLAMMINIDAE** Marie, 1941

Subfamily **BUCCICRENATINAE** Loeblich & Tappan, 1955

Genus **BUCCICRENATA** Loeblich & Tappan, 1949

Type species: Ammobaculites subgoodlandensis Vanderpool

Buccicrenata sp. cf. B. libyca Gohrbandt

(Pl. 4, Figs 20-25)

Buccicrenata libyca Gohrbandt, 1966, p. 67-68, pl. 1, figs 11-16.

Remarks: Rare specimens, tentatively assigned to Buccicrenata sp. cf. B. libyca, were recovered from the uppermost Aptian. They are distinguished by their laterally compressed test, of variable size (varying from c. 1000-1560μm in maximum diameter, in the upper Aptian, to 300-370μm in the lowermost Albian) with a planispiral, involute, stage, later tending to uncoil; 4 to 5 chambers in the last coil, with a reduced uniserial stage of 1 or 2 chambers; aperture elongate, terminal, and irregular slit-like; wall finely agglutinated, with calcareous and organic cement (cf. Loeblich & Tappan, 1988). The morphotypes are similar to Buccicrenata libyca described from the Cenomanian of northwestern Libya. They differ from B. subgoodlandensis (Vanderpool), described from the Albian of North America (Loeblich & Tappan, 1949) and of the Central Oman mountains (Simmons & Hart, 1987), and from B. australis (Howchin), described from the Aptian-Albian of the Great Australian Basin (Scheibnerovà, 1976, p. 47, text-fig. 19, pl. 8, figs 1-4), by having generally smoother surface, less compressed test and broad, crescent-shaped rather than petaloid chambers. Because of the scarcity of the recovered specimens the precise taxonomic atribution of the present species is uncertain, and it may eventually be shown that they represent a different species.

Range: late Aptian to earliest Albian.

Occurrence: locality A-32, well 1-CA-1-SE.

Palaeo-environment: paralic (lagoonal environment).

Subfamily **ALVEOLOPHRAGMIINAE** Saidova, 1981

Genus **ALVEOLOPHRAGMIUM** Shchedrina, 1936

Type species: Alveolophragmium orbiculatum Shchedrina, 1936

Alveolophragmium sp. A

(Pl. 4, Figs 26-27)

Remarks: Alveolophragmium sp. A is characterised by having a large, involute, planispiral test (varying from c.1200μm to 1910μm in maximum diameter), commonly distorted by compaction; 8 to 10 chambers in the last whorl; marginal periphery broadly rounded; circular equatorial periphery; coarsely agglutinated wall with alveolar subepidermal layer.

Range: latest Campanian to early-late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Superfamily **SPIROPLECTAMMINACEA**

Cushman, 1927

Family **SPIROPLECTAMMINIDAE** Cushman, 1927

Subfamily **SPIROPLECTAMMININAE** Cushman, 1927

Genus **QUASISPIROPLECTAMMINA** Loeblich & Tappan, 1982

Type species: Spiroplectammina nuda Lalicker, 1935

Remarks: This genus differs from Spiroplectammina Cushman in having an early planispiral coil that is of lesser diameter than the succeeding first few pairs of biserial chambers, whereas in Spiroplectammina the coiled stage is larger (Loeblich & Tappan, 1982, p. 60).

Quasispiroplectammina ex gr. alexanderi (Lalicker)

(Pl. 4, Figs 28-29)

Spiroplectammina alexanderi Lalicker, 1935, p. 1, pl. 1, figs 1a-c.

Spiroplectammina linki Petri, 1962, p. 47-48, pl. 1, fig. 5 (not fig. 4).

Quasispiroplectammina alexanderi (Lalicker). Loeblich & Tappan, 1982, p. 60, pl. 1, figs 11-17.

Remarks: Specimens of *Quasispiroplectammina* ex gr. *alexanderi* are distinguished by having a small, elongate, slightly tapering test (c. 360-370µm in maximum length); minute, compressed, early planispiral coil, usually indistinct and sometimes broken off, followed by a short biserial stage of somewhat inflated chambers, increasing slowly to gradually in size; rounded to oval peripheral margin in cross section; wall rather coarsely agglutinated.

Range: late Aptian to middle Albian.

Occurrence: localities A-15, A-38, wells 1-CA-1-SE, 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow to middle neritic.

Quasispiroplectammina* sp. cf. *Q. anceps (Reuss)

(Pl. 4, Fig. 30)

Textularia anceps Reuss, 1860, p. 234, pl. 13, fig. 2.

Spiroplectammina anceps (Reuss). Hofker, 1957, p. 60, text-figs 56a-d.

Remarks: Specimens referable to *Quasispiroplectammina* sp. cf. *Q. anceps* are characterised by having an elongate, slightly tapering test, of medium size (c. 500µm in maximum length); minute, compressed, early planispiral coil, usually indistinct and sometimes broken off, followed by a long biserial stage of chambers increasing gradually in size; subacute to somewhat rounded peripheral margin in cross section; wall finely agglutinated.

Range: late Aptian to middle Albian.

Occurrence: locality A-15, well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Quasispiroplectammina* ex gr. *goodlandana (Lalicker)

(Pl. 4, Fig 31-32)

Spiroplectammina goodlandana Lalicker, 1935, p. 2, pl. 1, figs 2-3.

Spiroplectammina lalickeri Albritton & Phleger. Cushman, 1946, p. 29, pl. 6, figs 28-29.

(?) *Spiroplectinata lata* Grabert. Gradstein, 1978, p. 675-676, pl. 2, figs 1-3, 6-7 (? not figs 4-5, 8).

Quasispiroplectammina goodlandana (Lalicker). Loeblich & Tappan, 1982, p. 60, pl. 1, figs 31-33.

Remarks: *Quasispiroplectammina* ex gr. *goodlandana* is characterised by its elongate, compressed test (varying from c. 260µm to 430µm in maximum length), which has an early minute planispiral stage that is often broken off. This is followed by a flaring biserial portion; ovate outline in cross section with narrowly rounded periphery margin; wall finely agglutinated. It differs from *Quasispiroplectammina* ex gr. *alexanderi* (Lalicker) by possessing a more compressed and elongate test, with a flaring biserial portion.

Range: late Aptian to middle Albian.

Occurrence: localities A-15, A-32, A-38, wells 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic.

Quasispiroplectammina linki (Petri)

(Pl. 4, Figs 33-34)

Spiroplectammina linki Petri, 1962, p. 47-48, pl. 1, fig. 4 (not fig. 5).

Remarks: Specimens of *Qasispiroplectammina linki* are characterised by possessing a large, elongate, slightly tapering test (c. 400-530µm in maximum length); minute, compressed, early coil, usually indistinct, followed by a biserial stage of inflated chambers, increasing gradualy in size, sometimes slightly twisted; rounded peripheral margin in cross section; wall finely agglutinated. It differs from *Quasispiroplectammina* ex gr. *alexanderi* (Lalicker) in its larger and more elongate test; from *Quasispiroplectammina* sp. cf. *Q. anceps* (Reuss) and *Quasispiroplectammina* ex gr. *goodlandana* (Lalicker) in having more inflated chambers in the biserial stage, with a rounded peripheral margin in cross section. The paratype illustrated by Petri (1962, pl. 1, fig. 5) is rather referable to *Quasispiroplectammina* ex gr. *alexanderi* (see above), as it has a much smaller, less elongate and more compressed test.

Range: late Aptian to middle Albian.

Occurrence: locality A-15, well 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Quasispiroplectammina navarroana (Cushman)

(Pl. 4, Figs 35-36)

Spiroplectammina navarroana Cushman, 1932, p. 96, pl. 11, fig. 14.
Spiroplectammina navarroana Cushman. Cushman, 1946, p. 27, pl. 5, figs 13-14.
Spiroplectammina regoi Petri, 1962, p. 48-49, pl. 1, fig. 6a-b.
Spiroplectammina navarroana Cushman. Hanzlíková, 1972, p. 47, pl. 10, figs 6-7 (not fig. 5).

Remarks: *Quasispiroplectammina navarroana* morphotypes are distinguished by their large, elongate, slightly tapering test, of variable size (varying from c. 600µm to 980µm in maximum length); minute, compressed, commonly indistinct, early planispiral coil, followed by a biserial stage of broad, somewhat inflated chambers, increasing slowly to gradually in size; rounded peripheral margin in cross section; slightly depressed sutures, nearly transverse; wall rather coarsely agglutinated. The early coiled stage is usually broken off. The specimens differ from *Q. linki* (Petri) in having larger and more elongate tests, with more inflated, globular-shaped last chambers in the biserial stage.

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Genus **SPIROPLECTAMMINA** Cushman, 1927

Type species: *Textularia agglutinans* d'Orbigny

Spiroplectammina chicoana Lalicker

(Pl. 4, Figs 37-38)

Spiroplectammina chicoana Lalicker, 1935, p. 7; pl. 1, figs 8-9.
Spiroplectammina chicoana Lalicker. Trujillo, 1960, p. 310, pl. 44, fig. 6a-b.
Spiroplectammina chicoana Lalicker. Sliter, 1968, p.46, pl. 2, fig.8.
Spiroplectammina sp. aff. *S. dentata* (Alth). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 192, pl. 7, fig 10 (not fig. 11).

Remarks: Specimens of Spiroplectammina chicoana are characterised by their large, compressed, elongate, tapering test (varying from c. 440/200µm to 530/240µm in maximum length/width ratio); early planispiral coil, distinct; biserial stage with low, broad chambers, rapidly increasing in breadth; irregular periphery outline; wall rather finely agglutinated.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Spiroplectammina laevis (Roemer)

(Pl. 4, Figs 39–40)

Textularia laevis Roemer, 1841, p. 97, pl. 15, fig. 17.

Spiroplectammina laevis (Roemer) var. cretosa. Cushman, 1946, p. 27–28, pl. 6, figs 1-3.

Spiroplectammina laevis (Roemer). Hofker,1957, p.61–62, figs 58a–f.

Spiroplectammina laevis (Roemer). Sliter, 1968, p. 46, pl. 1, fig. 9.

Spiroplectammina cretosa Cushman. Hanzlíková, 1972, p. 47, pl. 10, fig. 9.

Remarks: Spiroplectammina laevis is distinguished by its tapering compressed test (varying from c. 290/190µm to 770/520µm in maximum length/width ratio); early planispiral stage, later biserial, with slightly inflated, low and broad chambers, increasing rapidly in size; sutures distinct, gently curved to horizontal; periphery subacute to acute; wall finely agglutinated.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CN-1-SE, 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to lower bathyal.

Spiroplectammina sigmoidina Lalicker

(Pl. 5, Figs 1–2)

Spiroplectammina sigmoidina Lalicker, 1935, p. 7, pl. 1, figs 10–11.

Spiroplectammina semicomplanata (Carsey) var. juncea Cushman. Cushman, 1946, p. 29, pl. 6, fig. 15.

Spiroplectammina sigmoidina Lalicker. Sliter, 1968, p. 46, pl. 2, fig. 12.

Bolivinopsis spectabilis (Grzybowski). Hanzlíková, 1972, p. 48, pl. 10, fig. 8.

Spiroplectammina sigmoidina Lalicker. Sliter, 1977b, pl. 2, fig. 3 (not fig. 2)

Spiroplectammina spectabilis (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 193, pl. 7, fig. 18 (not figs 16-17).

Remarks: Specimens of Spiroplectammina sigmoidina have a very elongate, compressed, slender test (varying from c.840/230µm to 870/250µm in maximum length/width ratio); early small planispiral coil, followed by a long biserial stage of chambers that increase slowly in size, with nearly parallel sides; subacute to acute peripheral margin in cross section; wall finely agglutinated. It differs from S. chicoana Lalicker in its narrower, elongate, test and smooth rather than lobate periphery.

Range: latest Campanian to early Maastrichtian.

Occurrence: well 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Spiroplectammina ex gr. spectabilis (Grzybowski)

(Pl. 5, Figs 3-4)

Spiroplecta spectabilis Grzbowski, 1898b, p. 293, pl. 12, fig. 12.

Spiroplectammina mordensis Wickenden. Cushman, 1946, p. 28, pl. 6, fig. 4.

Spiroplectammina regularis Hofker, 1957, p. 58-59, figs 54a-k.

Spiroplectammina regularis Hofker. Beckmann, 1978, p. 769, pl. 1, fig. 6.

(?) Spiroplectammina cf. semicomplanata (Carsey). Beckman, 1978, p. 769, pl. 1, fig. 7 (not fig. 13).

Spiroplectammina spectabilis (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 193, pl. 7, figs 16-17 (not fig. 18).

Remarks: Spiroplectammina ex gr. spectabilis morphotypes are characterised by having a somewhat compressed, elongate test (varying from c. 590/210µm to 770/430µm in maximum length/width ratio); well developed early planispiral coil, followed by nearly parallel sided biserial stage, almost rectangular; wall moderately to finely agglutinated.

Range: early-late Maastrichtian.

Occurrence: well 1-SES-1A.

Palaeo-environments: upper to middle bathyal.

Superfamily **TROCHAMMINACEA**
Schwager, 1877

Family **TROCHAMMINIDAE** Schwager, 1877

Subfamily **TROCHAMMININAE** Schwager, 1877

Genus **AMMOGLOBIGERINA** Eimer & Fickert, 1899

Type species: Ammoglobigerina bulloides Eimer & Fickert, 1899 = Lituola nautiloidea Lamarck var. globigeriniformis Parker & Jones, 1865

Ammoglobigerina ex gr. globigeriniformis (Parker & Jones)
(Pl. 5, Figs 5-7)

Lituola globigeriniformis Parker & Jones, 1865, p. 407, pl. 15, figs 46-47, pl. 17, figs 96-98.

Trochammina globigeriniformis (Parker & Jones). Cushman, 1946, p. 51, pl. 15, 8, 10-11.

Trochammina globigeriniformis Cushman (non Parker & Jones). Hanzlíková, 1972, p. 50, pl. 10, fig. 12a-c.

Trochammina globigeriniformis altiformis Cushman & Renz. Krasheninnikov, 1974, p. 641-642, pl. 6, figs 4-5.

Trochammina ex gr. bulloides (Parker & Jones). Malumián & Proserpio, 1978, p. 411, pl. 2, figs 9-10.

Remarks: Specimens of Ammoglobigerina ex gr. globigeriniformis are characterised by having a large trochospiral test (varying from c. 640/520μm to 680/530μm in maximum diameter/breadth), which is usually crushed by compaction; 4 subglobular to broadly oval chambers in ventral view, increasing rapidly in size; depressed sutures, almost straight; narrow and small umbilicus; lobate equatorial periphery; moderately to coarsely agglutinated wall.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to lower bathyal.

Genus **TROCHAMMINA** Parker & Jones, 1859

Type species: Nautilus inflatus Montagu, 1859

Trochammina gatesensis Stelck & Wall
(Pl. 5, Figs 8-10)

Trochammina gatesensis Stelck & Wall, 1955, p.53, pl. 4, figs 9-11.
Trochammina gatesensis Stelck & Wall. Eicher, 1967, p. 183, pl. 18, fig. 11a-c.

Remarks: The specimens are distinguished by their large, compressed, trochospiral test (c. 530-540µm in maximum length); 6 to 7 chambers in ventral view; sutures depressed and radial to slightly curved on the umbilical side; lobate equatorial periphery; wall moderately to coarsely agglutinated.

Range: late Santonian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Trochammina ex gr. minuta Crespin
(Pl. 5, Figs 11-12)

Trochammina minuta Crespin, 1953, p. 32, pl. 5, figs 19a-b.

Trochammina minuta Crespin. Scheibnerovà, 1974a, p. 710, pl. 1, figs 18-20, pl. 10, figs 9-10.
Trochammina aff. lattai Loeblich & Tappan. Magniez-Jannin, 1975, p. 60-61, pl. 4, figs 21-29.
Trochammina aff. wetteri Stelck & Wall. Magniez-Jannin, 1975, p. 57-60, pl. 4, figs 1-8, 19-20 (? figs 9-18).
Trochammina minuta Crespin. Scheibnerovà, 1976, p. 54, pl. 15, figs 4-8, pl. 16, figs 1-3, text-fig. 37.
Trochammina minuta Crespin. Haig, 1980, p. 117-118, pl. 6, figs 8-10, pl. 11, fig. 6.
Trochammina umiatensis Tappan. Sliter, 1980, pl. 4, figs 1-2, 6-7.

Remarks: Trochammina ex gr. minuta morphotypes are distinguished by their trochospiral test (c. 570-580µm in maximum diameter) which is commonly compressed; 4 to 5 globular chambers in ventral view; sutures depressed and radial; circular equatorial periphery; wall rather finely agglutinated.

Range: late Aptian.

Occurrence: wells 1-CN-1-SE, 1-US-1-SE (rare occurrence).

Palaeo-environments: middle to deep neritic.

***Trochammina* sp. A**

(Pl. 5, Figs 13-16)

Remarks: Specimens of *Trochammina* sp. A have a small, strongly compressed and distorted trochospiral test (varying from c. 360µm to 580µm in maximum diameter); 4 to 5 chambers; wall thin and moderately coarsely agglutinated. Preservation characteristics prevents the precise taxonomic attribution of the morphotypes. The closest morphological affinity, however, appears to be with *Trochammina* ex gr. *depressa* Lozo, but with fewer chambers in the last whorl.

Range: latest Cenomanian to earliest Turonian.

Occurrence: localities A-9, A-35.

Palaeo-environments: deep neritic to upper bathyal.

Superfamily **VERNEUILINACEA** Cushman, 1911

Family **VERNEUILINIDAE** Cushman, 1911

Genus **EGGERELLINA** Marie, 1941

Type species: *Bulimina* *brevis* d'Orbigny, 1840

Eggerellina* *mariae ten Dam

(Pl. 5, Figs 17-18)

Eggerellina *mariae* ten Dam, 1950, p. 15, pl. 1, figs 17a-e.
Eggerellina *mariae* ten Dam. Magniez-Jannin, 1975, p. 94, pl. 6, figs 12-21.
Eggerellina *mariae* ten Dam. Carter & Hart, 1977, p. 17, pl.2, fig.7.
Eggerellina *mariae* ten Dam. Hart *et* *al.*, 1981, p. 176, pl. 7.2, figs 1-2.
Eggerellina *mariae* ten Dam. Hart *et* *al.*, 1989, p. 318, pl. 7.2, figs 1-2.

Remarks: Specimens of *Eggerellina* *mariae* are characterised by their small, triserial test (varying from c. 310/260µm to 330/280µm in maximum length/breadth ratio), with inflated, subglobular chambers which increase rapidly in size (c. 280-290µm in maximum width); aperture a narrow vertical hooklike slit extending up the apertural face; wall finely agglutinated.

Range: late Aptian to early Albian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: middle to deep neritic.

Genus **GAUDRYINOPSIS** Podobina, 1975

Type species: Gaudryina vulgaris Kipriyanova, 1960

Remarks: The genus differs from Gaudryina d'Orbigny in its early triserial stage which is rounded in section; from Verneuilinoides Loeblich & Tappan in the later biserial stage; from Dorothia in having only three chambers per whorl in the early stage (cf. Loeblich & Tappan, 1988, p. 133).

Gaudryinopsis filiformis (Berthelin)

(Pl. 5, Figs 19-20)

Gaudryina filiformis Berthelin, 1880, p. 25, pl. 1, figs 8a-d.
Dorothia filiformis (Berthelin). Cushman, 1937, p.73, pl.8, figs 1-2.
Dorothia filiformis (Berthelin). Bartenstein, Bettenstaedt & Bolli, 1966, p. 144, pl. 1, fig. 43.
Dorothia filiformis (Berthelin). Magniez-Jannin, 1975, p. 83-86, pl. 8, figs 1-2, text-fig. 34.
Gaudryina bevissensis Ludbrook. Scheibnerová, 1976, p. 60, pl. 21, figs 5-6.
Dorothia filiformis (Berthelin). Carter & Hart, 1977, p. 7, pl. 1, fig. 3.
Gaudryina filiformis Berthelin. Haig, 1980, p. 120-121, pl. 8, figs 1-5, pl. 11, fig. 2.
Dorothia filiformis (Berthelin . Hart et al., 1981, p. 174, pl. 7.1, figs 11-12.
Dorothia filiformis (Berthelin . Hart et al., 1989, p. 316, pl. 7.1, figs 11-12.

Remarks: Specimens of Gaudryinopsis filiformis are characterised by having a narrowly elongate, slender test (varying from c. 470/130µm to

620/150µm in maximum length/breadth ratio), commonly compressed by compaction; triserial early portion of few chambers, followed by a long biserial stage of globular and inflated chambers, increasing slowly in size; rounded to ovoid peripheral margin in cross section throughout; wall moderately to coarsely agglutinated. The species is here assigned to Gaudryinopsis following the usage of Loeblich & Tappan (op. cit., see above).

Range: late Aptian to middle Albian.

Occurrence: localities A-15, A-38, wells 1-CA-1-SE, 1-US-1-SE.

Palaeo-environments: middle to deep neritic.

Gaudryinopsis glabrata (Cushman)

(Pl. 5, Figs 21-23)

Dorothia glabrata Cushman, 1933b, p. 56, pl. 6, fig. 10.
Gaudryina glabrata (Cushman). Sliter, 1968, p. 48, pl. 3, figs 4-5.

Remarks: Gaudryinopsis glabrata is characterised by having a slightly tapering, elongate test (varying from c. 350µm to 1130µm in maximum length); early triserial stage, subtriangular in cross section, followed by a short biserial portion of moderately inflated, overlapping chambers, increasing rapidly in width; wall rather coarsely agglutinated.

Range: middle to late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to lower bathyal.

Gaudryinopsis sp. cf. gradata (Berthelin)

(Pl. 5, Figs 24-27)

cf. Gaudryina gradata Berthelin, 1880, p. 24, pl. 1, figs 6a-c.
cf. Gaudryina dispansa, Chapman, 1892, p. 753, pl. 11, fig. 10a-b.
cf. Dorothia gradata (Berthelin). Magniez-Jannin, 1975, p. 86-87, pl. 8, figs 3-6, text-fig. 38.
Gaudryina sp. cf. G. gradata Berthelin. Haig, 1980, p. 122, pl. 8, figs 21-24.
Gaudryina gradata Berthelin. Crittenden, 1983a, p. 22, pl. 2, fig. 21.
cf. Gaudryinopsis gradata (Berthelin). Loeblich & Tappan, 1988, p. 36, pl. 140, figs 28-29.

Remarks: Specimens referable to Gaudryinopsis sp. cf. G. gradata are distinguished by having an elongate and narrow test (c. 420-660µm in maximum length) of nearly parallel sides; short early triserial portion, followed by an elongate biserial stage of subglobular chambers, increasing slowly in size; test rounded to ovoid in cross section thoroughout; wall finely agglutinated. The species is here assigned to Gaudryinopsis following the usage of Loeblich & Tappan (op. cit., see above). Distorted specimens (see Pl. 5, Figs 26-27), probably by post-mortem compaction, are commonly observed (similar to the morphotypes described as Gaudryina dispansa by Chapman, op. cit.).

Range: early to middle Albian.

Occurrence: locality A-15, wells 1-CN-1-SE, 1-US-1-SE, 1-SES-9.

Palaeo-environments: middle to deep neritic.

Subfamily **VERNEUILININAE** Cushman, 1911

Genus **GAUDRYINA** d'Orbigny, 1839

Type species: Gaudryina rugosa d'Orbigny, 1840

Gaudryina laevigata Franke

(Pl. 5, Figs 28-31)

Gaudryina laevigata Franke, 1914, p. 431, pl. 27, figs 1-2.
Gaudryina laevigata Franke. Cushman, 1946, p. 33, pl. 8, fig. 4.
Gaudryina pyramidata Cushman. Trujillo, 1960, p.308, pl. 44, fig. 9.
Gaudryina laevigata Franke. Sliter, 1968, p. 48, pl. 3, fig. 8.
Gaudryina laevigata Franke. Sliter, 1977b, pl. 2, fig. 8.

Remarks: Gaudryina laevigata has an large, elongate, tapering test (varying from c. 920µm to 1530µm in maximum length); early triserial portion, sharply triangular in cross section with subacute angles, later biserial stage of inflated and overlapping chambers, subrectangular in section; aperture an arch at the inner margin of the last chamber; wall finely agglutinated.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to lower bathyal.

Gaudryina pyramidata Cushman

(Pl. 5, Figs 32)

Gaudryina laevigata Franke var. pyramidata Cushman, 1926b, p. 587, pl. 16, fig. 8.

Gaudryina pyramidata Cushman. Sliter, 1968, p.48-49, pl. 3, fig. 9.

Gaudryina carinata Franke. Hanzlíková, 1972, p. 51, pl. 11, fig. 4.

Gaudryina pyramidata Cushman. Sliter, 1977b, pl. 2, fig. 9.

Gaudryina pyramidata Cushman. Beckmann, 1978, p. 766, pl. 1, figs 9-10.

Gaudryina pyramidata Cushman. Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 194, pl. 8, fig. 7.

Remarks: Specimens of Gaudryina pyramidata are distinguished by having a moderately elongate, tapering test (c. 680/530µm in maximum length/breadth ratio), sharply triangular in cross section with acute angles; early portion triserial, rapidly increasing in size, followed by a short biserial stage with slightly inflated chambers; aperture a low interiomarginal arch; wall finely agglutinated.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Genus **PSEUDOGAUDRYINELLA** Cushman, 1936

Type species: Gaudryinella capitosa Cushman

Remarks: This genus differs from Gaudryina d'Orbigny in its later uniserial portion, and from Tritaxia by possessing an intermediate biserial stage.

Pseudogaudryinella ex gr. capitosa (Cushman)

(Pl. 5, Figs 33-34)

Gaudryinella capitosa Cushman, 1933b, p. 52, pl. 5, fig. 8a-c.

Pseudogaudryinella colombiana Cushman & Hedberg, 1941, p. 84-85, pl. 21, figs 9-10.

Pseudogaudryinella capitosa (Cushman). Cushman, 1946, p. 40, pl. 10, figs 15-19.

Pseudogaudryinella capitosa (Cushman) var. serrulata (Cushman). Cushman, 1946, p. 40, pl. 10, figs 20-23.

Tritaxia capitosa (Cushman). Hanzlíková, 1972, p. 54, pl. 12, fig. 2.

Tritaxia capitosa (Cushman). Beckmann, 1978, p. 769, pl. 1, fig. 11.

Remarks: Pseudogaudryinella ex gr. capitosa specimens are distinguished by having a large, elongate test (c. 980-1050µm in maximum length); early triserial stage, triangular in cross section, followed by a biserial portion of broad chambers, later stage uncoiled, uniserial, with inflated globular chambers, circular in cross section; aperture small, rounded, terminal in the uniserial stage; wall moderately coarsely agglutinated.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CRL-1-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Genus **SPIROPLECTINATA** Cushman, 1927

Type species: Textularia annectens Parker & Jones, 1863

Pseugaudryinella-Spiroplectinata plexus

Remarks: Specimens assigned to this plexus show considerable variation in morphology (either triserial-biserial or triserial-biserial-uniserial) and test size. The specimens from Sergipe fall within the plexus of Pseugaudryinella ex gr. dividens-Spiroplectinata of Aptian-Albian age (sensu Gradstein, 1978, p. 675).

Pseudogaudryinella/Spiroplectinata ex gr. dividens (Grabert)

(Pl. 5, Figs 35-37)

Tritaxia D4 Hecht (Gaudryina cf. alexanderi Cushman). Bettenstaedt & Wicher, 1955, p. 504, pl. 4, figs 23-25.

Gaudryina dividens Grabert, 1959, p. 9, pl. 1, figs 3-5, pl. 2, figs 16-30, pl. 3, figs 53-59.

Gaudryina dividens Grabert. Bartenstein, Bettenstaedt & Bolli, 1966, p. 141, pl. 1, figs 56-57.

Gaudryina aff. dividens Grabert. Magniez-Jannin, 1975, p. 66-67, p. 5, figs 1-4.
Gaudryina dividens Grabert. Gradstein, 1978, p. 675-678, pl. 2, figs 16-18.
Gaudryina dividens Grabert var. reicheli Bartenstein. Gradstein, 1978, p. 675-678, pl. 2, figs 14-15.

Remarks: Specimens of Pseudogaudryinella/Spiroplectinata ex gr. dividens are characterised by having a large, elongate test (c. 760-900μm in maximum length), with an early, small, triserial stage, followed by a biserial and later uniserial chamber arrangement; tests usually deformed by compaction; wall finely agglutinated. The morphotypes are similar to the late Cretaceous Pseudogaudryinella ex gr. capitosa (Cushman), but differ in having a smaller test size (usually distorted), with a small and less sharply angled triserial portion.

Range: early Albian.

Occurrence: wells 1-CA-1-SE, 1-US-1-SE, 1-SES-9.

Palaeo-environments: middle to deep neritic.

Genus **VERNEUILINA** d'Orbigny, 1839

Type species: Verneuilina tricarinata d'Orbigny, 1840

Verneuilina cretacea Karrer

(Pl. 5, Figs 38-40)

Verneuilina cretacea Karrer, 1870, p. 164, pl. 1, fig. 1 (fide Krasheninnikov, 1974, p. 643).
Verneuilina cretacea Karrer. Krasheininnikov, 1974, p. 643, pl. 7, fig. 1a-c.

Remarks: The species is distinguished by its moderately large, pyramidal triserial test (varying from c. 340/290μm to 380/320μm in maximum length/breadth ratio), that is triangular in cross section; trapeziform chambers increasing very rapidly in width; slight concave lateral sides; subacute to acute peripheral margins in cross section; wall very finely agglutinated.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-24.

Palaeo-environments: upper to middle bathyal.

Verneuilina cretosa Cushman

(Pl. 5, Figs 41)

Verneuilina cretosa Cushman, 1933a, p. 31, pl. 5, fig. 7a-b.
Verneuilina cretosa Cushman. Cushman, 1946, p. 31, pl. 7, fig. 7.

Remarks: Specimens of *Verneuilina cretosa* are characterised by their large, elongate, triserial test (c. 990µm in maximum length); numerous chambers in a triserial arrangement throughout, increasing gradually in size; triangular outline in cross section, with acute angles and serrate periphery; wall finely to moderately agglutinated.

Range: latest Campanian to early-late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Family **TRITAXIIDAE** Plotnikova, 1979

Genus **TRITAXIA** Reuss, 1860

Type species: *Textularia tricarinata* Reuss, 1844

Tritaxia ellisorae Cushman

(Pl. 6, Figs 1-2)

Tritaxia ellisorae Cushman, 1936a, p. 5, pl. 1, fig. 9a-b.
Tritaxia ellisorae Cushman. Cushman, 1946, p. 32, pl. 7, figs 10-11.

Remarks: *Tritaxia ellisorae* morphotypes are distinguished by having a large, elongate test (c. 860-910µm in maximum length), triangular in cross section throughout; triserial early stage with carinate angles, followed by a few uniserial chambers; terminal aperture, usually broken or indistinct because of recrystallization; wall moderately to coarsely agglutinated.

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Superfamily **ATAXOPHRAGMIACEA** Schwager, 1877

Family **ATAXOPHRAGMIIDAE** Schwager, 1877

Subfamily **ATAXOPHRAGMIINAE** Schwager, 1877

Genus **HAGENOWELLA** Cushman, 1933

Type species: Valvulina gibbosa d'Orbigny, 1840

Hagenowella ex gr. subsphaerica (Reuss), emended

(Pl. 6, Figs 3-5)

Bulimina subsphaerica Reuss, 1846, p. 109, pl. 24, fig. 23.
Arenobulimina ex gr. subsphaerica (Reuss). Hanzlíková, 1972, p. 56, pl. 13, fig. 4a-b.

Remarks: Hagenowella ex gr. subsphaerica morphotypes are distinguished by having a subglobular to ovoid, trochospiral test, variable in size (varying from c. 210/190μm to 420/340μm in maximum length/breadth ratio, in the neanic and early ephebic stages, to c. 770/590μm in the late ephebic/gerontic stage); conical early portion, indistinct, followed by an inflated trochospiral stage; 3 to 4 greatly inflated and subglobular chambers in the last whorl; single aperture, a low interiomarginal arch at the base of the last chamber; circular peripheral margin in cross section throughout; wall moderately finely agglutinated. The specimens are herein placed in Hagenowella by having intercameral sutures nearly parallel to the axis of coiling, rather than at a broadly acute angle as in Arenobulimina Cushman (cf. Loeblich & Tappan, 1988, p. 139-140). The morphotypes are similar to Eggerella Cushman, but differ in apertural features (low interiomarginal arch positioned at the base of the last chamber, rather than a low slit near the base of the apertural face).

Range: Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to middle bathyal.

Superfamily **ORBITOLINACEA**
Martin, 1890

Family **ORBITOLINIDAE** Martin, 1890

Subfamily **DICTYOCONINAE** Moullade, 1965

Genus **PARACOSKINOLINA** Moullade, 1965

Type species: *Coskinolina* *sunnilandensis* Maync, 1955

***Paracoskinolina*(?) sp. A**

(Pl. 6, Figs 6-7)

Remarks: A single orbitolinid specimen was recovered from turbiditic deposits (Angico Member) of the lower Albian. It is characterised by having an highly conical test (c. 400/370µm in maximum height/breadth ratio), with a concave base; numerous chambers, with interior partially subdivided by radial or transverse partitions; aperture not observed; wall finely agglutinated, of organic and microgranular calcareous cement. The lack of further specimens made it impossible to carry out a thin-sectioning of the specimen, which, consequently, ruled out its precise generic attribution. It seems, however, that the closest morphological affinity may be found with *Paracoskinolina* Moullade (*sensu* Loeblich & Tappan, 1988, p. 162), to which the present species is tentatively assigned.

Range: early Albian (rare occurrence).

Occurrence: well 1-US-1-SE.

Palaeo-environments: shallow neritic carbonate platforms (specimen drifted by gravity down-flow currents to deep neritic-upper bathyal environments).

Superfamily **TEXTULARIACEA**
Ehrenberg, 1838

Family **EGGERELLIDAE** Cushman, 1937

Subfamily **DOROTHIINAE** Balakhmatova, 1972

Genus **DOROTHIA** Plummer, 1931, emended, Desai & Banner, 1987, p.16.

Type species: *Gaudryina* *bulleta* Carsey, 1926.

Dorothia ex gr. bulleta (Carsey)

(Pl. 6, Fig. 8)

Gaudryina bulleta Carsey, 1926, p. 28, pl. 4, fig. 4.
Dorothia bulleta (Carsey). Cushman, 1946, p. 46, pl. 12, figs 21-26.
Dorothia retusa (Cushman). Cushman, 1946, p. 46, pl. 13, figs 1-4.
Dorothia bulleta (Carsey). Sliter, 1968, p. 49, pl. 3, fig. 11a-b.
Dorothia bulleta (Carsey). Hanzlíková, 1972, p.57, pl. 12, figs 4, 9.
Dorothia pupa (Reuss). Hanzlíková, 1972, p.57, pl. 13, fig. 3 (not pl. 12, fig. 8, pl. 13, fig. 8a-b).
Dorothia bulleta (Carsey). Sliter, 1977b, pl. 3, fig. 7.
Dorothia bulleta (Carsey). Beckmann, 1978, p. 765, pl. 1, fig. 18.
Dorothia retusa (Cushman). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 195, pl. 9, fig. 6 (not fig. 11)

Remarks: Dorothia ex gr. bulleta morphotypes are distinguished by having an elongate, subcylindrical, robust test (varying from c. 400μm to 1240μm in maximum length); early trochospiral coil, conical-shaped, followed by a biserial stage of inflated chambers; peripheral margin nearly circular in cross section throughout; elongate interiomarginal aperture; wall finely agglutinated. The synonymy list exemplifies the morphological variability of this species-group.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to lower bathyal.

Genus **MARSSONELLA** Cushman, 1933

Type species: Gaudryina oxycona Reuss, 1860.

Remarks: The marssonellids are basically distinguished from dorothiid forms by their characteristic conical to subconical test and concave apertural face. Close morphological affinity suggests very probable intergrading variants (ecophenotypic variations) among the identified species and varieties. However, this has not been precisely established in this study because of a lack of specimens and their sporadic occurrence.

Marssonella kummi Zedler

(Pl. 6, Figs 9–10)

Marssonella kummi Zedler, 1961, p. 31, pl. 7, fig. 1.

Marssonella kummi Zedler. Bartenstein & Bolli, 1977, p. 548, pl. 1, figs 23-24.

Dorothia kummi (Zedler). Sliter, 1980, pl. 5, figs 5-6.

cf. Praedorothia zedlerae (Moullade) luterbacheri Desai & Banner, 1987, p. 20, pl. 5, figs 1a-b (not figs 1c?-d).

Protomarssonella kummi (Zedler). Desai & Banner, 1987, p.24, pl.5, figs 2a-e.

Remarks: This species is characterised by a narrow and slowly tapering, subconical test (varying from c. 200/250µm to 260/270µm in maximum length/breadth ratio), with very weakly depressed sutures; last chambers of the biserial stage are usually broader than high and strongly overlapping; wall finely agglutinated.

Desai & Banner (1987, p. 24) assigned Marssonella kummi to a new genus, Protomarssonella, based on the solid, noncanaliculate, wall structure of the species, which differs from the canaliculate wall character of Marssonella. However, internal wall structure is a feature not readily visible without the use of a Scanning Electronic Microscope which, for obvious reasons, cannot be used for the study of all recovered specimens. It is also probable that this wall character may actually be either an interspecific differentiation or an ecophenotypic feature among the marssonellid morphogroup, and because of this the species is maintained in the Marssonella genus. Giving support to the latter hypothesis of ecophenotypic variations is the evidence presented by A. Almogi-Labin, A. Bein & E. Sass (oral communication, Tubingen, 21st September, 1989) from the upper Cretaceous of Israel. Specimens of agglutinated foraminifera with a canaliculate wall structure (Gaudryina pyramidata Cushman) were shown to predominate in nearly anoxic sediments of the lower Maastrichtian, in the southeastern Zin Valley. Non-canaliculate species dominate in more diversified assemblages from dysaerobic sediments of the uppermost Campanian in the western, less restricted basin of the Shefela.

Range: late Aptian to early Albian, latest Cenomanian.

Occurrence: locality A-9, wells 1-CN-1-SE, 1-CPB-1R-SE, 7-CP-252-SE, 1-US-1-SE, 1-SES-1A.

Palaeo-environments: shallow middle to deep neritic (late Aptian-early Albian biotopes), upper bathyal (latest Cenomanian biotopes).

Marssonella ozawai Cushman

(Pl. 6, Figs 11-12)

Marssonella ozawai Cushman, 1936, p. 43, pl. 4, figs 10a-b.

Marssonella ozawai Cushman. Barnard, 1963, p.41-42, text-figs 1a-c.

Remarks: This species is characterised by its large, conical test (varying from c. 330/190µm to 530/320µm in maximum length/breadth ratio); initial trochospire with 3 to 5 chambers, later becoming biserial; usually straight outline, but occasionally slightly arcuate or even arranged in several stepped stages; wall coarsely agglutinated, with little calcareous cement (cf. Barnard, 1963).

Range: late Aptian to early Albian.

Occurrence: wells 7-CP-252-SE, 1-US-1-SE, 1-SES-1A.

Palaeo-environments: middle to deep neritic.

Marssonella* ex gr. *trochus (d'Orbigny)

Textularia trochus d'Orbigny, 1840, p. 45, pl. 4, figs 25-26.

Remarks: Specimens referred to this species-group have a considerable variable morphology. The morphotypes include specimens described as *M. turris* (d'Orbigny) and *M. oxycona* (Reuss), here considered as intraspecific variants of *M. trochus*, following the usage of Jarvis *et al.* (1988, p. 21, figs 8, 10e, 11c) and Leary (1988, p. 65-70).

Marssonella trochus (d'Orbigny) *sensu stricto*

(Pl. 6, Figs 13-15)

Textularia trochus d'Orbigny, 1840, p. 45, pl. 4, figs 25-26.

Marssonella trochus (d'Orbigny). Hofker, 1957, p. 81-82, text-figs 82a.a-e (not text-figs 82a-g, 83a-i).

Dorothia ocycona (Reuss). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 195, pl. 9, fig. 9.

Remarks: Specimens of Marssonella trochus s.s. are distinguished by having a large, rapidly flaring, conical test (varying from c. 430/380µm to 520/410µm in maximum length/breadth); wall finely agglutinated, with organic and/or calcareous cement (cf. Barnard, 1963). The morphotypes are similar to Marssonella trochus var. oxycona (Reuss), which has been considered as a junior synonym of M. trochus by several previous authors (e.g., Hofker, 1957, Barnard, opp. cit.). They differ, however, in in the more rapidly flaring, cyclindrical-shaped test, rather than broadly flaring and rounded.

Range: late Aptian to middle Albian, early Coniacian to Maastrichtian.

Occurrence: locality A-15, wells 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: middle to deep neritic (late Aptian-middle Albian biotopes), upper to middle bathyal (early Coniacian-Maastrichtian biotopes).

Marssonella trochus (d'Orbigny) **var. oxycona** (Reuss)

(Pl. 6, Figs 16-18)

Gaudryina oxycona Reuss, 1860, p. 229, pl. 12, fig. 3.

Marssonella oxycona (Reuss). Cushman, 1946, p. 43-44, pl. 12, fig. 3a-b (not figs 4-5).5

Marssonella oxycona (Reuss). Bandy, 1951, p. 492, pl. 72, fig. 8.

Marssonella oxycona (Reuss). Hofker, 1957, p. 85-87, text-figs 87a-c, 88a-d, 89a-e (not text-figs 86, 90

Dorothia oxycona (Reuss). Trujillo, 1960, p. 309, pl. 44, fig. 5.

Dorothia oxycona (Reuss). Hanzlíkovâ, 1972, p. 57, pl. 11, fig. 8.

Dorothia oxycona (Reuss). Krasheninnikov, 1974, p. 643, pl. 7, fig. 2a-b.

Dorothia cf. oxycona (Reuss). Beckmann, 1978, p. 765, pl. 1, figs 14 (not fig. 15).

Remarks: Marssonella trochus var. oxycona morphotypes are characterised by their conical test, of variable size, with a broadly flaring outline (varying from c. 190/180µm to 530/510µm in maximum length/breadth ratio); early trochospire with 4 to 5 chambers per whorl, followed by a biserial stage with chambers rapidly increasing in breadth; circular in cross section throughout; wall finely agglutinated, with organic and/or calcareous cement (cf. Barnard, 1963); smooth test surface. The mid-Cretaceous specimens have, characteristically, smaller (about half to one third the size) and more fine-grained tests than the late Cretaceous morphotypes.

Range: late Aptian to Albian, late Campanian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 7-CP-252-SE, 1-CPB-1R-SE, 1-US-1-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: shallow middle to deep neritic (late Aptian-Albian biotopes), upper to middle bathyal (late Campanian-Maastrichtian biotopes).

Marssonella trochus (d'Orbigny) **var. turris** (d'Orbigny)

(Pl. 6, Figs 19-20)

Textularia turris d'Orbigny, 1840, p. 46, pl. 4, figs 27-28.

cf. Marssonella oxycona (Reuss). Cushman, 1946, p. 43-44, pl. 12, figs 4-5 (not fig. 3a-b)

Marssonella turris (d'Orbigny). Hofker, 1957, p.83, text-figs 84a-e, 85a-e.

Marssonella turris (d'Orbigny). Barnard, 1963, p. 42-43, text-figs 2a-h.

Marssonella oxycona (Reuss). Haig, 1980, p. 126, pl. 8, fig. 19.

Remarks: Marssonella trochus var. turris is distinguished by its generally long and narrow, conical test (varying from c. 430/310µm to 630/390µm in maximum length/breadth ratio), with a more slowly tapering elongated shape; wall finely agglutinated, with organic and/or calcareous cement (cf. Barnard, 1963).

Range: late Aptian to Cenomanian, late Coniacian to early-late Maastrichtian.

Occurrence: outcrops A-9, A-15, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 7-CP-252-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: middle neritic to upper bathyal (late Aptian-Cenomanian biotopes), upper to middle bathyal (late Coniacian to early-late Maastrichtian biotopes).

Subfamily **EGGERELLINAE** Cushman, 1937

Genus **KARRERIELLA** Cushman, 1933

Type species: Gaudryina siphonella Reuss, 1851

Karreriella ex gr. conversa (Grzybowski)

(Pl. 6, Fig. 21)

Gaudryina conversa Grzybowski, 1901, p. 235, pl. 7, figs 15-16.
Gaudryina bentonensis (Carmen). Cushman, 1946, p. 33, pl. 7, figs 15-16.
Gaudryina foeda (Reuss). Trujillo, 1960, p. 307-308, pl. 44, fig. 7a-b.
Gaudryina bentonensis (Carman). Sliter, 1968, p. 48, pl. 3, fig. 10.
Gaudryina tailleuri (Tappan). Hanzlíková, 1972, p. 52, pl. 11, fig. 6.
Plectina conversa (Grzybowski). Hanzlíková, 1972, p. 59, pl. 13, figs 10, 14.
Plectina aff. conversa (Grzybowski). Krasheninnikov, 1974, p. 643, pl. 7, figs 3-4.
Karreriella conversa (Grzybowski). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 196, pl. 9, figs 17-18.
Plectina conversa (Grzybowski). Moullade, Kuhnt & Thurow, 1988, pl. 9, figs 1-33.

Remarks: Karreriella ex gr. conversa morphotypes are characterised by having a large elongate test (varying from c. 720/210μm to 1220/240μm in maximum length/breadth ratio); early multiserial, trochospiral portion, cylindrical in shape, followed by a longer biserial stage of somewhat inflated chambers, slightly twisted; test ovoid to rounded in cross section; wall moderately coarsely agglutinated.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Family **TEXTULARIIDAE** Ehrenberg, 1838

Subfamily **TEXTULARIINAE** Ehrenberg, 1838

Genus **TEXTULARIA** Defrance, 1834

Type species: Textularia sagittula Defrance in de Blainville, 1824

Textularia ex gr. subconica Franke

(Pl. 6, Figs 22-24)

Textularia trochus d'Orbigny var. subconica Franke, 1928, p. 131, pl. 12, fig. 1.

Textularia subconica (Franke). Cushman, 1946, p. 30, pl. 6, figs 21-22.

cf. Textularia alexanderi (Lalicker). Haig, 1980, p. 112, pl. 5, figs 1-4.

Remarks: Specimens of Textularia ex gr. subconica are characterised by a tapering biserial test (varying from c. 270/170μm to 350/310μm in maximum length/breadth ratio); inflated chambers, gradually to rapidly increasing in size; ovate to nearly circular outline in cross-section in the last chambers; wall very finely agglutinated. Most of the specimens recovered from Sergipe seem to be biserial throughout. Rare specimens show a minute, indistinct, early coil and are, therefore, somewhat similar to Queensland specimens described by Haig (1980, see synonymy list) and attributed to Textularia alexanderi (Lalicker). Several of the Sergipe morphotypes have a thicker and nearly circular outline in cross-section of the last chambers than have the Queensland specimens. According to Loeblich & Tappan (1982, p. 60), "Haig's specimens are not conspecific with Q. alexanderi". However, it is possible that the early coiled stage be completely masked by agglutinated overgrowth during latter ontogenetic stages, and/or much reduced in rapidly growing individuals. In whatever the case, the morphological differences are too erratic and insufficient to support the proposal of a different taxon. Until further evidence is produced, the Sergipe morphotypes are regarded as Textularia, following, therefore, the usage of Haig (op. cit.).

Range: middle/late Albian to Cenomanian, Coniacian.

Ocurrence: localities A-1, A-3, A-9, A-10, A-15, well 1-SES-3.

Palaeo-environments: middle neritic to upper bathyal.

Textularia minuta Bethelin

(Pl. 6, Figs 25-28)

Textularia minuta Berthelin, 1880, p. 26.
Textularia convexa Antonova *et al.*, 1964, p. 36-37, pl. 4, fig. 7a-b.
Textularia chapmani Lalicker. Magniez-Jannin, 1975, p. 54-56, pl. 3, figs 1-9.
Textularia minuta Berthelin. Crittenden, 1983a, p. 20-21, pl. 2, figs 9-10.

Remarks: *Textularia minuta* is distinguished by its moderately small, compressed, tapering biserial test (varying from c. 260/200µm to 330/220µm in maximum length/breadth ratio); slight lobate periphery; wall finely agglutinated. It differs from *Textularia* ex gr. *subconica* Franke in its smaller and more compressed test, with fewer chambers.

Range: late Aptian to middle Albian.

Occurrence: locality A-15, wells 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow to middle-deep neritic.

Family **PSEUDOGAUDRYINIDAE** Loeblich & Tappan, 1985

Subfamily **PSEUDOGAUDRYININAE** Loeblich & Tappan, 1985

Genus **CLAVULINOIDES** Cushman, 1936

Type species: *Clavulina trilatera* Cushman, 1926
(sensu Banner & Desai, 1985, and Loeblich & Tappan, 1988)

Clavulinoides* ex gr. *trilatera (Cushman)

(Pl. 6, Fig. 29)

Clavulina trilatera Cushman, 1926b, p. 588, pl. 17, fig. 2.
Clavulina trilatera Cushman var. *aspera* Cushman, 1926b, p. 589, pl. 17, fig. 3.

Clavulinoides trilatera (Cushman). Cushman, 1946, p. 38, pl. 9, figs 11, 13, 16 (not figs 10, 12?, 14-15).
Clavulinoides trilatera (Cushman) var. concava (Cushman). Cushman, 1946, p. 38, pl. 9, figs 18-19, 21 (not figs 17, 20, 22).
Clavulinoides aspera (Cushman). Cushman, 1946, p. 38-39, pl. 9, figs 24-30.
Tritaxia aspera (Cushman). Sliter, 1977b, pl. 3, fig. 2 (? not figs 3-4).
Tritaxia trilatera (Cushman). Beckmann, 1978, p. 769, pl. 1, fig. 17.
Clavulinoides aspera (Cushman). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 194, pl. 8, figs 11-12.
Clavulinoides trilatera (Cushman). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 195, pl. 9, fig. 2.

Remarks: Specimens of Clavulinoides ex gr. trilatera are characterised by having a large, elongate test (varying from c. 1460µm to 2430µm), triangular in section throughout with carinate angles; early triserial stage followed by a longer uniserial portion with chambers increasing slowly in size; wall finely to moderately agglutinated.

Range: middle to late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **PSEUDOCLAVULINA** Cushman, 1936

Type species: Clavulina clavata Cushman, 1926

Remarks: The genus differs from Clavulinoides Cushman in possessing an uniserial stage rounded in cross section (cf. Loeblich & Tappan, 1988, p. 179).

Pseudoclavulina arenata (Cushman)

(Pl. 6, Figs 30-31)

Clavulina arenata Cushman, 1933, p. 54, pl. 6, fig. 5a-b. .
Pseudoclavulina arenata (Cushman). Cushman, 1946, p. 37, pl. 9, fig. 9.
Tritaxia gaultina (Morozova). Sliter, 1977b, pl. 3, figs 5-6.

Clavulinoides globulifera (ten Dam & Sigal). Kaminski, Gradstein, Berggren, Geroch & Beckmann, 1988, p. 194, pl. 8, figs 14-15.

Remarks: Specimens of Pseudoclavulina arenata are distinguished by having a large, elongate, cylindrical test (varying from c. 1250/430µm to 1730/450µm in maximum length/ breadth ratio); early triserial portion, triangular in cross section, followed by a long uniserial stage, circular in section, with chambers increasing very slightly in size; wall moderately to coarsely agglutinated.

Range: late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Family **VALVULAMMINIDAE** Loeblich & Tappan, 1986

Genus **VALVULAMMINA** Cushman, 1933

Type species: Valvulina globularis d'Orbigny, 1826

Valvulammina(?) sp. A

(Pl. 6, Figs 32-33)

Remarks: Rare specimens tentatively assigned to Valvulammina (?) sp. A are distinguished by having a moderately large, concavo -convex trochospiral test (varying from 440/220µm to 450/220µm in maximum diameter/height ratio); chambers in a moderately low trochospire, increasing rapidly in size; wall finely agglutinated, with a rather smooth test surface.

Range: earliest Albian.

Occurrence: well 1-US-1-SE (rare occurrence).

Palaeo-environments: deep neritic.

Family **VALVULINIDAE** Berthelin, 1880

Subfamily **TRITAXILININAE** Loeblich & Tappan, 1986

Genus **TRITAXILINA** Cushman, 1911

Type species: Clavulina caperata Brady, 1881

Tritaxilina(?) sp. A

(PL. 6, Figs 34-35)

Remarks: Rare specimens tentatively referred to Tritaxilina(?) sp. A were recovered from the uppermost Cenomanian. They are characterised by having a large, elongate test (varying from c. 480/230µm to 620/250µm in maximum length/breadth), strongly distorted by compaction; high trochospiral early coil, followed by an uniserial stage, partially broken off; wall rather coarsely agglutinated.

Range: latest Cenomanian.

Occurrence: locality A-46.

Palaeo-environments: shallow to middle neritic.

Suborder **INVOLUTININA**

Hohenegger & Piller, 1977

Remarks: Proloculus followed by enrolled tubular second chamber; wall calcareous, perforate, radiate, originally aragonitic but commonly recrystallised to homogeneous micrugranular structure (cf. Loeblich & Tappan, 1988, p. 294).

Family **INVOLUTINIDAE** Butschli, 1880

Subfamily **INVOLUTININAE** Butschli, 1880

Genus **TROCHOLINA** Paalzow, 1922

Type species: Involutina conica Schlumberger, 1898

Trocholina sp. A

(Pl. 7, Figs 1-2)

Remarks: A single specimen referred to Trocholina sp. A was recovered from the lowermost Albian. It is characterised by having a high conical, trochospiral test (c. 380μm in maximum height), poorly preserved due to recrystallization; umbilical side contains nodes and pillars of lamellar structure.

Range: earliest Albian.

Occurrence: well 1-US-1-SE (rare occurrence).

Palaeo-environment: oolitic/oncolitic carbonate shoals (specimen drifted by gravity down-flow currents to middle-deep neritic environments).

Suborder **SPIRILLININA**

Hohenegger & Piller, 1975

Remarks: Coiling planispiral to high trochospiral, proloculus followed by enrolled tubular undivided chamber or with few chambers per whorl; wall calcareous, hyaline, optically a single calcite crystal or few to a mosaic of crystals (cf. Loeblich & Tappan, 1988, p. 303).

Family **SPIRILLINIDAE** Reuss & Fritsch, 1861

Genus **SPIRILLINA** Ehrenberg, 1843

Type species: *Spirillina vivipara* Ehrenberg, 1843

Spirillina minima Schacko

(Pl. 7, Figs 3-4)

Spirillina minima Schacko, 1892, p. 159, pl. 1, fig. 4.

Spirillina minima Schacko. Petri, 1962, pp. 105-106, pl. 13, fig. 4.

Spirillina minima Schacko. Bartenstein & Kovatcheva, 1982, p. 652, pl. 4, figs 38-39, pl. 5, figs 43-44.

Remarks: *Spirillina minima* is characterised by having a small (c. 200-320μm in maximum diameter), discoidal, planispiral and evolute test; proloculus followed by an undivided tubular second chamber, gradually enlarging; surface with numerous pores randomly distributed. This is a long ranging species.

Range: late Aptian to middle Albian, Cenomanian to Turonian.

Occurrence: localities A-1, A-6, A-7, A-12, A-15, A-18, A-22, A-38, Itaporanga 2, wells 1-US-1-SE, 1-SES-9.

Palaeo-environments: shallow to middle neritic (rare drifted specimens occur in Albian turbiditic sediments of deep neritic-upper bathyal settings).

Genus **TURRISPIRILLINA** Cushman, 1927

Type species: *Spirillina conoidea* Paalzow, 1917

Turrispirillina subconica Tappan

(Pl. 7, Figs. 5-8)

Turrispirillina subconica Tappan, 1943, p. 510, pl. 82, figs. 2-3.

Turrispirillina subconica Tappan. Haig, 1982, p. 40, pl. 8, fig. 12.

Remarks: Specimens of *Turrispirillina subconica* are distinguished by having a small (c. 200-300μm in maximum diameter), low conical, concave-convex test; proloculus followed by a long undivided tubular second chamber; wall finely perforated. This is a long ranging species.

Range: late Aptian to middle Albian, Turonian.

Occurrence: localities A-7, A-12, A-22, A-38, wells 1-US-1-SE, 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic (rare drifted specimens occur in Albian turbiditic sediments of deep neritic-upper bathyal settings).

Family **PATELLINIDAE** Rhumbler, 1906

Subfamily **PATELLININAE** Rhumbler, 1906

Genus **PATELLINA** Williamson, 1858

Type species: Patellina corrugata Williamson, 1858

Patellina subcretacea Cushman & Alexander

(Pl. 7, Figs 9-12)

Patellina subcretacea Cushman & Alexander, 1930, p.10, pl.3, fig. 1.

Patellina subcretacea Cushman & Alexander. Petri, 1962, p. 109-110, pl. 13, figs 8-9.

Patellina subcretacea Cushman & Alexander. Sliter, 1968, p. 92-93, pl. 13, fig. 14.

Patellina subcretacea Bartenstein & Kovatcheva, 1982, p. 652, pl. 4, fig. 37.

Remarks: This species is characterised by its small (c. 210-230µm in maximum diameter), low conical, plano-convex test; spiral side convex and evolute; umbilical side flattened to slightly concave, involute; chambers subdivided by numerous radial septula extending inward from the chamber periphery. There is considerable variation in test height. This is a long ranging species.

Range: late Aptian to middle Albian, early-middle Cenomanian, latest Turonian.

Occurrence: localities A-1, A-6, A-15, A-16, A-18, A-38, Itaporanga 2, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 1-US-1-SE.

Palaeo-environments: shallow to middle neritic (rare drifted specimens occur in Albian turbiditic sediments of deep neritic-upper bathyal settings).

Suborder **MILIOLINA**
Delage & Hérouard, 1896

Remarks: Test of fine randomly oriented crystals of high magnesium calcite, resulting in a milky opacity or porcellaneous appearance in reflected light (cf. Loeblich & Tappan, 1988, p. 309).

Superfamily **MILIOLACEA**
Ehrenberg, 1839

Family **SPIROLOCULINIDAE** Wiesner, 1920

Genus **SPIROLOCULINA** d'Orbigny, 1826
Type species: Spiroloculina depressa d'Orbigny, 1826

Spiroloculina cretacea Reuss
(Pl. 7, Figs 13-16)

Spiroloculina cretacea Reuss, 1854, p. 72, pl. 26, fig. 9.

Spiroloculina cretacea Reuss. Cushman & Todd, 1944, p. 3-4, pl. 2, figs 1-4.

Remarks: Specimens referred to Spiroloculina cretacea are characterised by a broadly elliptical, longer than broad, much compressed test (c. 400/250 to 460/290µm in maximum length/width ratio), poorly preserved due to recrystalization; periphery slightly rounded; chambers one-half coil in length added in a single plane. They are morphologically similar to specimens attributed to Massilina planoconvexa Tappan by Eicher & Worstell (1970, p. 283-284, pl. 2, fig. 6a-b) . They differ, however, in lacking the early, apparently quinqueloculine stage, which is observed to protrude on one side of most specimens reported by Eicher & Worstell (op. cit.) from the Greenhorn Formation of South Dakota.

Range: early Cenomanian.

Occurrence: locality A-3.

Palaeo-environments: shallow to middle neritic.

Spiroloculina sp. A

(Pl. 7, Figs 17-20)

Remarks: Spiroloculina sp. A morphotypes are distinguished by an elliptical, slightly longer than broad, thick test (c. 430/270μm to 440/290μm in maximum length/width ratio); concave in the early portion; periphery squarely truncate, flat or slightly convex, sharply angled at the margins; chambers one-half coil in length added in a single plane, increasing gradually in length and breadth but rapidly in thickness; last two chambers are much broader than previous ones, with thickened keels along the margins. The specimens have morphological affinities with some late Neogene-Quaternary species of Spiroloculina illustrated in Cushman & Todd (1944), for instance: S. angulosa Terquem (p. 34-35, pl. 5, fig. 17; Pliocene), S. dentata Cushman & Todd (p. 71-72, pl. 9, fig. 34a-b; Holocene), and S. soldanii (p. 37, pl. 6, figs 5-8; Pliocene).

Range: Cenomanian to early Coniacian.

Occurrence: localities A-3, A-9, A-10, A-45.

Palaeo-environments: shallow middle neritic to upper bathyal.

Family **HAUERINIDAE** Schwager, 1876

Remarks: Occasional hauerinid specimens occur in the mid-Cretaceous succession of Sergipe. These are mostly represented by poorly preserved, recrystalized tests or internal casts. As the specimens are not well enough preserved to support a specific determination, they are placed in open nomenclature.

Subfamily **HAUERININAE** Schwager, 1876

Genus **QUINQUELOCULINA** d'Orbigny, 1826

Type species: Serpula seminulum Linné, 1758

Quinqueloculina (?) sp. A

(Pl. 7, Fig. 21)

Remarks: Specimens assigned to Quinqueloculina (?) sp. A have a minute, ovate test (c. 160/100µm in maximum length/width ratio); rounded equatorial periphery; quinqueloculine coiling, with 4 chambers visible from one side and 3 from that opposite.

Range: late Aptian to Albian.

Occurrence: locality A-33, wells 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow to middle neritic (rare drifted specimens occur in turbiditic deposits from deep neritic to upper bathyal settings).

Subfamily **MILIOLINELLINAE** Vella, 1957

Genus **PSEUDOSIGMOILINA** Bartenstein, 1965

Type species: Triloculina lecalvezae Kaaschieter, 1961

Pseudosigmoilina (?) sp. A

(Pl. 7, Figs 22-23)

Remarks: Specimens tentatively referred to Pseudosigmoilina (?) sp. A have been recovered from the Albian. They have a moderately large, elongate, somewhat compressed, fusiform test (c. 360/160µm in maximum length/width ratio); quinqueloculine arrangement with chambers one-half coil in length.

Range: Albian.

Occurrence: locality A-33, well 1-US-1-SE.

Palaeo-environments: shallow to middle neritic (rare drifted specimens occur in turbiditic deposits from deep neritic to upper bathyal settings).

Suborder **LAGENINA**
Delage & Hérouard, 1896

Remarks: Wall of monolamellar, radiate calcite crystals, with c-axes perpendicular to the outer surface (cf. Loeblich & Tappan, 1988, p. 386).

Superfamily **ROBULOIDACEA**
Reiss, 1963

Family **ICHTHYOLARIIDAE** Loeblich & Tappan, 1986

Genus **LINGULONODOSARIA** A. Silvestri, 1903

Type species: Lingulina nodosaria Reuss, 1863

Lingulonodosaria nodosaria (Reuss)

(Pl. 7, Figs 24-27)

Lingulina nodosaria Reuss, 1863, p. 59, pl. 5, figs 12a-b.
Lingulina nodosaria Reuss. Magniez-Jannin, 1975, p. 217-219, text-fig. 112.
Lingulina nodosaria Reuss. Scheibnerová, 1976, p. 68, pl.36, fig. 1.
Lingulina sp. cf. L. nodosaria Reuss. Haig, 1982, p. 19, pl. 3, fig. 9, 16.
Lingulina nodosaria Reuss. Haig, 1981, p. 346, pl. 2, fig. 27.
Lingulonodosaria nodosaria (Reuss). Loeblich & Tappan, 1988, pl. 433, figs 13-16.

Remarks: Specimens of Lingulonodosaria nodosaria are characterised by their elongate, uniserial, straight or slightly arcuate test (c. 250-340μm in maximum length); few globular chambers increasing slowly in size; oval to rounded peripheral margin in cross section; slit-like terminal aperture; smooth test surface.

Range: late Aptian.

Occurrence: wells 7-CP-252-SE, 1-CPB-1R-SE.

Palaeo-environments: shallow neritic.

Superfamily **NODOSARIACEA**
Ehrenberg, 1838

Family **NODOSARIIDAE** Ehrenberg, 1838

Subfamily **NODOSARIINAE** Ehrenberg, 1838

Genus **DENTALINA** Risso, 1826

Type species: Nodosaria cuvieri d'Orbigny, 1826

Dentalina basiplanata Cushman

(Pl. 7, Fig. 28)

Dentalina basiplanata Cushman, 1938a, p. 38, pl. 6, figs 6-8.
Dentalina basiplanata Cushman. Cushman, 1946, p. 68, pl. 24, figs 1-6.
Dentalina mirandai Petri, 1962, p. 72, pl. 8, fig. 6.
Dentalina basiplanata Cushman. Sliter, 1968, p.57, pl. 5, figs 8-11.

Remarks: The species has a large, very elongate, slightly curved and tapering uniserial test (c. 1000-1200μm in maximum length); early chambers strongly overlapping; chambers increasing slowly in size and becoming more inflated and somewhat elongated in the late stage, with more depressed sutures; smooth test surface.

Range: late Campanian.

Occurrence: well 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Dentalina communis d'Orbigny

(Pl. 7, Figs 29-30)

Nodosaria (Dentalina) communis d'Orbigny, 1826, p. 254.
Dentalina communis d'Orbigny. Bartenstein, Bettenstaedt & Bolli, 1966, p. 153, pl. 3, figs 187-194, 208.
Dentalina cf. deflexa Reuss. Bartenstein, Bettenstaedt & Bolli, 1966, p. 153-154, pl. 3, figs 206-207.
Lenticulina / Dentalina/ distincta (Reuss). Magniez-Jannin, 1975, p. 147-148, pl. 11, figs 37-39, text-fig. 75.
Dentalina distincta Reuss. Bertenstein & Kovatcheva, 1982, p. 637, pl. 2, figs 6-7.

Dentalina sp. cf. D. communis d'Orbigny. Haig, 1982, p. 5-6, pl. 1, figs 13-15.

Remarks: Specimens referred to Dentalina communis have an elongate, slightly arcuate, uniserial test, variable in length; moderately inflated chambers, increasing slowly in size and becoming somewhat elongated in the last chambers; sutures distinct, progressively more depressed; smooth test surface. This species is often recorded as broken fragments (individual chambers varying from 130µm to 200µm in maximum length).

Range: late Aptian to earliest Cenomanian.

Occurrence: locality A-38, wells 1-CN-1-SE, 7-CP-252-SE, 1-CRL-1-SE, 1-US-1-SE.

Palaeo-environments: shallow middle to deep neritic (rare drifted specimens were recovered from turbiditic sediments of deep neritic to upper bathyal settings).

Dentalina ex gr. legumen Reuss

(Pl. 7, Figs 31-33)

Dentalina legumen Reuss, 1851, p. 10, pl. 1, fig. 14.
Dentalina legumen Reuss. Cushman, 1946, p. 65, pl. 23, figs 1-2.
Dentalina legumen Reuss. Sliter, 1968, p. 58, pl. 5, figs 17-18, 24.

Remarks: Specimens of Dentalina ex gr. legumen are characterised by having a large, elongate, slightly arcuate, uniserial test (c. 500-520µm in maximum length); early chambers strongly overlapping, later stage of elongated, inflated chambers, with oblique sutures. This is a long ranging species-group.

Range: earliest Albian, Turonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE,, 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle to deep neritic (earliest Albian biotopes); deep neritic to upper bathyal (Turonian-Maastrichtian biotopes).

Dentalina raristriata (Chapman)

(Pl. 7, Figs 34-35)

Nodosaria (Dentalina) raristriata Chapman, 1893, p. 591, pl. 9, fig. 4.

Dentalina cf. porcatulata Loeblich & Tappan. Bartenstein, Bettenstaedt & Bolli, 1966, p. 154, pl. 3, fig. 226.

cf. Nodosaria spectrum Reuss. Bartenstein & Bolli, 1977, p. 553, pl. 2, fig. 13.

Dentalina raristriata Chapman. Haig, 1982, p. 9, pl. 2, figs 8-11.

Remarks: Specimens of Dentalina raristriata are characterised by having a slender, elongate, slightly curved uniserial test, with longitudinal costae; globular chambers, slightly inflated, increasing gradually in size and length; sutures distinct, depressed. This species is often recorded as broken fragments (individual chambers varying from 110µm to 260µm in maximum length).

Range: late Aptian.

Occurrence: well 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic.

Dentalina vistulae Pozaryska

(Pl. 7, Figs 36-38)

Dentalina cf. D. consobrina d'Orbigny. Cushman & Hedberg, 1841, p. 89, pl. 21, figs 30-31.

Dentalina cf. D. consobrina d'Orbigny. Cushman, 1946, p. 69, pl. 24, figs 23-27.

Dentalina vistulae Pozaryska, 1957, p. 89, fig. 18, pl. 7, fig. 10.

Dentalina vistulae Pozaryska. Sliter, 1968, p. 59, pl. 5, fig. 25.

Dentalina cf. D. consobrina d'Orbigny. Tinoco, 1978, p. 1036, pl. 2, figs 6-7.

Remarks: Specimens referred to Dentalina vistulae are represented by large, very elongate fragments, showing chambers rapidly increasing in length (individual chambers varying from 200µm to 660µm in maximum length); smooth test surface.

Range: late Cenomanian to Campanian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Genus **NODOSARIA** Lamarck, 1812

Type species: Nautilus radicula Linné, 1758

Nodosaria ex gr. affinis Reuss

(Pl. 8, Fig. 1)

Nodosaria affinis Reuss, 1845, p. 26, pl. 13, fig. 16.
Nodosaria paupercula Reuss. Cushman & Hedberg, 1941, p. 89, pl. 21, figs 32-33.
Nodosaria affinis Reuss. Cushman, 1946, p.70-71, pl. 25, figs 8-23.
Nodosaria paupercula Reuss. Cushman, 1946, p. 75, pl. 27, figs 10-12.
Detalina alternata (Jones). Sliter, 1968, p. 56-57, pl. 5, figs 12-13.
Nodosaria affinis Reuss. Tinoco, 1978, p. 1035, pl. 2, fig. 1.
Nodosaria pauperculata Reuss. Tinoco, 1978, p. 1036, pl. 2, figs 2-4.
Nodosaria sp. "A", Tinoco, 1978, p. 1036, pl. 2, fig. 5.

Remarks: Specimens of Nodosaria ex gr. affinis are recognised by having a very elongate, straight to slightly arcuate, uniserial test, with longitudinal costae; chambers inflated, subglobular, increasing gradually in size, with distinct, depressed sutures. Broken fragments of variable sizes are commonly found (individual chambers varying from 140μm to 190μm in maximum length).

Range: late Santonian to Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Nodosaria limbata d'Orbigny

(Pl. 8, Fig. 2)

Nodosaria limbata d'Orbigny, 1840, p. 12, pl. 1, fig. 1.
Nodosaria limbata d'Orbigny. Cushman, 1946, p. 74, pl. 27, figs 1-2.
Nodosaria limbata d'Orbigny. Sliter, 1968, p. 53, pl. 4, fig. 15.
Nodosaria limbata d'Orbigny. Beckmann, 1978, p. 767, pl. 1, fig. 24.

Remarks: Nodosaria limbata morphotypes are characterised by a large, elongate, uniserial test; few subglobular, inflated chambers, of nearly uniform size; distinct, depressed sutures; smooth surface. This species is often recorded as broken fragments (individual chambers varying from 100µm to 180µm in maximum length).

Range: Turonian to Campanian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Nodosaria ex gr. obscura Reuss

(Pl. 8, Figs 3-4)

Nodosaria (Nodosaria) obscura Reuss, 1845, p. 26, pl. 13, figs. 7-9 (fide Haig, 1982, p. 13).

Nodosaria proboscidea Reuss. Cushman, 1946, p. 72-73, pl. 26, p. 12-13.

Nodosaria bighornensis Young. Eicher & Worstell, 1970, p. 287, pl. 3, figs 21-22.

Nodosaria harrisi Vieaux. Magniez-Jannin, 1975, p. 195-196, pl. 12, figs 38-42.

Nodosaria obscura Reuss. Magniez-Jannin, 1975, p. 192-194, pl. 12, figs 22-34, text-fig. 105.

Nodosaria gidya Ludbrook. Scheibnerová, 1976, p.78, pl. 34, fig. 2, text-fig. 92.

Nodosaria obscura Reuss. Haig, 1982, p. 13, pl. 2, figs 39-43.

Remarks: Specimens referred to Nodosaria ex gr. obscura have a short, elongate, straight, uniserial test, with proeminent longitudinal costae, commonly widely spaced; globular chambers increasing gradually to rapidly in size. They are similar to Nodosaria ex gr. affinis Reuss morphotypes, but differ in the usually smaller, less elongate test with few, widely spaced costae. This species is often recorded as broken fragments (individual chambers varying from 85µm to 140µm in maximum length).

Range: middle-late Cenomanian to Turonian.

Occurrence: locality A-2, wells 1-CA-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Genus **PSEUDONODOSARIA** Boomgaart, 1949

Type species: Glandulina discreta Reuss, 1850

Pseudonodosaria ex gr. humilis (Roemer)

(Pl.8, Fig. 5)

Nodosaria humilis Roemer, 1841, p. 95, pl. 15, fig. 6.

Pseudoglandulina manifesta (Reuss). Cushman, 1946, p. 76, pl. 27, figs 20-26.

Pseudonodosaria manifesta (Reuss). Sliter, 1968, p. 72, pl. 8, fig. 18.

Rectoglandulina humilis (Roemer). Bartenstein & Bolli, 1973, p. 406, pl. 6, figs 9-12.

Pseudonodosaria humilis (Roemer). Magniez-Jannin, 1975, p. 198-200, text-fig. 106.

Pseudonodosaria aff. scotti (Tappan). Magniez-Jannin, 1975, p. 200-201, text-fig. 107.

Pseudonodosaria manifesta (Reuss). Tinoco, 1978, p. 1038, pl. 2, fig. 19.

Pseudonosaria humilis (Roemer). Haig, 1982, p.15-16, pl.3, figs 4-5.

Pseudonodosaria manifesta (Reuss). Dailey, 1983, pl. 3, fig. 1.

Remarks: Pseudonodosaria ex gr. humilis morphotypes are characterised by having an elongate, nearly cylindrical and relatively broad, tapering, uniserial test (c. 540/290µm in maximum length/breadth ratio); strongly overlapping chambers in the early stages, with flush sutures; chambers increasing gradually in size and becoming inflated in later stages, with distinct, depressed sutures; smooth surface. This is a long ranging species-group.

Range: late Aptian to early Albian (rare occurrence), late Campanian to Maastrichtian.

Occurrence: wells 7-CP-252-SE, 1-SES-1A, 1-SES-9.

Palaeo-environments: shallow middle to deep neritic (late Aptian-early Albian biotopes); upper bathyal (late Campanian to Maastrichtian biotopes).

Pseudonodosaria obesa (Loeblich & Tappan)

(Pl. 8, Fig. 6)

Rectoglandulina obesa Loeblich & Tappan, 1955, p. 5, pl. 1, figs 5-6.
Rectoglandulina pygmaea (Reuss). Trujillo, 1960, p. 326, pl. 47, fig. 1a-b.
Pseudonodosaria obesa (Loeblich & Tappan). Sliter, 1968, p. 72, pl. 8, fig. 7.

Remarks: Pseudonodosaria obesa is characterised by having a large, ovate, subglobular, uniserial test (c. 580/450μm in maximum length/ breadth ratio); pointed early chambers and large last one; chambers strongly embrancing; sutures distinct, flush; smooth surface.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Subfamily **LINGULININAE** Loeblich & Tappan, 1961

Genus **LINGULINA** d'Orbigny, 1826

Type species: Lingulina carinata d'Orbigny

Lingulina kelleri Petri

(Pl. 8, Fig. 7)

Lingulina kelleri Petri, 1962, p. 82, pl. 10, figs 3-4.

Remarks: The specimens are characterised by having an elongate, straight, laterally compressed, uniserial test (c. 250-500μm in maximum length), which is often poorly preserved because of recrystallisation; chambers arcuate, strongly overlapping earlier ones; smooth test surface.

Range: early Cenomanian.

Occurrence: locality A-1 (rare occurrence).

Palaeo-environments: shallow to middle neritic.

Subfamily **FRONDICULARIINAE** Reuss, 1860

Genus **FRONDICULARIA** Defrance, 1826

Type species: Renulina complanata Defrance

Frondicularia clarki Bagg

(Pl. 8, Figs 8-9)

Frondicularia clarki Bagg, 1898, p. 48, pl. 3, fig. 4.
Frondicularia clarki Bagg. Cushman, 1946, p. 92, pl. 38, figs 1-5.

Remarks: The species is characterised by having a large, elongate test, flattened and slender, with a somewhat lanceolate shape; uniserial chambers; sutures distinct, strongly curved; surface smooth. This species is often recorded as broken fragments (c. 930µm in maximum length).

Range: early Maastrichtian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Frondicularia microdisca Reuss

(Pl. 8, Fig. 10)

Frondicularia microdisca Reuss, 1860, p. 195, pl. 5, fig. 4.
Frondicularia microdisca Reuss. Cushman, 1946, p.90, pl. 30, fig. 2.

Remarks: Frondicularia microdisca is characterised by its large, flattened, palmate test, nearly as broad as long (c. 3330/2800µm in maximum length/breadth ratio); chambers numerous, broad and low, increasing gradually in size; sutures distinct, strongly curved; surface smooth.

Range: early Campanian.

Occurrence: well 1-AU-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Genus **TRISTIX** Macfadyen, 1941

Type species: Rhabdogonium liasinum Berthelin, 1879

Tristix ex gr. excavata (Reuss)

(Pl. 8, Figs 11-13)

Rhabdogonium excavatum Reuss, 1863, p. 91, pl. 12, fig. 8a-c.
Reussella moraisi Petri, 1962, p. 103-104, pl. 13, fig. 2 (not figs 1, 3).
Tristix excavata (Reuss). Magniez-Jannin, 1975, p.224-225, pl. 12, figs 7-11.
Tristix excavatus (Reuss). Gradstein, 1978, pl. 3, fig. 10.
Tribrachia australiana Ludbrook. Scheibnerovà, 1978, pl. 1, fig. 16.
Tribrachia sp., Scheibnerovà, 1978, pl. 1, fig. 15.

Remarks: Specimens of Tristix ex gr. excavata have an elongate (c. 300-470μm in length), uniserial, rectilinear test which is triangular in cross section throughout with sharp acute angles and concace sides; chambers narrow, curved, increasing gradually in size; sutures distinct, slightly depressed; aperture terminal, slightly produced; smooth test surface.

Range: middle to late Albian.

Occurrence: well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Family **VAGINULINIDAE** Reuss, 1860

Subfamily **LENTICULININAE** Chapman, Parr & Collins, 1934

Genus **LENTICULINA** Lamarck, 1804

Type species: Lenticulites rotulata Lamarck, 1804

Remarks: One of the most typical and frequent coiled vaginulinids in the marine realm, specimens belonging to the genus are characterised by having a lenticular, planispiral test; generally biumbonate; aperture at peripheral angle of last chamber, radiate. The difficulties in speciating Cretaceous *Lenticulina*, especially unornamented forms, have been discussed in detail by several authors (e.g., Bartenstein, Bettenstaedt & Bolli, 1957, p. 12-13, 22, and 1966, p. 145-151). Most specimens recovered from Sergipe are, therefore, lumped into highly variable species-groups, which include morphotypes similar to the nominated species types.

Lenticulina ex gr. *gaultina* (Berthelin)

(Pl. 8, Figs 14-16)

Cristellaria gaultina Berthelin, 1880, p. 49, pl. 3, figs. 15-19.

Lenticulina gaultina (Berthelin). Tappan, 1940, p. 101, pl. 15, fig. 11a-b.

Lenticulina (*L.*) *subgaultina* Bartenstein. Bartenstein, Bettenstaedt & Bolli, 1966, p. 147-148, pl. 2, figs 128-129

Lenticulina /*Lenticulina-Astacolus*/ *gaultina* (Berthelin). Magniez-Jannin, 1975, p. 102-104, pl. 9, fig. 17.

Remarks: Specimens assigned to *Lenticulina* ex gr. *gaultina* are characterised by having a large planispiral test (c. 530-860µm in maximum diameter), tending to become partially evolute in the last chamber, with a subacute to thinly keeled periphery; 8 to 10 chambers increasing gradually in size; smooth test surface.

Range: late Aptian to Albian, Turonian.

Occurrence: locality A-15, wells 1-CA-1-SE, 1-CPB-1R-SE, 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow middle neritic to upper bathyal.

Lenticulina ex gr. *nodosa* (Reuss)

(Pl. 8, Figs 17-19)

Cristellaria nodosa Reuss, 1863, p. 78, pl. 9, fig. 6.

Lenticulina (*L.*) *nodosa nodosa* (Reuss). Bartenstein, 1974, p. 540-547, pl. 1, figs 1-17, pl. 2, figs 5-6, 9-12, 16-17.

Lenticulina (*L.*) *nodosa* (Reuss). Bartenstein & Bolli, 1977, p. 550, pl. 1, figs 34-36.

Lenticulina (*L.*) *nodosa nodosa* (Reuss). Aubert & Bartenstein, 1976, pl. 1, figs 1-2, 4-13, 17-21, pl. 2, figs 6-8, 13-15, 20-24, pl. 3, figs 6-8, pl. 4, figs 1, 4-8.

Lenticulina ex gr. nodosa (Reuss). Gradstein, 1978, pl. 4, fig. 10.

Remarks: Specimens referred to Lenticulina ex gr. nodosa have a biumbonate test (c. 240–370µm in maximum diameter), with distinct knot-like thickenings of the ledges on the keel edge and a nearly circular equatorial periphery; 8 to 9 chambers in the last whorl, increasing slowly in size; sutures moderately to strongly raised.

Range: late Aptian.

Occurrence: well 1-US-1-SE (rare occurrence).

Palaeo-environments: middle to deep neritic.

Lenticulina revoluta (Israelsky)

(Pl. 8, Figs 20–22)

Robulus revolutus Israelsky, 1955, p. 49, pl. 15, figs 3–6.
Lenticulina revoluta (Israelsky). Sliter, 1968, p. 67, pl. 7, fig. 11.

Remarks: The specimens have a moderately small, lenticular, planispiral test (c. 300µm in maximum diameter), with a keeled periphery; 8 to 10 chambers in the last whorl, increasing gradually in size; sutures distinct, flush, strongly curved; smooth test surface.

Range: Turonian to late Coniacian.

Occurrence: wells 1-CA-1-SE, 1-SES-3 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Lenticulina ex gr. rotulata (Lamarck)

(Pl. 8, Figs 23–25)

Lenticulites rotulata Lamarck, 1804, p. 188.
Robalina munsteri Roemer, 1839, p. 48, pl. 22, fig. 29.
Robulus munsteri (Roemer). Cushman, 1946, p. 53, pl. 17, figs. 3–9.
Lenticulina gaultina (Berthelin). Petri, 1962, p.62, pl. 6, figs 1–4, pl. 7, fig. 1.
Lenticulina muensteri (Roemer). Sliter, 1968, p. 66, pl. 7, figs. 9, 13.

Lenticulina /Lenticulina/ rotulata (Lamarck). Magniez-Jannin, 1975, p. 100, pl. 9, fig. 3a-b.

Lenticulina (L.) muensteri (Roemer). Bartenstein & Bolli, 1977, p. 550, pl. 1, fig. 33.

Lenticulina (Lenticulina) muensteri (Roemer). Bartenstein & Kovatcheva, 1982, p. 642, pl. 3, figs 4-5.

Remarks: Morphotypes referred to Lenticulina ex gr. rotulata are characterised by their large, biumbonate test with a sharply keeled to acute periphery (c. 470-510µm in maximum diameter); 8 to 12 chambers in the last whorl, increasing slowly to gradually in size; distinct limbate sutures, gently curved, flush to slightly elevated. There is considerable variation in the number of chambers, thickness of the umbonal boss and sutures. This is a long ranging and eurytopic species-group.

Range: late Aptian to Maastrichtian.

Occurrence: localities A-1, A-10, A-11, A-15, A-32, A-37, A-45, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24

Palaeo-environments: neritic to bathyal (peak in abundance at deep neritic to upper bathyal depths).

Lenticulina ex gr. subangulata (Reuss)

(Pl. 8, Figs 26-29)

Cristellaria subangulata Reuss, 1863, p. 74, pl. 7, fig. 7.

Lenticulina subangulata (Reuss). Sliter, 1980, pl. 10, figs 17-18.

Remarks: The specimens are typically represented by having a moderately large test (c. 300-500µm in maximum diameter) with an angled periphery; 7 to 9 chambers in the last whorl, increasing gradually in size.

Range: late Aptian to Albian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow middle neritic to upper bathyal.

Lenticulina sp. A

(Pl. 8, Figs 30-32)

Remarks: Lenticulina sp. A is characterised by having a moderately large, laterally compressed test (c. 360-430μm in maximum diameter); 5 to 8 chambers in the last whorl, increasing rapidly in size; sutures distinctly raised, curved, forming thickened ridges towards the umbilicus; thin distinct peripheral keel. The morphotypes are similar with those reported as Lenticulina sp. 1 by Scheibnerová (1974, p. 711, pl. 3, figs 16-22) from the Aptian-Albian of DSDP Sites 260 and 263, in the eastern Indian Ocean.

Range: early Albian.

Occurrence: locality A-27 (rare occurrence), well 1-US-1-SE.

Palaeo-environments: shallow to middle neritic.

Genus **MARGINULINOPSIS** A. Silvestri, 1904

Type species: Cristellaria bradyi Goes, 1894

Marginulinopsis sp. A

(Pl. 8, Figs 33-34)

Remarks: Specimens of Marginulinopsis sp. A are characterised by having a large, elongate test (c. 1400μm in maximum length); equatorial periphery carinate; early planispiral coil followed by an uniserial stage with chambers circular in cross-section; surface with numerous longitudinal costae.

Range: late Maastrichtian.

Occurrence: well 1-SES-24.

Palaeo-environments: middle to lower bathyal.

Genus **SARACENARIA** Defrance, 1824

Type species: Saracenaria italica Defrance, 1824

Saracenaria* sp. cf. *S. crassicosta Eichenberg

(Pl. 8, Figs 35-36)

Saracenaria italica Defrance var. *crassicostata* Eichenberg, 1933, p. 17, pl. 5, fig. 2a-c.
Lenticulina/Saracenaria/ crassicosta (Eichenberg) Magniez-Jannin, 1975, p. 176-184, pl. 13, figs 22-34, text-fig. 96.

Remarks: Specimens of *Saracenaria* sp. cf. *S. crassicostata* are characterised by having a large biconvex test (c. 420-560µm in maximum length), triangular in cross-section; keeled equatorial periphery; early chambers in a planispiral coil, later flaring and tending to become rectilinear; apertural face broad; sutures curved, flush to slightly depressed; surface smooth.

Range: late Albian to earliest Cenomanian.

Occurrence: wells 1-CRL-1-SE, 1-US-1-SE.

Palaeo-environment: deep neritic.

Subfamily **PALMULINAE** Saidova, 1981

Genus **NEOFLABELLINA** Bartenstein, 1948

Type species: *Flabellina rugosa* d'Orbigny

Neoflabelina* ex gr. *pilulifera (Cushman & Campbell)

(Pl. 9, Figs 1-2)

Flabelina pilulifera Cushman & Campbell, 1935, p. 67, pl. 10, fig.6.
Flabellina numismalis Wedekind, 1940, p. 200, pl. 9, figs 1-3, pl. 11, figs 8-9.
Neoflabelina pilulifera (Cushman & Campbell). Sliter, 1968, p. 71, pl. 8, figs 19-20.
Neoflabelina ex gr. *numismalis* (Wedekind). Hanzlikovà, 1972, p. 70, pl. 17, fig. 5.
Neoflabelina pilulifera (Cushman & Campbell). Hanzlikovà, 1972, p. 71, pl. 17, fig. 6.

Remarks: The species is distinguished by having a large, flattened, oval test (neanic stage c. 390/210µm in maximum length/breadth ratio; ephebic and gerontic specimens c. 930/580µm in maximum length/breadth ratio); early planispiral coil, later uniserial; tuberculate surface between sutures in early portion.

Range: Santonian to early Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A.

Palaeo-environments: upper to middle bathyal.

Neoflabelina reticulata (Reuss)

(Pl. 9, Figs 3-4)

Flabelina reticulata Reuss, 1851, p. 30, pl. 1, fig. 22.

Palmula reticulata (Reuss). Cushman, 1946, p. 84, pl. 31, figs 1-6.

Neoflabelina reticulata (Reuss). Hart *et al.*, 1981, p. 212, pl. 7.20, fig. 3.

Neoflabelina reticulata (Reuss). Hart *et al.*, 1989, p. 354, pl. 7.20, fig. 3.

Remarks: Specimens of *Neoflabelina reticulata* have a large, flattened, palmate test (c. 660/370 to 1000/800µm in maximum length/breadth ratio); surface between sutures strongly ornamented by numerous ridges. It differs from *Neoflabelina semireticulata* (Cushman & Jarvis) in having a more regular, reticulate test surface ornamentation between sutures, throughout the test.

Range: early Maastrichtian.

Occurrence: well 1-SES-1A.

Palaeo-environments: upper to middle bathyal.

Neoflabelina semireticulata (Cushman & Jarvis)

(Pl. 9, Fig. 5)

Flabelina semireticulata Cushman & Jarvis, 1928, p. 98, pl. 13, fig. 14.

Palmula semireticulata (Cushman & Jarvis). Cushman, 1946, p. 85, pl. 31, figs 7-8.

Neoflabelina praereticulata Hiltermann, 1952, p. 53, pl. 3, fig. 37.

Neoflabelina praereticulata Hiltermann. Hart *et al.*, 1981, p. 212, pl. 7.20, fig. 2.

Neoflabelina praereticulata Hiltermann. Hart et al., 1989, p. 354, pl. 7.20, fig. 2.

Remarks: Specimens of Neoflabelina semireticulata are characterised by a large, flattened, palmate test (c. 830/560μm in maximum length/breadth ratio); tuberculate surface between sutures in early portion, later strongly ornamented by numerous short ridges. It differs from Neoflabelina reticulata (Reuss) in the test surface reticulations between sutures, which are much smaller and much more irregular in both size and shape.

Range: earliest Maastrichtian.

Occurrence: well 1-SES-1A.

Palaeo-environments: upper to middle bathyal.

Neoflabelina rugosa (d'Orbigny)

(Pl. 9, Fig. 6)

Flabellina rugosa d'Orbigny, 1840, p. 23, pl. 2, figs 4-5, 7.
Palmula rugosa (d'Orbigny). Cushman, 1946, p. 83, pl. 31, figs 9-16.
Neoflabellina rugosa (d'Orbigny). Sliter, 1968, p. 71-72, pl. 8, fig. 21.
Neoflabelina ex gr. rugosa (d'Obigny). Hanzlíkovà, 1972, p. 71, pl. 17, fig. 7.
Neoflabellina cf. praereticulata Hiltermann. Beckmann, 1978, p. 767, pl. 1, fig. 33.

Remarks: Neflabeina rugosa morphotypes have a large, flattened, broadly palmate test (c. 1000/670μm in maximum length/breadth ratio); periphery truncate; sutures distinct, raised; tuberculate surface ornamentation between sutures.

Range: late Campanian.

Occurrence: well 1-SES-1A.

Palaeo-environments: upper to middle bathyal.

Subfamily **MARGINULININAE** Wedekind, 1937

Genus **ASTACOLUS** Montfort, 1808

Type species: Astacolus crepidulatus Montfort, 1808.

Astacolus sp. cf. A. scitula (Berthelin)

(Pl. 9, Figs 7-8)

cf. Cristellaria scitula Berthelin, 1880, p. 54, pl. 3, fig. 3.

cf. Astacolus scitula (Berthelin). Haig, 1982, p.20, pl. 4, figs 5-7.

Remarks: Specimens referable to Astacolus sp. cf. A. scitula are distinguished by having a small, elongate, uniserial test (c. 250-280μm in maximum length); few broad and low chambers, added on a slightly curved axis; early stage slightly curved but not completely enrolled; sutures strongly oblique, curved; incipient peripheral keel; surface with few faint longitudinal costae. The specimens denote a transitional trend between Vaginulina ex gr. debilis (Berthelin) and Marginulina ex gr. aequivoca Reuss morphotypes.

Range: late Aptian to middle Albian.

Occurrence: locality A-15, wells 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow middle to deep neritic.

Astacolus sp. A

(Pl. 9, Fig. 9)

Remarks: Specimens of Astacolus sp. A have a small, elongate test (c. 260-270μm in maximum length), with broad and low chambers in a planispiral stage, later uncoiling in the last one or two chambers; equatorial periphery acute; smooth test surface.

Range: late Aptian.

Occurrence: well 7-CP-252-SE (rare occurrence).

Palaeo-environments: shallow to middle neritic.

Genus **MARGINULINA** d'Orbigny, 1826

Type species: Marginulina raphanus d'Orbigny, 1826

Marginulina ex gr. aequivoca Reuss

(Pl. 9, Figs 10-11)

Marginulina aequivoca Reuss, 1863, p. 60-61, pl. 5, fig. 17.
Marginulina aequivoca Reuss. Gawor-Biedowa, 1972, p. 38-39, pl. 3, fig. 7.

Remarks: Specimens of Marginulina ex gr. aequivoca are distinguished by their large, elongate, uniserial test (c. 320-530μm in maximum length), straight to slightly arcuate; chambers inflated, oval to circular in cross-section; early stage slightly curved; few longitudinal costae. The morphotypes are similar to specimens described as Lenticulina/Marginulina/ striatocostata (Reuss) by Magniez-Jannin (1975, p. 122-123, pl. 10, figs 9-12, text-fig. 55), but differ in having fewer and thinner longitudinal costae.

Range: late Aptian.

Occurrence: well 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic.

Subfamily **VAGINULININAE** Reuss, 1860

Genus **CITHARINA** d'Orbigny, 1839

Type species: Vaginulina (Citharina) strigillata Reuss, 1846

Citharina navarroana (Cushman)

(Pl. 9, Fig. 12)

Vaginulina navarroana Cushman, 1936d, p. 416, pl. 1, fig. 3.
Vaginulina navarroana Cushman. Cushman, 1946, p. 80-81, pl. 29, figs 17-22.

Remarks: The species is distinguished by having a large, compressed, uniserial test (c. 430μm in maximum length), subtriangular in outline, broadest at the apertural end; chambers distinct, low and broad; sutures strongly curved; surface with a few continuous longitudinal costae.

Range: late Santonian.

Occurrence: well 1-CA-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Citharina multicostata (Cushman)

(Pl. 9, Fig. 13)

Vaginulina multicostata Cushman, 1930, p. 28, pl. 4, fig. 4.
Vaginulina multicostata Cushman. Cushman, 1946, p. 79, pl. 29, figs 9-16.
Citharina multicostata (Cushman). Sliter, 1968, p. 55-56, pl. 5, fig. 6.

Remarks: Specimens of Citharina multicosta have a large, elongate, compressed, uniserial test, slightly arcuate; numerous chambers, low, elongate, curved, increasing rapidly in breadth; sutures strongly oblique, slightly depressed; test surface ornamented with discontinuous longitudinal costae, finely developed. Only broken fragments (c. 1360μm in maximum length) were recovered.

Range: late Coniacian-early Santonian.

Occurrence: well 1-SES-9.

Palaeo-environment: upper bathyal.

Citharina sp. A

(Pl. 9, Fig. 14)

Remarks: Specimens of Citharina sp. A have a large, elongate, flattened, uniserial test (c. 610μm in maximum length), subtriangular in outline; surface with numerous longitudinal costae, not continuous.

Range: earliest Albian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environment: deep neritic.

Genus **PLANULARIA** Defrance, 1826

Type species: Peneroplis auris Defrance, in de Blainville, 1824

Planularia complanata (Reuss)

(Pl. 9, Figs 15-18)

Cristellaria complanata Reuss, 1845, p. 33, pl. 13, fig. 54a-b.
Planularia bradyana (Chapman). Gawor-Biedowa, 1972, p. 40-41, pl. 3, fig. 11.

Lenticulina /Planularia/ complanata (Reuss). Magniez-Jannin, 1975, p. 151-158, pl. 9, figs 26-38, text-fig. 83.

Remarks: Specimens of Planularia complanata have a moderately large, flat, suboval test (c. 380-410µm in maximum length); early planispiral coil followed by an uncoiled stage; 10 to 11 low chambers in the last whorl, increasing rapidly in breadth; sutures slightly raised and curved; acute equatorial periphery.

Range: early Cenomanian.

Occurrence: locality A-1, well 1-CN-1-SE (rare occurrence).

Palaeo-environments: deep neritic.

Genus **VAGINULINA** d'Orbigny, 1826

Type species: Nautilus legumen Linné, 1758

Vaginulina ex gr. debilis (Berthelin)

(Pl. 9, Fig. 19)

Marginulina debilis Berthelin, 1880, p. 35, pl. 3, fig. 28.

Lenticulina/Vaginulina-Dentalina/ debilis (Berthelin) f. costata, Magniez-Jannin, 1975, p. 159-164, pl. 12, figs 44-54, text-fig. 87.

Remarks: Vaginulina ex gr. debilis morphotypes are characterised by having a small, tapering, elongate, uniserial test (c. 280-290µm in maximum length), subtriangular in cross-section; chambers inflated; early stage slightly curved; test surface smooth.

Range: late Aptian.

Occurrence: well 7-CP-252-SE (rare occurrence).

Palaeo-environments: shallow to middle neritic.

Vaginulina ex gr. kochii Roemer

(Pl. 9, Figs 20-21)

Vaginulina kochii Roemer, 1841, p. 96, pl. 15, fig. 10.

Vaginulina cf. recta tenuistriata Chapman. Bartenstein, Bettenstaedt & Bolli, 1966, p. 156, pl. 3, figs 260-264.

Vaginulina arguta Reuss. Gawor-Biedowa, 1972, p. 46-47, pl. 4, fig. 14.
Lenticulina/Vaginulina/ kochii (Roemer). Magniez-Jannin, 1975, p. 166-170, pl. 14, figs 26-32, text-fig. 90.

Remarks: Vaginulina ex gr. kochii morphotypes have a large, elongate, flattened, uniserial test, broadest at the apertural end; sutures flush with surface, moderately oblique, parallel; smooth test surface. This species is often recorded as broken fragments (c. 760µm in maximum length).

Range: late Aptian.

Occurrence: well 7-CP-252-SE (rare occurrence).

Palaeo-environments: shallow to middle neritic.

Vaginulina trilobata (d'Orbigny)

(Pl. 9, Fig. 22)

Marginulina trilobata d'Orbigny, 1840, p. 16, pl. 1, figs 16-17.
Vaginulina taylorana Cushman. Cushman, 1946, p. 81-82, pl. 28, figs 28-29.
Vaginulina trilobata (d'Orbigny). Hanzlíková, 1972, p. 72, pl. 17, figs 8-9.

Remarks: Specimens of Vaginulina trilobata are characterised by their large, elongate, somewhat compressed, uniserial test (c. 1480µm in maximum length); periphery subacute; chambers numerous, distinct, broader than high, increasing gradually in size; early stage slightly curved; sutures distinct, the medium portion of each thickened; test surface smooth, except for the thickened sutures.

Range: latest Maastrichtian.

Occurrence: well 1-MO-1-SE.

Palaeo-environment: upper bathyal.

Family **LAGENIDAE** Reuss, 1862

Genus **LAGENA** Walker & Jacob, 1798

Type species: Serpula (Lagena) sulcata Walker & Jacob,
in Kanmacher, 1798

Lagena acuticosta Reuss

(Pl. 9, Fig. 23)

Lagena acuticosta Reuss, 1862, p. 305, pl. 1, fig. 4.
Lagena striatifera Tappan, 1940, p. 112, pl. 17, fig. 18.
Lagena acuticosta Reuss. Cushman, 1946, p. 94, pl. 39, figs 14-15.
Lagena acuticosta Reuss. Sliter, 1968, p. 63-64, pl. 6, figs.22-23.
Lagena striatifera Tappan. Eicher & Worstell, 1970, p. 285-286, pl. 2, fig. 10.

Remarks: The species is distinguished by having a small, globular test (c. 230-270µm in maximum diameter), ornamented with several longitudinal costae; aperture terminal, at the end of a short tubular neck.

Range: latest Maastrichtian.

Occurrence: well 1-SES-1A.

Palaeo-environments: upper bathyal.

Lagena paucicostata Franke

(Pl. 9, Figs 24-25)

Lagena amphora Reuss var. paucicostata Franke, 1928, p. 87, pl. 7, fig. 38.
Lagena amphora Reuss var. paucicostata Franke. Cushman, 1946, p. 94, pl. 40, figs 4-5.
Lagena paucicostata Franke. Sliter, 1968, p. 64, pl. 6, figs 16-18.
Lagena sulcata (Walker & Jacob). Eicher & Worstell, 1970, p. 286, pl. 2, figs 8-9.

Remarks: Lagena paucicostata morphotypes are distinguished by having an small, elongate, pyriform test (c. 180-290µm in maximum diameter), ornamented with few longitudinal costae; aperture terminal, at the end of a short neck.

Range: Turonian to Campanian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: upper bathyal.

Family **POLYMORPHINIDAE** d'Orbigny, 1839

Subfamily **POLYMORPHININAE** d'Orbigny, 1839

Genus **EOGUTTULINA** Cushman & Ozawa, 1930

Type species: Eoguttulina anglica Cushman & Ozawa, 1930

Eoguttulina anderyi Petri
(Pl. 9, Figs 26-27)

Eoguttulina anderyi Petri, 1962, p. 84-85, pl. 10, fig. 5.

Remarks: The species is distinguished by having a moderately small, elongate, fusiform test (c. 240-440µm in maximum length), rounded in cross-section; chambers elongate in a triserial coil; sutures oblique, depressed; smooth surface.

Range: late Aptian to middle Albian, early Cenomanian.

Occurrence: localities A-1, A-15, well 7-CP-252-SE.

Palaeo-environments: shallow middle to deep neritic.

Genus **GLOBULINA** d'Orbigny, 1839

Type species: Polymorphina gibba d'Orbigny, 1826.

Remarks: Specimens of Globulina are distinguished by their subglobular test with chambers strongly overlapping; terminal radiate aperture; wall finely perforate with a smooth surface (cf. Loeblich & Tappan, 1988, p. 419).

Globulina lacrima Reuss

(Pl. 9, Figs 28-29)

Polymorphina (*Globulina*) *lacrima* Reuss, 1845, p. 40, pl. 12, fig. 6, pl. 13, fig. 83.
Globulina lacrima Reuss. Cushman, 1946, p. 96, pl. 40, figs 11-12.
Globulina lacrima Reuss. Hofker, 1957, p. 170, figs 212-213.
Globulina lacrima Reuss. Sliter, 1968, p. 77, pl. 9, fig. 17, pl. 10, fig. 1.
Globulina lacrima Reuss. Haig, 1982, p. 34-35, pl. 7, figs 3-4.

Remarks: *Globulina lacrima* is characterised by its minute, somewhat elongate, subglobular test (c. 130-250µm in maximum length), with flush sutures; chambers strongly overlapping, extending nearly to the base, becoming sigmoidal.

Range: late Aptian, latest Cenomanian.

Occurrence: locality A-9, well 7-CP-252-SE.

Palaeo-environments: shallow middle neritic to upper bathyal.

Globulina prisca Reuss

(Pl. 9, Figs 30-31)

Polymorphina (*Globulina*) *prisca* Reuss, 1863, p. 79, pl. 9, fig. 8.
Globulina prisca Reuss. Berthelin, 1880, p. 57, pl. 4, figs 20-21.
Globulina prisca Reuss. Bartenstein & Bolli, 1977, p. 555, pl. 2, figs 20-22.
Globulina prisca Reuss. Haig, 1982, p. 35, pl. 7, fig. 7.

Remarks: *Globulina prisca* is similar to *G. lacrima* Reuss, but differs in having a more elongate and compressed test (c. 150-270µm in maximum length), which causes it to be more produced at the base.

Range: late Aptian, late Albian, latest Cenomanian.

Occurrence: locality A-9, wells 1-CA-1-SE, 7-CP-252-SE.

Palaeo-environments: shallow middle neritic to upper bathyal.

Genus **GUTTULINA** d'Orbigny, 1839

Type species: *Polymorphina communis* d'Orbigny, 1826.

Guttulina communis d'Orbigny

(Pl. 9, Fig. 32)

Guttulina communis d'Orbigny, 1826, pl. 12, figs 1-4.

Guttulina communis d'Orbigny. Hofker, 1957, p. 164-165, text-figs 201-202.

Remarks: Specimens of Guttulina communis are characterised by having a small, ovate, slightly elongate test (c. 320µm in maximum length); inflated clavate chambers, somewhat sigmoidal, arranged spirally in a quinqueloculine series, strongly overlapping previous ones and increasing rapidly in size; sutures distinct, depressed; aperture terminal, radiate; smooth test surface.

Range: late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Guttulina sp. A

(Pl. 9, Figs 33-34)

Remarks: The species is characterised by having a minute, ovate, elongate test (c. 190-240µm in maximum length); strongly overlapping chambers, arranged spirally; sutures distinct, slightly depressed; smooth surface.

Range: late Aptian.

Occurrence: well 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic.

Genus **PYRULINA** d'Orbigny, 1839

Type species: Polymorphina gutta d'Orbigny, 1826

Pyrulina cylindroides (Roemer)

(Pl. 9, Figs 35-36)

Polymorphina cylindroides Roemer, 1838, p. 385, pl. 3, fig. 26.

Pyrulina cylindroides (Roemer). Cushman, 1946, p. 97, pl. 40, figs 18-19.

Pyrulina cylindroides (Roemer). Hofker, 1957, p. 168, figs 207-209.

Remarks: Pyrulina cylindroides is characterised by its small, elongate, cylindrical shaped test (c. 240-260µm in maximum length); initial stage triserial coiling, later irregularly biserial; chambers elongate, somewhat embracing; flush sutures, initially somewhat indistinct, later distinct. This is a long-ranging species.

Range: late Aptian, late Coniacian–early Santonian, latest Maastrichtian.

Occurrence: wells 1-SES-24, 7-CP-252-SE.

Palaeo-environments: shallow to middle neritic (late Aptian biotopes), middle to lower bathyal (late Coniacian–early Santonian to late Maastrichtian biotopes).

Subfamily **RAMULININAE** Brady, 1884

Genus **RAMULINA** Jones, 1875

Type species: Ramulina laevis Jones, 1875.

Remarks: Representative specimens referred to this genus are in general found as single fragments, and more rarely as tubular projections of two or more chambers, which makes the precise systematic differentiation of the morphotypes difficult and confusing.

Ramulina aculeata (d'Orbigny)

(Pl. 10, Figs 1–3)

Dentalina aculeata d'Orbigny, 1840, p. 13, pl. 1, figs 2-3.

Ramulina aculeata (d'Orbigny). Cushman, 1946, p. 100, pl. 43, figs 11-16.

Ramulina aculeata Wright. Bartenstein, Bettenstaedt & Bolli, 1966, p. 159, pl. 4, figs 315-339.

Bullopora laevis (Sollas). Eicher & Worstell, 1970, p. 289, pl. 3, fig. 15.

Ramulina aculeata (d'Orbigny). Eicher & Worstell, 1970, p. 289, pl. 3, fig. 24 (? not fig. 25).

Ramulina aculeata (d'Orbigny). Magniez-Jannin, 1975, p. 232-234, text-fig. 124.

Remarks: The species is characterised by moderately large, single fragments or tubular projections of two or more subglobular, elongated and somewhat inflated, chambers (individual chambers varying from 280μm to 290μm in maximum length), with broad necks at both ends; sparse spinose ornamentation. Long-ranging ramuline morphotypes.

Range: early Albian, early Cenomanian, late Coniacian to Maastrichtian.

Occurrence: locality A-3, wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-9, 1-US-1-SE.

Palaeo-environments: middle to deep neritic (early Albian and Cenomanian biotopes), deep neritic to upper bathyal (Santonian to Maastrichtian biotopes).

Ramulina fusiformis Khan

(Pl. 10, Fig. 4)

Ramulina fusiformis Khan, 1950, p. 272, pl. 2, figs 1-2.

Ramulina aculeata (d'Orbigny). Eicher & Worstell, 1970, p. 289, pl. 3, fig. 25 (not fig. 24).

Ramulina fusiformis Khan. Magniez-Jannin, 1975, p. 230-231, pl. 15, fig. 21, text-fig. 122.

Remarks: Single fragments of long, sub-ellipsoidal chambers (c. 280-600µm in maximum diameter), with broad openings at both ends; sparse spinose ornamentation. The morphotypes differ from Ramulina aculeata (d'Orbigny) in having more elongated and less inflated fusiform chambers.

Range: late Aptian to early Albian.

Occurrence: wells 7-CP-252-SE, 1-US-1-SE (rare occurrence).

Palaeo-environments: shallow middle to deep neritic.

Ramulina tetrahedralis Ludbrook

(Pl. 10, Figs 5-6)

Ramulina tetrahedralis Ludbrook, 1966, p. 131, pl. 8, figs 27-28.

Remarks: Specimens of Ramulina tetrahedralis are characterised by small, single fragments of subglobular chambers (c. 260µm in maximum diameter) with three long thin necks; sparse spinose ornamentation.

Range: late Albian.

Occurrence: well 1-US-1-SE.

Palaeo-environments: middle to deep neritic.

Suborder **ROBERTININA** Loeblich & Tappan, 1984

Remarks: Test planispirally to trochospirally enrolled; wall calcareous, hyaline, perforate, optically radial, aragonitic (cf. Loeblich & Tappan, 1988, p. 437).

Superfamily **CERATOBULIMINACEA** Cushman, 1927

Family **CERATOBULIMINIDAE** Cushman, 1927

Subfamily **REINHOLDELLINAE** Seiglie & Bermúdez, 1965

Genus **PSEUDOLAMARCKINA** Myatlyuk, 1959

Type species: Pulvinulina rjasanensis Uhlig, 1883

Pseudolamarckina sp. A

(Pl. 10, Figs 7-11)

Remarks: Specimens assigned to Pseudolamarckina sp. A are characterised by having a large, asymmetrically biconvex to plano-convex, moderately high trochospiral test (around 400-580µm in maximum diameter); sutures thickened, elevated, curved on the dorsal side, flush to slightly depressed on the ventral side; equatorial periphery carinate to angular; surface smooth; aperture a narrow interiomarginal, extraumbilical-umbilical slit, partly covered by an umbilical flap.

Range: early Maastrichtian.

Occurrence: well 1-AU-1-SE.

Palaeo-environments: middle to deep neritic.

Family **EPISTOMINIDAE** Wedekind, 1937

Subfamily **EPISTOMININAE** Wedekind, 1937

Genus **EPISTOMINA** Terquem, 1883

Type species: Epistomina regularis Terquem, 1882.

Remarks: A consistent differentiation between Epistomina and Hoeglundina Brotzen can not be made based just on single external features such as test shape (biconvex to plano-convex) or surface ornamentation (smooth to strongly sculptured) - (e.g., Loeblich & Tappan, 1988, p. 445-446), here considered of only inter- or intraspecific significance.

Furthermore, the generic classification of the epistominids based on internal structure has also been considered as invalid (e.g. Haig, 1982, p. 44), of no taxonomic value. Epistominid species previously assigned to these two genera are, henceforth, placed into Epistomina, the senior nominated genotype. Unfortunately, most of the epistominid morphotypes from Sergipe are strongly corroded and/or recrystalised, which biased the precise specific attribution of several specimens.

Epistomina carpenteri (Reuss)

(Pl. 10, Figs 12-14)

Rotalia carpenteri Reuss, 1863, p. 94, pl. 13, fig. 6.
Hoeglundina carpenteri (Reuss). Carter & Hart, 1977, p. 50-51, pl. 1, figs 15-17.
Hoeglundina carpenteri (Reuss). Hart, 1984, p. 292, pl. 2, figs 13-14, 17-19.

Remarks: Specimens of Epistomina carpenteri are distinguished by having a large, lenticular, biconvex, trochospiral test (c. 330-430μm in maximum diameter), with a more convex ventral side; circular equatorial periphery with sharp acute, somewhat crenulated, peripheral margin; sutures thick, curved, raised; test surface commonly with incipient spinose ornamentation. It differs from Epistomina chapmani ten Dam in its generally larger test, with a crenulate equatorial periphery and spinose surface ornamentation.

Range: early to middle Albian.
Occurrence: wells 1-CPB-1R-SE, 1-US-1-SE.
Palaeo-environments: deep neritic to upper bathyal.

Epistomina chapmani ten Dam

(Pl. 10, Figs 15-17)

Epistomina chapmani ten Dam, 1948, p. 166, pl. 1, fig. 5.
Epistomina chapmani (ten Dam). Magniez-Jannin, 1975, p. 274, pl. 16, figs 1-2.
Hoeglundina chapmani (ten Dam). Carter & Hart, 1977, p. 51, pl. 1, figs 18-20.

Epistomina chapmani ten Dam. Haig, 1982, p.43-44, pl.8, figs 13-16.
Hoeglundina chapmani (ten Dam). Hart, 1984, p. 292, pl. 2, figs 1-8.

Remarks: Epistomina chapmani is characterised by its moderately large, lenticular test (c. 260-360µm in maximum diameter), with a more convex ventral side; circular equatorial periphery with sharp acute peripheral margin; sutures thick, curved, slightly raised or flush; smooth surface.

Range: early Albian.

Occurrence: locality A-32, well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Epistomina spinulifera (Reuss)

(Pl. 10, Figs 18-20)

Rotalia spinulifera Reuss, 1862, p. 93, figs 3-5.
Epistomina spinulifera (Reuss). Magniez-Jannin, 1975, p. 274-275, pl. 16, figs 4-6.
Epistomina spinulifera (Reuss). Carter & Hart, 1977, p. 50, pl. 4, fig. 25.
Epistomina spinulifera (Reuss). Hart, 1984, p.292, pl. 1, figs 10-12.

Remarks: Specimens of Epistomina spinulifera are characterised by having a moderately large, asymmetrical test (c. 360µm in maximum diameter) with a slightly convex dorsal side and a more convex ventral side, of variable height; distinctive coarse surface ornamentation with raised limbate sutures on both sides; circular equatorial periphery with sharp acute margin, commonly with spinose ornamentation.

Range: middle Albian.

Occurrence: locality A-15, well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Epistomina supracretacea ten Dam

(Pl. 10, Figs 21-23)

Epistomina supracretacea ten Dam, 1948, p. 163, pl. 1, fig. 8.
Hoeglundina supracretacea (ten Dam). Trujillo, 1960, p. 338, pl. 49, fig. 3.
Hoeglundina supracretacea (ten Dam). Sliter, 1968, p. 128, pl. 24, fig.9.

Remarks: Specimens of Epistomina supracretacea are distinguished by having a large, biconvex, trochospiral test (c. 400-420µm in maximum diameter); acute equatorial periphery; round and even in peripheral outline; 7 to 8 chambers in the last whorl, increasing gradually in size; sutures thick, curved, slightly raised on the dorsal side; smooth test surface.

Range: late Campanian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Superfamily **CONORBOIDACEA** Thalmann, 1952

Family **CONORBOIDIDAE** Thalmann, 1952

Genus **CONORBOIDES** Hofker, 1952

Type species: Conorbis mitra Hofker, 1951.

Conorboides ex gr. minutissima (Tappan)

(Pl. 10, Figs 24-28)

Discorbis minutissima Tappan, 1943, p. 511, pl. 82, figs 5-6.

Conorboides minutissima (Tappan). Eicher & Worstell, 1970, p. 295, pl. 6, figs 9, 11, pl. 7, fig. 1.

Conorboides minutissima (Tappan). Sliter, 1977a, pl. 13, figs 7-8.

Conorboides minutissima (Tappan). Haig, 1982, p.43, pl. 9, figs 6-9.

Remarks: Specimens of Conorboides ex gr. minutissima are characterised by having a moderately small (c. 250-320µm in maximum diameter) plano/concavo-convex test, of a low to moderately high trochospire; periphery subacute; 4 to 5 chambers in the last whorl, increasing rapidly to gradually in size; sutures strongly oblique; aperture a low interiomarginal slit, partially covered by a broad short flap. This is a long ranging species-group.

Range: late Aptian to early Coniacian

Occurrence: localities A-1, A-9, A-15, A-16, A-29, A-33, A-38, A-46, Tabocas 2, wells 1-CN-1-SE, 7-CP-252-SE, 1-US-1-SE, 1-SES-9.

Palaeo-environments: shallow to middle neritic (rare specimens occur in deep neritic to upper bathyal settings, probably drifted by bottom currents).

Suborder **ROTALIINA**

Delage & Hérouard, 1896

Remarks: Wall calcareous, of finely perforate hyaline lamellar calcite, optically radial or granular (cf. Loeblich & Tappan, 1988, p. 496-497).

Superfamily **BOLIVINACEA**

Glaessner, 1937

Family **BOLIVINIDAE** Glaessner, 1937

Genus **BOLIVINA** d'Orbigny, 1839

Type species: Bolivina plicata d'Orbigny, 1839

Bolivina ex gr. afra (Reyment)

(Pl. 10, Figs 29-33)

Afrobolivina afra Reyment, 1959, p. 21, pl. 2, figs 1-3, pl. 3, figs 1-3, pl. 4, fig. 1.

Bolivina afra (Reyment). Ogbe, 1980, p. 264, pl. 1, figs 1, 4-5.

Bolivina afra (Reyment) fayosei Ogbe, 1980, p.266, pl. 1, figs 2-3.

Bolivina afra (Reyment). Petters, 1982, p. 59, pl. 11, figs 33-34.

Afrobolivina afra Reyment. Reyment, 1983a, p. 54, 56, pl.5, figs 1-8.

Remarks: Specimens of Bolivina ex gr. afra have an elongate, gradually flaring, biserial test (varying from c. 230µm to 440µm in maximum length), rounded to ovate in cross-section; basal end apiculate to broadly rounded (what seem to represent ecopenhotypic differentiation - see Pl. , Figs); chambers broad and low; well developed, vertically oriented, numerous, imperforate finger-like processes, that extend up from the basal portions of chambers and occur at fairly regularly spaced intervals; surface ornamented with irregularly anastomosing, somehat reticulate, longitudinal costae, usually masking the finger-like processes; loop shaped aperture, at the base of the last chamber or areal in position. This species-group shows a wide range of ecophenotypic variability (e.g., Reyment, 1982). The morphotypes show a characteristic increase in overall length and strength of costae from outer neritic down to bathyal biotopes.

Range: late Santonian to Campanian (common occurrence), latest Maastrichtian (rare).

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-1A.

Palaeo-environments: deep neritic to upper bathyal.

Bolivina ex gr. incrassata Reuss

(Pl. 11, Figs 1-2)

Bolivina incrassata Reuss, 1851, p. 29, pl. 5, fig. 13.
Bolivina incrassata Reuss. Cushman, 1946, p.127, pl. 53, figs 8-11.
Bolivina incrassata Reuss forma gigantea Wicher, 1949, p. 85, pl. 5, figs 2-3.
Bolivina incrassata Reuss. Hofker, 1957, p.228, figs 282-286, 291.
Bolivina incrassata Reuss. Petri, 1962, p. 95-96, pl. 11, fig. 14.
Bolivina incrassata Reuss. Sliter, 1968, p. 88, pl. 12, fig. 14.
Bolivina incrassata gigantea Wicher. Sliter, 1968, p. 88, pl. 12, fig.15.
Bolivina incrassata Reuss. Bertels, 1972, p.339-340, pl. 2, fig. 5.
Bolivina incrassata Reuss. Hanzlìkovà, 1972, p.80, pl. 19, figs 5-6.
Bolivina incrassata Reuss. Sliter, 1977a, pl. 12, fig. 7.
Bolivina incrassata Reuss. Hart et al., 1981, p. 180, pl. 7.4, figs 8-9.
Bolivina incrassata Reuss. Hart et al., 1989, p. 322, pl. 7.4, figs 8-9.

Remarks: This species-group is characterised by its large, elongate, biserial, compressed test (c. 680-830μm in maximum length); subacute to acute periphery; chambers low, broad, increasing gradually in size, gently arcuate and commonly becoming slightly inflated; sutures distinct, gently curved, depressed; smooth wall surface.

Range: late Coniacian-Santonian to Maastrichtian.

Occurrence: localities A-6, A-19, wells 1-CA-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: deep neritic to middle bathyal.

Bolivina sp. cf. B. incrassata Reuss

(Pl. 11, Figs 3-4)

cf. Bolivina incrassata Reuss, 1851, p. 29, pl. 5, fig. 13.
Bolivina cf. incrassata Reuss. Petri, 1962, p.96-97, pl. 11, fig. 15.

Remarks: Specimens tentatively referred to Bolivina sp. cf. B. incrassata were recorded in abundance from shallow to middle neritic biotopes of the uppermost Turonian. They are distinguished by having small, elongate, flaring biserial tests (c. 180-260μm in maximum length), compressed laterally; periphery acute to carinate; chambers broad and low; sutures oblique; smooth wall surface. The specimens may actually represent an ecophenotypic variation of the *Bolivina incrassata* species-group to shallow water conditions.

Range: latest Turonian.

Occurrence: locality A-6.

Palaeo-environments: shallow to middle neritic.

Genus **GABONITA** Dieni, 1974

Type species: *Gabonella elongata* de Klasz & Meijer, in de Klasz *et al.*, 1960

Remarks: Specimens of *Gabonita* are distinguished from other bolivinids and turrilinids by their elongate and biserial test, distinctly twisted in plane, with a characteristic low hook-shaped aperture (instead of a high loop-shaped aperture), extending upward from base of the last chamber, then curving sharply to run nearly parallel to suture.

Gabonita levis (de Klasz, Marie & Rérat)

(Pl. 11, Figs 5-9)

Gabonella levis de Klasz, Marie & Rérat, 1961, pp. 77-78, fig. 2.

Gabonella levis de Klasz, Marie & Rérat. Hamaoui, 1965, pl. 1, figs 7-10.

Remarks: Specimens of *Gabonita levis* are characterised by their moderately small, elongate and somewhat compressed test (c. 280-370μm in maximum length); chambers broad and low; sutures strongly depressed, re-entrant at the base and towards the centre; smooth test surface. They differ from *Gabonita obesa* (de Klasz, Marie & Rérat) in having a generally larger and slender test.

Range: latest Cenomanian to Turonian.

Occurrence: localities A-21, A-22, A-46, well 1-US-1-SE.

Palaeo-environments: shallow middle to deep neritic.

Gabonita obesa (de Klasz, Marie & Rérat)

(Pl. 11, Figs 10-12)

Gabonella obesa de Klasz, Marie & Rérat, 1961, p. 78-79, fig. 2.
Gabonella obesa de Klasz, Marie & Rérat. Hamaoui, 1965, pl. 1, figs 11-12.

Remarks: *Gabonita obesa* is characterised by having a small, elongate test (c. 220-260µm in maximum length), with somewhat inflated chambers, increasing rapidly in size, which gives a broad width to the last chambers.

Range: early Turonian.

Occurrence: locality A-22, well 1-US-1-SE.

Palaeo-environments: deep neritic.

Gabonita* sp. cf. *G. parva (de Klasz, Marie & Meijer)

(Pl. 11, Figs 13-15)

cf. *Gabonella parva*, de Klasz, Marie & Meijer, 1960, p. 175, pl. 2, fig. 4.

Remarks: A single specimen referred to *Gabonita* sp. cf. *G. parva* was recovered from a lower-middle Turonian section. It is characterised by having a small (c. 290µm in maximum length), elongate, irregularly arranged and twisted, biserial test (plane of biseriality twisted); chambers arched, increasing gradually in size, lower margins strongly reentrant, dentate-shaped; aperture a narrow low arch on the base of the last chamber; smooth surface. The specimen is similar to the type-species of *Gabonita parva* de Klasz, Marie & Meijer (1960, p. 175, pl. 2, fig. 4a-b), first recorded in Turonian-Santonian strata of Gabon and Angola, but differs mostly in having a less elongate test with fewer chambers and a slightly rounded basal end rather than apiculate. However, these are minor morphological differences and the present specimen may actually represent an intraspecific variation.

Range: early-middle Turonian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: deep neritic.

Family **BOLIVINOIDIDAE** Loeblich & Tappan, 1984

Genus **BOLIVINOIDES** Cushman, 1927

Type species: Bolivina draco Marsson, 1878

Bolivinoides draco (Marsson)

(Pl. 11, Fig. 16)

Bolivina draco Marsson, 1878, p. 157, pl. 3, figs 25 a–d.

Bolivinoides draco draco (Marsson). Sliter, 1968, p.88, pl.12, fig.17.

Bolivinoides draco (Marsson). Barr, 1970, p. 646, pl. 99, figs 2-3.

Bolivinoides draco (Marsson). Hanzlíková, 1972, p. 81-82, pl. 19, figs 10-11.

Bolivinoides draco (Marsson). Petters, 1977, p. 1032, pl. 1, fig. 1.

Bolivinoides draco draco (Marsson). Beckmann, 1978, p. 765, pl. 2, figs 12, 18-19.

Bolivinoides draco (Marsson). Hart et al., 1981, p. 180, 182, pl. 7.4, fig. 13.

Bolivinoides draco (Marsson). Hart et al., 1981, p. 324, pl. 7.4, fig. 13.

Remarks: Bolivinoides draco is characterised by its compressed, flaring test (c. 430/370µm in length/breadth ratio); chambers in a biserial arrangement, increasing rapidly in breadth; presence of well defined raised median sulcus separated by two parallel costae; surface ornamentation of strongly developed, elongate, thick lobes, forming ridges. The species is similar to Bolivinoides miliaris Hiltermann & Koch, from which it differs in having a slightly broader test, with a lower length/breadth ratio, and by the presence of better defined elongated lobes forming ridges and of a well defined median longitudinal sulcus.

Range: early-late Maastrichtian.

Occurrence: well 1-SES-1A (rare occurrence).

Palaeoenvironments: upper to middle bathyal.

Superfamily **EOUVIGERINACEA**

Cushman, 1927

Family **LACOSTEINIDAE** Sigal, 1952

Genus **LACOSTEINA** Marie, 1945

Type Species: Lacosteina gouskovi Marie, 1945

Lacosteina gouskovi Marie

(Pl. 11, Figs 17-20)

Lacosteina gouskovi Marie, 1945, p. 296-297, figs 1-6.

Remarks: Specimens of Lacosteina gouskovi are characterised by having a smaal, elongate test (varying from c. 160 to 250µm in maximum length) with an early planispiral coil, followed by a high trochospiral coil; 3 inflated chambers per whorl in the later stage; sutures distinct, depressed, oblique; aperture loop-shaped, at inner margin of last chamber; smooth test surface.

Range: Campanian.

Occurrence: locality A-19, wells 1-AU-1-SE, 1-CA-1-SE, 1-SES-3.

Palaeo-environments: deep neritic to upper bathyal.

Superfamily **TURRILINACEA**

Cushman, 1927

Family **TURRILINIDAE** Cushman, 1927

Genus **NEOBULIMINA** Cushman & Wickenden, 1928

Type species: Neobulimina canadensis Cushman & Wickenden, 1928

Remarks: This genus is characterised by its elongate test with an initial triserial coil followed by a biserial stage; aperture loop-shaped extending from base of the last chamber.

Neobulimina aspera (Cushman & Parker)

(Pl. 11, Fig. 21)

Bulimina aspera Cushman & Parker, 1940, p 44, pl. 8, figs 18-19.

Bulimina aspera Cushman & Parker. Cushman, 1946, p. 121, pl. 51, figs 7, 10, 13, 15-16.

Praebulimina aspera (Cushman & Parker). Sliter, 1968, p. 83, pl. 11, figs 11-13.

Remarks: Neobulimina aspera is distinguished by its slightly twisted and gradually tapering, elongate test (c. 365µm in maximum length), circular in cross-section; numerous inflated, somewhat elongate, subglobular chambers, in a nearly vertical arrangement; sutures distinct, depressed; smooth surface.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Neobulimina canadensis Cushman & Wickenden

(Pl. 11, Fig. 22)

Neobulimina canadensis Cushman & Wickenden, 1928, p. 13, pl. 1, figs 1-2.

Bulimina canadensis (Cushman & Wickenden). Cushman, 1946, p. 125, pl. 52, figs 11-12.

Neobulimina canadensis Cushman & Wickenden. Sliter, 1968, p. 82-83, pl. 11, figs 10, 14.

Remarks: This species is characterised by its moderately small and elongate test (c. 310µm in maximum length), with inflated, subglobular chambers; sutures distinct, depressed; smooth surface.

Range: late Santonian to Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: middle neritic to middle bathyal.

Neobulimina minima Tappan

(Pl. 11, Fig. 23)

Neobulimina minima Tappan, 1940, p. 117, pl. 19, figs 5-6.

Remarks: Specimens of Neobulimina minima are distinguished by their small, slightly tapering, elongate test (c. 250µm in maximum length) circular in cross section; chambers inflated, elongate; sutures distinct, slightly depressed to almost flush; smooth surface.

Range: Cenomanian to Coniacian.

Occurrene: localities A-9, Tabocas 2, wells 1-CRL-1-SE, 1-US-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Neobulimina subcretacea Cushman

(Pl. 11, Figs 24-26)

Neobulimina subcretacea Cushman, 1936a, p. 46, pl. 7, fig. 2a-b.

Neobulimina minima Tappan. Moullade, 1984, pl. 3, figs 23-24.

Neobulimina albertensis (Stelck & Wall). Haig, 1982, p. 48-50, pl. 9, figs 10-14, 16-20 (not fig. 15).

Remarks: Specimens of Neobulimina subcretacea have a moderately large, twisted and tapering, elongate test (c. 340-420µm in maximum length); early triserial portion followed by an irregular, well developed, biserial stage; chambers inflated, globular, loosely arranged, increasing gradually in size; sutures distinct, depressed; surface smooth. The morphotypes differ from Neobulimina minima Tappan in having a looser chamber arrangement.

Range: late Albian.

Occurrence: wells 1-CN-1-SE, 1-CRL-1-SE.

Palaeo-environments: deep neritic.

Neobulimina subregularis de Klasz, Magné & Rérat

(Pl. 11, Figs 27-28)

Bulimina (Neobulimina) subregularis de Klasz, Magné & Rérat, 1963, p. 150, pl. 1, fig. 9, pl. 2, fig. 13.

Neobulimina subregularis de Klasz, Magné & Rérat. Tronchetti, 1981, p. 33, pl. 2, figs 4-7.

Neobulimina subregularis de Klasz, Magné & Rérat. Petters, 1982, p. 56, pl. 10, figs 28-29.

Remarks: *Neobulimina subregularis* morphotypes are characterised by their large, somewhat irregular, elongate test; chambers globular, increasing gradually in size; smooth surface. They differ from *Neobulimina aspera* (Cushman & Parker) in having a more irregular chamber arrangement.

Range: late Santonian to earliest Maastrichtian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-SES-9.

Palaeo-environments: middle neritic to upper bathyal.

Genus **PRAEBULIMINA** Hofker, 1953

Type species: *Bulimina ovolum* Reuss, 1844

Praebulimina* ex gr. *bantu de Klasz, Magné & Rérat

(Pl. 11, Figs 29-30)

Bulimina (*Praebulimina* ?) *bantu* de Klasz, Magné & Rérat, 1963, p. 145-146, pl. 1, fig. 2, pl. 2, fig. 3.

Praebulimina bantu de Klasz, Magné & Rérat. Tronchetti, 1981, p. 34, pl. 2, figs 8-9.

Remarks: Specimens of *Praebulimina* ex gr. *bantu* are distinguished by having a moderately large, ovate, triserial test, about 1.5 to 2 times as long as broad (varying from c. 360/220µm to 420/290µm in maximum length/breadth ratio), circular in cross-section; sutures distinct, depressed; surface smooth. The morphotypes show considerable variation in test size and outline but occur together in a single population.

Range: late Santonian to late Maastrichtian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle neritic to middle bathyal.

Praebulimina* ex gr. *fang de Klasz, Magné & Rérat

(Pl. 12, Figs 1-2)

Bulimina (*Praebulimina* ?) *fang* de Klasz, Magné & Rérat, 1963, p. 147, pl. 1, fig. 6, pl. 2, fig. 9.

Praebulimina fang de Klasz, Magné & Rérat. Tronchetti, 1981, p. 34, pl. 3, figs 5–8.

Praebulimina fang de Klasz, Magné & Rérat. Petters, 1982, p. 56, pl. 6, fig. 5.

Remarks: Praebulimina ex gr. fang morphotypes are characterised by their moderately small, tapering, elongate, triserial test (c. 280–310µm in maximum length), with an apiculate basal stage; chambers, subglobular, increasing rapidly in size; sutures distinct, slightly depressed; surface smooth.

Range: late Coniacian to early Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle neritic to middle bathyal.

Praebulimina kickapooensis (Cole)

(Pl. 12, Fig. 3)

Bulimina kickapooensis Cole, 1938, p. 45, pl. 3, fig. 5.

Bulimina kickapooensis Cole. Cushman & Hedberg, 1941, p. 94, pl. 22, fig. 28a-b.

Bulimina kickapooensis Cole. Cushman, 1946, p.123, pl.51, figs 11-12,14.

Praebulimina kickapooensis (Cole). Hofker, 1957, p. 190, figs 233-234.

Praebulimina kickapooensis (Cole). Sliter, 1968, p. 84, pl. 11, figs 17-19.

Remarks: Specimens of Praebulimina kickapoensis are characterised by their large, elongate, cylindrical-shaped, somewhat tapering test (c. 420-460µm in maximum length); slightly inflated, subglobular chambers in triserial arrangement; sutures distinct, depressed. It differs from Praebulimina ex gr. prolixa (Cushman & Parker) by its larger test size, more inflated chambers and slightly tapering chamber arrangement.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Praebulimina* ex gr. *nannina (Tappan)

(Pl. 12, Fig 4)

Bulimina nannina Tappan, 1940, p. 116, pl. 19, fig. 4a-b.

Remarks: *Praebulimina* ex gr. *nannina* morphotypes have a minute, gradually tapering, triserial test (c. 140-190µm in maximum length); chambers inflated, overlapping, regularly arranged, increasing rapidly to gradually in size; sutures distinct, depressed; smooth surface.

Range: Cenomanian to Coniacian.

Occurrence: localities A-3, A-6, A-9, A-45, wells 1-CRL-1-SE.

Palaeo-environments: shallow middle neritic to upper bathyal.

Praebulima* ex gr. *prolixa (Cushman & Parker)

(Pl.112 , Figs 5-8)

Bulimina prolixa Cushman & Parker, 1925, p. 98, pl. 15, fig. 5.
Bulimina prolixa Cushman & Parker Cushman, 1946, p. 122, pl. 51, figs 19-22.
Reussella prolixa (Cushman & Parker). Hofker, 1957, p. 209, figs 255-256.
Pyramidina prolixa (Cushman & Parker). Sliter, 1968, p. 86, pl. 12, figs 7-8.
Praebulimina prolixa (Cushman & Parker). Petters, 1982, p. 57, pl. 6, fig. 1.

Remarks: *Praebulimina* ex gr. *prolixa* morphotypes are distinguished by their elongate, gradually tapering, regularly arranged, narrow test (varying from c. 210-280µm in maximum length, in the upper Coniacian, to c. 360-370µm in length, in the Santonian to lower Maastrichtian), triserial throughout; subtriangular in cross-section with rounded angles; numerous chambers, distinct, slightly inflated, increasing rather slowly in size, arranged directly over one another or somewhat twisted; distinct sutures, slightly depressed; smooth surface.

Range: late Coniacian to early Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle neritic to middle bathyal.

Praebulimina reussi (Morrow)

(Pl. 12, Fig. 9)

Bulimina reussi Morrow, 1934, p. 195, pl. 29, fig. 12.
Bulimina reussi Morrow. Cushman & Hedberg, 1941, p. 95, pl. 22, fig. 30a-b.
Bulimina reussi Morrow. Cushman, 1946, p. 120, pl. 51, figs 1-5.
Bulimina ventricosa Brotzen, 1936, p. 124, fig. 42-43, pl. 8, fig. 1.
Praebulimina reussi (Morrow). Hofker, 1957, p. 187, figs 223-224.
Praebulimina ventricosa (Brotzen). Hofker, 1957, p. 187, figs 223-224.
Praebulimina reussi (Morrow). Sliter, 1968, p. 85, pl. 12, figs 1-2.

Remarks: Specimens of *Praebulimina reussi* are characterised by their small, ovate in outline and more widely flaring, triserial test (c. 250-260μm in maximum length), subcircular in section; chambers distinct, inflated, increasing rapidly in size; sutures slightly depressed to nearly flush; surface smooth. They differ from *Praebulimina* ex gr. *fang* de Klasz, Magné & Rérat morphotypes in having a less elongate and more broadly tapering test.

Range: early Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Praebulimina spinata (Cushman & Campbell)

(Pl. 12, Figs 10-12)

Bulimina spinata Cushman & Campbell, 1935, p. 72, pl. 11, fig. 1.
Praebulimina spinata (Cushman & Campbell). Sliter, 1968, p. 85-86, pl. 12, figs 3-4.
Praebulimina spinata (Cushman & Campbell). Hanzlíková, 1972, p. 77, pl. 18, fig. 12.

Remarks: This species is characterised by its tapering, triserial test; chambers inflated, increasing rapidly in size, lower margin acute with distinct shoulder; initial chambers with short spines projecting towards basal apex, later chambers smooth. There is considerable variation in test size (c. 190-350μm in maximum length) and development of chamber spines. The morphotypes seem to derive from a Praebulimina ex gr. fang de Klasz, Magné & Rérat stock (ecophenotypic differentiation ?), from which they differ in having short basal spines.

Range: late Campanian to early Maastrichtian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **PSEUDOUVIGERINA** Cushman, 1927

Type species: Uvigerina cristata Marsson, 1878

Pseudouvigerina plummerae Cushman

(Pl. 12 , Figs 13-15)

Pseudouvigerina plummerae Cushman, 1927a, p. 115, pl. 23, fig. 8.

Pseudouvigerina plummerae Cushman. Cushman, 1946, p. 116, pl. 49, figs 14-16.

Pseudouvigerina plummerae Cushman. Sliter, 1968, p. 91, pl. 13, fig. 11a-b.

Pseudouvigerina plummerae Cushman. Dailey, 1983, pl. 3, fig. 1.

Remarks: The species is characterised by having a moderately large, elongate, triserial test (c. 300-360µm in maximum length), triangular in cross-section with rounded to subacute angles; chambers moderately inflated, increasing rapidly in size; sutures distinct, depressed; surface smooth.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-24.

Palaeo-environments: deep neritic to middle bathyal.

Genus **PYRAMIDINA** Brotzen, 1948

Type species: Bulimina ? curvisuturata Brotzen, 1940

Pyramidina rudita (Cushman & Parker)

(Pl. 12, Figs 16-17)

Bulimina rudita Cushman & Parker, 1936, p. 45.

Bulimina rudita Cushman & Parker. Cushman, 1946, p. 122, pl. 51, fig.24.

Pyramidina rudita (Cushman & Parker). Sliter, 1968, p. 86-87, pl. 12, fig. 12.

Pyramidina rudita (Cushman & Parker). Tjalsma & Lohman, 1983, pl. 4, fig. 2.

Remarks: Pyramidina rudita morphotypes are characterised by having a large, tapering, pyramidal-shaped, triserial test (c. 360-450µm in length), some specimens twisted on axis; subtriangular in section, with rounded angles and flattened to slightly concave sides; chambers distinct, broad and low; sutures distinct, flush to slightly depressed, oblique; aperture nearly terminal, loop-shaped, at base of the last chamber; surface smooth.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-24.

Palaeo-environments: deep neritic to upper bathyal (rare specimens occur in middle to lower bathyal environments drifted downslope by bottom currents).

Superfamily **BULIMINACEA**
Jones, 1875

Family **SIPHOGENERINOIDIDAE** Saidova, 1981

Subfamily **SIPHOGENERINOIDINAE** Saidova, 1981

Genus **SIPHOGENERINOIDES** Cushman, 1927

Type Species: Siphogenerina plummerae Cushman, 1926

Siphogenerinoides bramlettei Cushman

(Pl. 12, Figs 18-20)

Siphogenerinoides bramlettei Cushman, 1929, p. 58, pl. 9, figs 14-15.

Siphogenerinoides bramlettei Cushman. Cushman & Hedberg, 1941, p. 93, pl. 22, fig. 19.

Siphogenerinoides *bramlettei* Cushman. Petri, 1962, p. 101-102, pl. 12, figs 8-13.

Remarks: *Siphogenerinoides* *bramlettei* morphotypes are characterised by their large, elongate, slender, slightly tapering, rectilinear test (c. 950-1010µm in maximum length); biserial in early stage, later uniserial; sutures of the uniserial stage distinct, curved backwards along the costae; surface with usually 7 to 9 distinct, continuous, regularly and widely spaced, longitudinal costae; the last one to two chambers of some specimens show lower margins with backwards re-entrants (see Pl. 12, Fig. 18); aperture terminal, elliptical to reniform, produced on short neck.

Range: Campanian to Maastrichtian.

Occurrence: locality A-18, wells 1-AU-1-SE, 1-CA-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Subfamily **TUBULOGERENINAE** Saidova, 1981

Genus **ORTHOKARSTENIA** Dietrich, 1935

Type Species: *Orthocerina* *ewaldi* Karsten, 1856.

Remarks: Specimens belonging to this genus are characterised by having large (about 1100-1800µm in maximum length), elongate, rectilinear tests, gradually enlarging; early triserial microspheric portion, tapering, with a rounded base, followed by short biserial and later uniserial megalospheric stage with the sides nearly parallel; lower chamber margins commonly crenulate; aperture terminal, elliptical to reniform, with distinct lip and produced on short neck; surface smooth or with fine longitudinal costae or striae (cf. Loeblich & Tappan, 1988, p. 518-519).

Orthokarstenia ***clarki*** (Cushman & Campbell)

(Pl. 12, Figs 21-24)

Siphogenerinoides *clarki* Cushman & Campbell, 1936, p. 91.

Remarks: Specimens of Orthokarstenia clarki -(c. 1370-1750μm in maximum length)- are distinguished by having a test surface smooth or ornamented with numerous, faint, very low and discontinuous longitudinal costae (see Pl. 12, Fig. 24); sutures distinct, flush to slightly depressed in the uniserial stage, straight to nearly horizontal.

Range: late Santonian to Maastrichtian (the greatest abundance in the late Campanian).

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Orthokarstenia clavata (Chenouard, de Klasz & Meijer)

(Pl. 12, Figs 25-28)

Siphogenerinoides clavata Chenouard, de Klasz & Meijer, 1960, p. 71-72, 74, pl. 1, figs 1-11.

Siphogenerinoides clavata Chenouard, de Klasz & Meijer. Tronchetti, 1981, p. 37, pl. 4, figs 5-9.

Siphogenerinoides clavata Chenouard, de Klasz & Meijer. Tronchetti, 1981, p. 37, pl. 4, figs 5-9.

Orthokarstenia clavata (Chenouard, de Klasz & Meijer). Petters, 1982, p. 66, pl. 10, fig. 25.

Remarks: Specimens of Orthokarstenia clavata - (c. 1130-1200μm in maximum length) - are characterised by having lower chamber margins crenulated, with numerous, rather high, regularly spaced, backwards re-entrants (see Pl. 12, Fig. 26); test surface of microspheric stage ornamented with few longitudinal costae, some continuous over the sutures; earlier chambers obscured by ornamentation.

Range: late Santonian to Campanian (although the species has been described from the upper Campanian-Maastrichtian of Gabon and Congo, no specimens were recovered from strata younger than the Campanian in Sergipe).

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-1A

Palaeo-environments: deep neritic to middle bathyal.

Orthokarstenia ewaldi (Karsten)
(Pl. 12, Figs 29-30)

Orthocerina ewaldi Karsten, 1856, p. 114, pl. 6, fig. 3.
Siphogenerinoides ewaldi (Karsten). Cushman, 1946, p. 118-119, pl. 50, figs 9-11.
Orthokarstenia ewaldi (Karsten). Petters, 1982, p.66, pl.10, fig. 24.

Remarks: Ortharstenia ewaldi morphotypes are characterised by having lower chamber margins crenulated, with high, regularly and widely spaced, backwards re-entrants, more numerous in the last chamber. Only rare fragmented specimens were recovered (varying from c. 550μm to 600μm in maximum length), all represented by internal casts where only the later uniserial stage was preserved.

Range: late Campanian.

Occurrence: well 1-CA-1-SE (rare occurrence).

Palaeo-environments: upper bathyal.

Family **BULIMINELLIDAE** Hofker, 1951

Genus **BULIMINELLA** Cushman, 1911

Type species: Bulimina elegantissima d'Orbigny, 1839

Buliminella ex gr. colonensis Cushman & Hedberg
(Pl. 13, Figs 1-3)

Buliminella colonensis Cushman & Hedberg, 1930, p. 65, pl. 9, figs 6-7.
Buliminella colonensis Cushman & Hedberg. Cushman, 1946, p. 120, pl. 50, figs 23-24.

Remarks: Buliminella ex gr. colonensis morphotypes are characterised by having a somewhat elongate, high trochospiral test (about 250-370μm in maximum length); numerous broad, low chambers, gradually increasing in size; sutures distinct, slightly depressed. The specimens differ from Buliminella pseudoelegantissima Bertels in having a generally larger test with more inflated chambers, i.e., a lower length/breadth ratio.

Range: late Coniacian-Santonian to Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Buliminella brevispira de Klasz, Magné & Rérat

(Pl. 13, Figs 4-5)

Buliminella brevispira de Klasz, Magné & Rérat, 1963, p. 152, pl. 1, fig. 11.
Buliminella brevispira de Klasz, Magné & Rérat. Tronchetti, 1981, pl. 1, fig. 6.

Remarks: Specimens of Buliminella brevispira are distinguished by their small, globular, very low trochospiral test (about 190-280µm in maximum length) of few whorls, nearly as broad as long; somewhat inflated low chambers, increasing rapidly in size, around 4 to 6 in the last whorl; sutures distinct, slightly curved and depressed; loop-shaped aperture in the depressed face of the last chamber.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3.

Palaeo-environments: deep neritic to middle bathyal.

Buliminella pseudoelegantissima Bertels

(Pl. 13, Fig. 6)

Buliminella pseudoelegantissima Bertels, 1972, p. 333, pl. 1, figs 1-3.

Remarks: The species is characterised by having a small, elongate and slender, high trochospiral test (c. 290µm in maximum length); numerous chambers, gradually increasing in height.

Range: late Campanian.

Occurrence: well 1-CA-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Buliminella quadrilobata de Klasz, Magné & Rérat

(Pl. 13, Figs 7-8)

Buliminella quadrilobata de Klasz, Magné & Rérat, 1963, p. 150, 152, pl. 1, fig. 10, pl. 2, figs 14-15.

Buliminella quadrilobata de Klasz, Magné & Rérat. Tronchetti, 1981, p. 32-33, pl. 1, figs 7-17.

Remarks: Buliminella quadrilobata is distinguished by its inflated, subglobular to globular test (c. 310/230µm in maximum length/ breadth), nearly as broad as long; chambers elongate, somewhat inflated, rather increasing gradually in size, around 4 in the last whorl; sutures distinct, slightly depressed. The morphotypes are somewhat similar to Buliminella brevispira de Klasz, Magné & Rérat, but differ in having more elongate and inflated chambers in the last whorl and a somewhat higher trochospire.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Buliminella sp. A

(Pl. 13, Figs 9-10)

Remarks: Specimens of Buliminella sp. A are distinguished by having a small, slender, elongate, high trochospiral test (c. 200-210µm in maximum length); sutures indistinct, flush.

Range: Turonian.

Occurrence: localities A-22, A-29, well 1-US-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Genus **QUADRATOBULIMINELLA** de Klasz, 1953

Type species: Quadratobuliminella pyramidalis de Klasz, 1953

Quadratobuliminella sp. A

(Pl. 13, Figs 11-13)

Remarks: Specimens of Quadratobuliminella sp. A are characterised by having a small, high trochospiral test, nearly as broad as long (varying from

c. 200/180µm to 250/200µm in maximum length/breadth ratio), subquadrate in cross-section; 4 inflated chambers per whorl; sutures depressed; surface smooth.

Range: earliest Cenomanian.

Occurrence: well 1-CN-1-SE.

Palaeo-environments: deep neritic.

Family **REUSSELLIDAE** Cushman, 1933

Genus **REUSSELLA** Gallowa, 1933

Type species: *Verneuilina spinulosa* Reuss

Reussella* ex gr. *szajnochae (Grzybowski)

(Pl. 13, Figs 14-16)

Verneuilina szajnochae Grzybowski, 1896, p. 287, pl. 9, fig. 19.

Reussella szajnochae californica Cushman & Goudkoff. Noth, 1951, p. 65, pl. 7, fig. 6.

Reussella szajnochae s.l. (Grzybowski). de Klasz & Knipscheer, 1954, p. 600-604, 606, tab. p. 605, figs 1-7, pl. 45, figs 1-13.

Reussella szajnochae (Grzybowski). Hofker, 1957, p. 214, text-fig. 262a-g.

Pyramidina szajnochae (Grzybowski). Sliter, 1968, p. 87, pl. 12, fig.13.

Reussella szajnochae (Grzybowsky). Hanzlíková, 1972, p. 85-86, pl. 20, figs 9-11

Reussella szajnochae (Grzybowsky). Beckmann, 1978, p. 768, pl. 2, figs 16-17.

Reussella szajnochae (Grzybowsky). Dailey, 1983, pl. 2, fig. 14.

Remarks: Specimens of *Reussella* ex gr. *szajnochae* are distinguished by their large, elongate, flaring, triserial test (c. 750-1130µm in maximum length); triangular to sub-triangular in cross-section; numerous chambers, subtriangular, with carinate angles; sutures distinct, depressed, curved and oblique; smooth surface; slit-like aperture at the base of the last chamber. Klasz & Knipscheer (1954) discussed the phylogenetic development of

Reussella szajnochae, which shows a gradual enlargement of tests and more advanced wall ornamentation, from the Santonian to Danian times, in the Tethyan bioprovince. The morphotypes recovered from the Santonian-lower Campanian of Sergipe are coeval with the early forms described as *Reussella szajnochae praecursor* de Klasz & Knipscheer (op. cit., p. 603-604, 606, tab. p. 605, fig. 1a-c). They differ, however, in having larger tests with well developed chamber arrangement and wall ornamentation.

Range: Santonian to early Campanian.

Occurrence: wells 1-CA-1-SE, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Superfamily **FURSENKOINACEA**
Loeblich & Tappan, 1961

Family **FURSENKOINIDAE** Loeblich & Tappan, 1961

Genus **CASSIDELLA** Hofker, 1951
Type species: *Virgulina tegulata* Reuss, 1846

Cassidella* ex gr. *viscidus (Khan)
(Pl. 13, Figs 17-19)

Virgulina viscidus Khan, 1950, p. 273-274, pl. 2, figs 3-5.
Cassidella viscida (Khan). Magniez-Jannin, 1975, p. 272, pl. 15, figs 12-13.
Cassidella viscidus (Khan). Haig, 1982, p. 62, pl. 12, figs 26-28.

Remarks: Specimens of *Cassidella* ex gr. *viscidus* have a small, slender, elongate, slightly twisted biserial test (c. 220-290µm in maximum length), ovoid in cross-section; early chambers low, closely packed and strongly twisted, somewhat tending to a triserial arrangement; aperture a high interiomarginal arch.

Range: middle Albian to early Turonian.

Occurrence: locality A-9, wells 1-CN-1-SE, 1-US-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Genus **CORYPHOSTOMA** Loeblich & Tappan

Type species: Bolivina plaitum Carsey, 1926

Coryphostoma sp. A

(PL. 13, Fig. 20)

Remarks: Specimens of Coryphostoma sp. A are distinguished by their small, elongate, flaring, compressed, biserial test (c. 250μm in maximum length); early chambers broad and low, later higher, elongate and with a tendency to become uniserial; surface smooth; interiomarginal loop-shaped aperture, extending from the base of the last chamber.

Range: early Cenomanian.

Occurrence: locality A-1 (rare occurrence).

Palaeo-environments: shallow to middle neritic.

Coryphostoma sp. B

(PL. 13, Figs 21-22)

Remarks: Coryphostoma sp. B morphotypes are characterised by having a small, elongate, narrow, biserial test (c. 190-210μm in maximum length), rounded to oval in cross-section; smmoth test surface.

Range: early Turonian.

Ocurrence: locality A-22, well 1-US-1-SE.

Palaeo-environments: deep neritic.

Family **CAUCASINIDAE** Bykova, 1959

Subfamily **CAUCASININAE** Bykova, 1959

Genus **CAUCASINA** Khalilov, 1951

Type species: Caucasina oligocenica Khalilov

Caucasina sp. A

(Pl. 13, Figs 23-24)

Remarks: A single specimen assigned to Caucasina sp. A was recovered from the lower Turonian. It is characterised by having a small, elongate test (c. 240μm in maximum length); early chambers in a low trochospiral coil, followed by a high coiled stage of 3 inflated chambers per whorl, in a somewhat twisted triserial coil; sutures distinct, depressed; surface smooth.

Range: early Turonian.

Occurrence: well 1-US-1-SE.

Palaeo-environment: deep neritic.

Superfamily **PLEUROSTOMELLACEA**
Reuss, 1860

Family **PLEUROSTOMELLIDAE** Reuss, 1860

Subfamily **PLEUROSTOMELLINAE** Reuss, 1860

Genus **ELLIPSOGLANDULINA** Silvestri, 1900

Type species: Ellipsoglandulina laevigata Silvestri

Ellipsoglandulina velascoensis Cushman

(Pl. 13, Fig. 25)

Ellipsoglandulina velascoensis Cushman, 1926b, p.590, pl. 16, fig. 7.

Ellipsoglandulina velascoensis Cushman. Cushman, 1946, p. 137, pl. 56, fig. 37.

Ellipsopolymorphina velascoensis (Cushman). Hanzlíková, 1972, p. 118, pl. 34, figs 8-9.

Remarks: Specimens of Ellipsoglandulina velascoensis have a large, elongate, inflated fusiform, uniserial test (c. 630/440µm in maximum length/breadth ratio), circular in cross-section; chambers strongly overlapping and increasing very rapidly in size, last one comprising about three-forths the test length; sutures nearly straight and horizontal, slightly depressed; surface smooth; aperture terminal, an elongate, narrow curved slit.

Range: Campanian.

Occurrence: wells 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Genus **BANDYELLA** Loeblich & Tappan, 1962

Type species: Pleurostomella greatvalleyensis Trujillo, 1960

Bandyella clavata (Cushman)

(Pl. 13, Figs 26-28)

Pleurostomella clavata Cushman, 1926b, p. 590, pl. 16, fig. 5.

Pleurostomella clavata Cushman. Cushman, 1946, p. 132-133, pl. 54, fig. 25.

Remarks: Specimens of Bandyella clavata are characterised by having an elongate, fusiform test (about 350-620µm in maximum length), nearly circular in cross-section; early triserial portion followed by a biserial stage with elongate, cuneate chambers; aperture a crescentic slit extending downwards.

Range: late Maastrichtian.

Occurrence: well 1-SES-3 (rare occurrence).

Palaeo-environment: middle bathyal.

Bandyella ex gr. greatvalleyensis (Trujillo)
(Pl. 13, Figs 29-30)

Pleurostomella greatvalleyensis Trujillo, 1960, p. 345, pl. 50, figs 5-6.
Bandyella greatvalleyensis (Trujillo). Sliter, 1968, p. 111, pl. 19, fig. 11.

Remarks: Bandyella ex gr. greatvalleyensis morphotypes are distinguished by having a short, elongate, inflated fusiform test (around 240-250µm in maximum length), nearly circular in cross-section; chambers inflated and elongate in the biserial stage; sutures distinct, depressed in the later stage; surface smooth. The specimens from Sergipe are mostly similar to the illustrated paratype (Trujillo, 1960, pl. 50, fig. 6), considered by Trujillo (op. cit.) to represent an early ontogenetic stage.

Range: late Santonian to Maastrichtian.

Occurrence: well 1-SES-3 (rare occurrence).

Palaeo-environments: middle bathyal.

Superfamily **STILOSTOMELLACEA** Finlay, 1947

Family **STILOSTOMELLIDAE** Finlay, 1947

Genus **NODOGENERINA** Cushman, 1927

Type species: Nodogenerina bradyi Cushman, 1927

Nodogenerina sp. cf. N. alexanderi (Cushman)
(Pl. 13, Figs 31-32)

cf. Ellipsonodosaria alexanderi Cushman, 1936b, p. 52, pl. 9, figs 6-9.

cf. Ellipsonodosaria alexanderi Cushman. Cushman, 1946, p. 135, pl. 56, figs 12-13 (not figs 14-15).

Remarks: Specimens referable to Nodogenerina sp. cf. N. alexanderi are distinguished by having a narrow, elongate, straight, uniserial test (c. 380µm in maximum lenth); chambers campanulate in form, increasing gradually in size and slightly overlapping; row of small spines at the edge of the chamber shoulder, near the base of the chambers; aperture terminal and ovate. The morphotypes are similar to specimens described as Bifarina calcarata (Berthelin) by Magniez-Jannin (1975, p. 247, pl. 20, figs 22-24) from the Albian of Aube, NE France, but differ in having a smooth rounded prolocus, more overlapping chambers and less constricted sutures.

Range: Turonian.

Occurrence: well 1-CA-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Nodogenerina stephensoni

(Pl. 13, Fig. 33)

Ellipsonodosaria stephensoni Cushman, 1936b, p. 52, pl. 9, figs 10-15.
Ellipsonodosaria stephensoni Cushman. Cushman, 1946, p. 134, pl. 56, figs 2-7.
Dentalina stephensoni (Cushman). Sliter, 1968, p. 59, pl. 5, figs 22-23.

Remarks: Specimens of Nodogenerina stephensoni are characterised by having an elongate, uniserial test, slightly arcuate; globular to elongate chambers, increasing gradually in size, with ring of spines at the base of each chamber; sutures distinct, depressed. This species is often recorded as broken fragments (individual chambers c. 130µm in maximum length).

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Palaeo-environments: upper bathyal.

Superfamily **DISCORBACEA**
Ehrenberg, 1838

Family **BAGGINIDAE** Cushman, 1927

Subfamily **BAGGININAE** Cushman, 1927

Genus **VALVULINERIA** Cushman, 1926
Type species: Valvulineria californica Cushman, 1926

Valvulineria amarali Petri
(Pl. 14, Figs 1-5)

Valvulineria amarali Petri, 1962, p. 112, pl. 14, fig. 4a-c.

Remarks: Valvulineria amarali has a biconvex, moderately high trochospiral test (about 350-370μm in maximum diameter), of about two and a half whorls, circular in outline; equatorial periphery broadly rounded; dorsal side moderately convex; 7 chambers in the last whorl, increasing gradually in size; umbilicus somewhat large and deep; aperture an interiomarginal, umbilical-extraumbilical arch, with imperforate apertural flaps projecting over the umbilicus, but do not completely cover it; surface smooth, coarsely perforate on both sides.

Range: late Coniacian-Santonian to Campanian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle-deep neritic to upper-middle bathyal.

Valvulineria sp. A
(Pl. 14, Figs 6-7)

Remarks: Valvulineria sp. A morphotypes are distinguished by their moderately small (around 300-310μm in maximum diameter), concavo-convex, low trochospiral test, circular in outline; equatorial periphery narrowly rounded; 6 chambers in the last whorl, increasing gradually in size; umbilicus moderately wide and shallow; apertural flaps projecting into umbilicus from each chamber; surface smooth, finely perforate in both sides. The specimens differ from Valvulineria sp. B in having a more asymmetrical, concavo-convex test, circular outline and a more open umbilicus with apertural flaps frojecting from each chamber. They both may actually represent ecophenotypic variations of a single species.

Range: latest Cenomanian to Turonian.

Occurrence: localityies A-2, A-9, well 1-CA-1-SE.

Palaeo-environments: middle-deep neritic to upper bathyal.

Valvulineria sp. B

(Pl. 14, Figs 8-12)

Remarks: Specimens of Valvulineria sp. B have a small (about 270-290um in maximum diameter), compressed, slightly biconvex, low trochospiral test, subcircular in outline and becoming lobate in the last two to three chambers; equatorial periphery narrowly rounded; 6 to 7 chambers in the last whorl, increasing gradually in size; umbilicus somewhat wide and deep; apertural flaps projecting over the umbilicus; surface smooth, coarsely perforate in both sides. The morphotypes are somewhat similar to specimens of Lingulogavelinella newtoni Eicher & Worstell (1970, p. 294, pl. 5, figs 2-4), reported from the upper Cenomanian-middle Turonian of the western interior of the United States, but differ in having a more compressed, low trochospiral test, subcircular outline and a perforate dorsal side.

Range: latest Turonian to early Coniacian.

Occurrence: localities A-6, A-10, A-11, Tabocas 2, Mata 10.

Palaeo-environments: shallow to middle neritic.

Family **EPONIDIDAE** Hofker, 1951

Subfamily **EPONIDINAE** Hofker, 1951

Genus **EPONIDES** de Montfort, 1808

Type species: Nautilus repandus Fichtel & Moll, 1798

Eponides aracajuensis Petri
(Pl. 14, Figs 13-16)

Eponides aracajuensis Petri, 1962, p. 115, pl. 15, figs 1-3.

Remarks: Specimens of Eponides aracajuensis are characterised by having a small (c. 230-260μm in maximum diameter), biconvex, low trochospiral test, of about three whorls, circular in outline; equatorial periphery subangular; 7 to 9 chambers in the last whorl, increasing slowly in size; sutures slightly curved on the dorsal side, nearly radial on the ventral side; surface smooth, finely perforate; aperture a broad low interiomarginal arch extending from the umbilicus to the periphery.

Range: late Coniacian to Maastrichtian.

Occurrence: locality A-18, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: middle-deep neritic to upper-middle bathyal.

Family **ROSALINIDAE** Reiss, 1963

Genus **GAVELINOPSIS** Hofker, 1951
Type species: Discorbina praegeri Heron-Allen & Earland

Gavelinopsis(?) sp. A
(Pl. 14, Figs 17-19)

Remarks: Specimens of Gavelinopsis(?) sp. A are distinguished by having a minute (c. 110-150μm in maximum diameter), plano/ concavo-convex, high trochospiral test, circular in outline; equatorial periphery subangular; surface smooth.

Range: latest Cenomanian to earliest Turonian.

Occurrence: localities A-9, A-22, well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Gavelinopsis(?) sp. B

(Pl. 14, Figs 20-25)

Remarks: Gavelinopsis(?) sp. B morphotypes have a small (about 220-280μm in maximum diameter), plano-convex, high trochospiral test, of about two and a half whorls, circular in outline; equatorial periphery narrowly rounded; dorsal side moderately to highly convex; 8 chambers in the last whorl, increasing gradually in size; umbilicus small and open; aperture interiomarginal, extending from the umbilicus nearly to the periphery; surface smooth, finely perforate on both sides. The specimens are tentatively placed in Gavelinopsis Hofker on the basis of their similar test morphology to the genotype, but differ in having a finely perforate dorsal side.

Range: late Coniacian.

Occurrence: well 1-CRL-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Superfamily **PLANORBULINACEA**

Schwager, 1877

Family **PLANULINIDAE** Bermúdez, 1952

Genus **PLANULINA** d'Orbigny, 1826

Type species: Planulina ariminensis d'Orbigny, 1826

Planulina taylorensis (Carsey)

(Pl. 14, Fig. 26)

Anomalina taylorensis Carsey, 1926, p. 47, pl. 6, fig. 1a-b.

Planulina taylorensis (Carsey). Cushman, 1946, p. 158, pl. 64, figs 14-15.

Remarks: Specimens of Planulina taylorensis are characterised by their large, nearly planispiral, compressed test (c. 1000-1500μm in maximum diameter), with an acute and slightly keeled equatorial periphery; 10 to 13 chambers in the last whorl, gradually increasing in size; sutures distinct, strongly curved on both sides; wall smooth, finely perforate.

Range: Campanian.

Occurrence: well 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Planulina sp. A

(PL. 14, Figs 27-30)

Remarks: The species has a minute, compressed, discoidal, very low trochospiral test (c. 150-190μm in maximum diameter); 8 to 9 broad, low and curved chambers in the last whorl, increasing gradually in size; aperture a low interiomarginal equatorial arch.

Range: latest Turonian.

Occurrence: locality A-8.

Palaeo-environments: shallow to middle neritic.

Family **CIBICIDIDAE** Cushman, 1927

Subfamily **CIBICIDINAE** Cushman, 1927

Genus **CIBICIDES** de Montfort, 1808

Type species: Cibicides refulgens de Montfort, 1808

Cibicides ex gr. beaumontianus (d'Orbigny)

(PL. 14, Figs 31-33; PL. 15, Figs 1-3)

Truncatulina beaumontiana d'Orbigny, 1840, p. 35, pl. 3, figs 17-19.

Cibicides beaumontianus (d'Orbigny). Cushman, 1946, p. 160, pl. 65, pl. 12.

Cibicides beaumontianus (d'Orbigny). Hart et al., 1981, p. 182, pl. 7.5, figs 9-10.

Cibicides beaumontianus (d'Orbigny). Hart et al., 1989, p. 326, pl. 7.5, figs 9-10.

Remarks: Cibicides ex gr. beaumontianus morphotypes have a large, plano/concavo-convex trochospiral test (varying from about 320μm to 590μm in maximum diameter), with a flattened to slightly concave dorsal side and strongly convex ventral side; subcircular in outline and becoming lobate in the latter chambers; equatorial periphery carinate; 7 to 8 somewhat inflated chambers in the last whorl, increasing rapidly in size; sutures distinct, flush to depressed; surface smooth, coarsely perforate on the dorsal side and more finely on the ventral side; aperture a low interiomarginal equatorial arch.

Range: late Coniacian-Santonian to early Maastrichtian.

Occurrence: well 1-SES-9.

Palaeo-environments: upper bathyal.

Cibicides sp. A

(Pl. 15, Figs 4-7)

Remarks: Cibicides sp. A morphotypes are characterised by having a large, very compressed, concavo-convex, low trochospiral test (c. 420-550μm in maximum diameter); equatorial periphery acute; 9 chambers in the last whorl, slowly increasing in size; aperture a low interiomarginal equatorial arch; sutures distinct, strongly curved; surface smooth, finely perforate.

Range: early to middle-late Cenomanian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE.

Palaeo-environment: deep neritic.

Cibicides sp. B

(Pl. 15, Figs 8-10)

cf. Cibicides sp., Cushman & Hedberg, 1941, p. 100, pl. 23, fig. 22a-c.

Remarks: Specimens of Cibicides sp. B are distinguished by their large, somewhat compressed, plano/concavo-convex trochospiral test (around 770-820μm in maximum diameter), with a moderately convex ventral side; equatorial periphery carinate; 5 to 6 chambers in the last whorl, increasing rather rapidly in size; surface smooth, coarsely perforate on the dorsal side and more finely on the ventral side. They differ from morphotypes of Cibicides ex gr. beaumontianus (d'Orbigny) in having a more compressed test, with a moderately convex ventral side and a less lobate subcircular outline.

Range: Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-CN-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Family **CYMBALOPORIDAE** Cushman, 1927

Subfamily **CYMBALOPORINAE** Cushman, 1927

Genus **ARCHAECYCLUS** A. Silvestri, 1908

Type species: Planorbulina cenomaniana Sequenza, 1882

Archaecyclus(?) sp. A

(Pl. 15, Fig. 11)

Remarks: A single specimen tentatively referred to Archaecyclus(?) sp. A was recovered from the lower Cenomanian. It is characterised by having a large (about 600μm in maximum diameter), somewhat flattened, discoidal test; later stage with numerous inflated chambers arranged in annular series in a single horizontal layer; numerous apertures present as small circular pores; surface smooth, finely perforate.

Range: early Cenomanian.

Occurrence: locality A-1.

Palaeo-environments: shallow to middle neritic.

Family **EPISTOMARIIDAE** Hofker, 1954

Subfamily **NUTTALLIDINAE** Saidova, 1981

Genus **NUTTALLINELLA** Belford, 1959

Type species: Nuttallina coronula Belford, 1958

Nuttallinella florealis (White)

(Pl.15 , Figs 12-14)

Gyroidina florealis White, 1928b, p. 293, pl. 40, fig. 3.
Pulvinulinella? florealis (White). Cushman, 1946, p.144-145, pl. 59, figs 11-12.
Gyroidina florealis White. Trujillo, 1960, p. 331, pl. 48, fig. 1a-c.
Nuttallinella florealis (White). Hanzlíkovà, 1972, p. 88, pl. 21, figs 4-5.
Nuttallinella florealis (White). Sliter, 1977b, pl. 6, figs 2-3.
Nuttallinella florealis (White). Nyong & Olsson, 1984, pl. 7, figs 10-11.

Remarks: Specimens of Nuttallinella florealis have a large (c. 980µm in maximum diameter), plano/concavo-convex, trochospiral test, with high convex ventral side and flattened to slightly concave dorsal side; equatorial periphery carinate, with broad poreless keel; 7 chambers in the last whorl, increasing gradually in size; sutures distinct, flush, radial in the ventral side; aperture interiomarginal, an elongate slit on the umbilical side.

Range: late Coniacian-Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Nuttallinella texana (Cushman)

(Pl. 15, Figs 15-19)

Pulvinulinella texana Cushman, 1938a, p. 49, pl. 8, fig. 8.

Pulvinulinella texana Cushman. Cushman, 1946, p. 143-144, pl. 59, figs 8-9.

Nuttallinella texana (Cushman). Hanzlíková, 1972, p. 88, pl. 21, figs 2-3.

Remarks: Specimens of Nuttallinella texana are characterised by their asymmetrically biconvex, low trochospiral test (varying from c. 260µm to 570µm in maximum diameter), with the ventral side more convex than the dorsal one; equatorial periphery carinate; 8 chambers in the last whorl, increasing rather gradually in size; sutures distinct, radial to slightly curved on the ventral side and strongly oblique on the dorsal view; surface smooth.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Superfamily **NONIONACEA**
Schultze, 1854

Family **NONIONIDAE** Schultze, 1854

Subfamily **NONIONINAE** Schultze, 1854

Genus **NONIONELLA** Cushman, 1926

Type species: Nonionella miocenica Cushman

Nonionella austinana Cushman
(Pl. 15, Figs 20-21)

Nonionella austinana Cushman, 1933b, p. 57, pl. 7, fig. 2a-c.
Nonionella austinana Cushman. Cushman, 1946, p. 100, pl. 43, figs 18-20.
Nonionella leonardosi Petri, 1962, p. 87, pl. 10, fig. 10a-c (not fig. 11a-c, probably N. cretacea Cushman, 1931).
Nonionella austinana Cushman. Hanzlíková, 1972, p. 124, pl. 36, fig. 3a-b.

Remarks: Nonionella austinana morphotypes have a small, somewhat compressed, low trochospiral test (c. 260µm in maximum diameter); equatorial periphery rounded; dorsal side partially evolute around an umbonal boss; umbilical side involute; 6 slightly inflated chambers, broad and low, in the last whorl, increasing rapidly in size; last chamber asymmetrically protruded towards the ventral side; sutures distinct, curved, depressed; surface smooth; aperture a small interiomarginal and nearly equatorial arch.

Range: late Campanian to Maastrichtian.

Occurrence: locality A-19, wells 1-CA-1-SE, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Nonionella sp. cf. N. austinana Cushman
(Pl. 15, Figs 22-24)

cf. Nonionella austinana Cushman, 1933b, p. 57, pl. 7, fig. 2a-c.

Remarks: Specimens referred to Nonionella sp. cf. N. austinana are distinguished by having a minute (c. 180-200µm in maximum diameter), compressed, low trochospiral test; equatorial periphery narrowly rounded; 6 to 7 chambers in the last whorl, increasing rapidly in size; sutures slightly curved and depressed. The specimens are rare and very recrystalised, which hinders a precise taxonomic evaluation of the species.

Range: early to early-late Turonian.

Occurrence: localities A-7, A-29.

Palaeo-environments: middle to deep neritic.

Subfamily **PULLENIINAE** Schwager, 1877

Genus **PULLENIA** Parker & Jones, 1862

Type species: *Nonionina bulloides* d'Orbigny, 1846

Pullenia cretacea Cushman

(Pl. 15, Figs 25-26)

Pullenia cretacea Cushman, 1936e, p. 75, pl. 13, fig. 8a-b.
Pullenia cretacea Cushman. Cushman & Hedberg, 1941, p. 98, pl. 23, fig. 17a-b.
Pullenia cretacea Cushman. Cushman, 1946, pl. 60, fig. 9a-b.
Pullenia cretacea Cushman. Sliter, 1968, p. 115, pl. 21, fig. 2a-b.
Pullenia cretacea Cushman. Hanzlíkovà, 1972, p.125, pl.36, fig.5a-b.
Pullenia cretacea Cushman. Olsson, 1977, pl. 2, fig. C.
Pullenia cretacea Cushman. Sliter, 1977, pl. 8, figs 6-7.

Remarks: *Pullenia cretacea* morphotypes are characterised by having a globular, slightly compressed, involute, planispiral test (c. 350μm in maximum diameter), circular in outline; equatorial periphery broadly rounded; 4 to 5 moderately inflated chambers in the last whorl; sutures radial, flush to slightly depressed; surface smooth; aperture a low, wide interiomarginal crescentic slit.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-24.

Palaeo-environments: upper to middle bathyal.

Pullenia jarvisi Cushman

(Pl. 15, Figs 27-28)

Pullenia jarvisi Cushman, 1936c, p. 77, pl. 13, fig. 6a-b.
Pullenia jarvisi Cushman. Cushman, 1946, p. 147, pl. 60, fig. 15.
Pullenia jarvisi Cushman. Sliter, 1968, p. 115-116, pl. 21, fig. 3a-b.

Remarks: Specimens of *Pullenia jarvisi* have a large, subglobular, lobate, involute, planispiral test (c. 470μm in maximum diameter), circular in outline; equatorial periphery broadly rounded; 5 somewhat inflated in the last whorl, increasing rapidly in size; sutures distinct, depressed; surface smooth. They differ from Pullenia cretacea Cushman in having a relatively larger size, depressed sutures and a lobate equatorial periphery.

Range: late Santonian to early Campanian.

Occurrence: well 1-SES-3.

Palaeo-environments: middle to lower bathyal.

Superfamily **CHILOSTOMELLACEA**
Brady, 1881

Family **CHILOSTOMELLIDAE** Brady, 1881

Subfamily **CHILOSTOMELLINAE** Brady, 1881

Genus **ALLOMORPHINA** Reuss, 1849

Type species: Allomorphina trigona Reuss, 1850

Allomorphina ex gr. cretacea Reuss

(Pl. 15, Figs 29–32)

Allomorphina cretacea Reuss, 1851, p. 42, pl. 5, fig. 6.

Allomorphina velascoensis Cushman. Cushman & Hedberg, 1941, p. 98, pl. 23, fig. 15.

Allomorphina cretacea Reuss. Sliter, 1968, p.113, pl. 20, fig. 4a–c.

Allomorphina cretacea Reuss. Hanzlíková, 1972, p. 123, pl. 35, fig. 19a–b.

Remarks: Allomorphina ex gr. cretacea morphotypes have a large, involute, trochospiral test (c. 570–620μm in maximum length), subtriangular in outline and circular in cross section; periphery broadly rounded; 3 strongly enveloping chambers in the last whorl, increasing rapidly in size; sutures slightly depressed; surface smooth; aperture an elongate slit, with a projecting bordering rim.

Range: late Coniacian-Santonian to Maatrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Family **QUADRIMORPHINIDAE** Saidova, 1981

Genus **QUADRIMORPHINA** Finlay, 1939

Type species: Valvulina allomorphinoides Reuss, 1860

Quadrimorphina ex gr. allomorphinoides (Reuss)

(Pl. 15, Figs 33-35)

Valvulina allomorphinoides Reuss, 1860, p. 223, pl. 11, fig. 6a-c.
Valvulineria allomorphinoides (Reuss). Cushman & Hedberg, 1941, p. 96-97, pl. 23, fig. 9a-c.
Valvulineria allomorphinoides (Reuss). Cushman, 1946, p.138, pl. 57, figs 6-7.
Quadrimorphina allomorphinoides (Reuss). Trujillo, 1960, p. 330-331, pl. 47, fig. 15a-c.
Quadrimorphina allomorphinoides (Reuss). Sliter, 1968, p. 114, pl. 20, fig. 7a-c.
Quadrimorphina allomorphinoides (Reuss). Hanzlíková, 1972, p. 123, pl. 35, fig. 16a-b.
Valvulineria allomorphinoides (Reuss). Beckmann, 1978, p.769, pl. 2, figs 25-27.
Quadrimorphina allomorphinoides (Reuss). Dailey, 1983, pl. 4, fig.9.

Remarks: Specimens of Quadrimorphina ex gr. allomorphinoides are distinguished by having a large, biconvex, low trochospiral test (c. 370-500µm in maximum length), oval in outline; equatorial periphery rounded; 3 to 6 slightly elongate chambers in the last whorl; sutures slightly depressed; surface smooth; aperture an interiomarginal-umbilical low arch, covered by a large apertural flap.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to middle bathyal.

Family **ANOMALINIDAE** Cushman, 1927

Subfamily **ANOMALININAE** Cushman, 1927

Genus **ANOMALINOIDES** Brotzen, 1942

Type species: Anomalinoides plummerae Brotzen, 1942

Anomalinoides sp. A

(Pl. 16, Figs 1-2)

Remarks: Anomalinoides sp. A morphotypes are characterised by having a moderately large, somewhat compressed, nearly symmetrically biconvex, low trochospiral test (c. 360-520μm in maximum length), lobate in outline; dorsal side partially evolute; equatorial periphery narrowly rounded; 5 to 6 somewhat inflated chambers in the last whorl, increasing rapidly in size; sutures distinct, slightly depressed, radial on the umbilical side, curved to oblique on the dorsal side; surface smooth. The specimens recovered are all recrystalised, which makes difficult a precise taxonomic assessment of the species.

Range: early Cenomanian.

Occurrence: locality A-1.

Palaeo-environments: shallow to middle neritic.

Subfamily **GYROIDINOIDINAE** Saidova, 1981

Genus **GYROIDINA** d'Orbigny, 1826

Type species: Gyroidina orbicularis d'Orbigny, 1826

Gyroidina beisseli White

(Pl. 16, Figs 3-7)

Gyroidina beisseli White, 1928b, p. 291, pl. 39, fig. 7.

Gyroidina beisseli White. Beckmann, 1978, p. 3, figs 29-30.

Gyroidinoides beisseli (White). Dailey, 1983, pl. 6, figs 5-6, 9.

Remarks: Specimens of Gyroidina beisseli are characterised by having a plano-convex, low trochospiral test (varying from c. 230μm to 360μm in maximum diameter); dorsal side flattened in the last whorl with a very low central cone; sutures distinct, flush to slightly depressed, somewhat curved on the ventral side and strongly curved backwards on the dorsal side; aperture a low interiomarginal slit, extending nearly to the periphery and about half way to the umbilicus; surface smooth.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Gyroidina megastoma (Grzybowski)

(Pl. 16, Figs 8-9)

Pulvinulina megastoma Grzybowski, 1896, p. 302, pl. 11, fig. 9.

Gyroidina megastoma (Grzybowski). Hanzlíková, 1972, p. 126, pl. 37, fig. 1a-c.

Remarks: Specimens of Gyroidina megastoma have a moderately large, plano-convex, low trochospiral test (c. 390µm in maximum diameter); dorsal side somewhat concave in the last whorl with slightly convex central cone; ventral side strongly convex; equatorial periphery narrowly rounded; sutures distinct, slightly depressed, oblique in the dorsal side; surface smooth.

Range: late Maastrichtian.

Occurrence: well 1-SES-1A (rareoccurrence).

Palaeo-environments: upper to middle bathyal.

Gyroidina sp. A

(Pl. 16, Figs 10-11)

Remarks: Morphotypes referred to Gyroidina sp. A have a moderately large, plano-convex, low trochospiral test (varying from c. 440/290µm to 520/400µm in maximum diameter/breadth ratio), circular in outline; dorsal side flattened to somewhat concave in the last whorl with slight convex central cone; ventral side strongly convex; equatorial periphery sharply rounded; 6 to 7 chambers in the last whorl, increasing gradually in size; sutures indistinct (under the S.E.M.), flush; smooth surface. The specimens are somewhat similar to Gyroidina bandyi (Trujillo, p. 332-333, pl. 48, figs 7a-c), but differ in their more asymmetrical, plano-convex test morphology.

Range: late Coniacian-Santonian to Campanian.

Occurrence: wells 1-SES-1A, 1-SES-9 (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Genus **GYROIDINOIDES** Brotzen, 1942

Type species: Rotalina nitida Reuss, 1844

Gyroidinoides ex gr. globosa (Hagenow)

(Pl. 16, Figs 12-18)

Nonionina globosa Hagenow, 1842, p. 574 (fide Cushman, 1946, p. 140).

Gyroidina globosa (Hagenow). Cushman, 1946, p. 140, pl. 58, fig.7a-c (not figs 6, 8)

Gyroidinoides globosa (Hagenow). Hofker, 1957, p.395, text-fig. 441.

Valvulineria crespinae Ludbrook. Haig, 1982, p. 57, pl. 11, figs 18-20, pl. 12, fig. 23

Gyroidinoides globosus (Hagenow). Dailey, 1983, pl. 7, figs 7-8.

Remarks: Gyroidinoides ex gr. globosa morphotypes are distinguished by having a globular, trochospiral test (varying from c. 240/200µm to 380/300µm in maximum diameter/breadth ratio); dorsal side moderately convex, rounded; equatorial periphery broadly rounded, with not clearly delineated peripheral shoulder; aperture a low interiomarginal slit extending from the periphery to the umbilicus; surface smooth. This is a long ranging species-group.

Range: late Aptian to Albian, late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: deep neritic to upper bathyal (late Aptian-Albian biotopes), upper to middle bathyal (late Coniacian-Maastrichtian biotopes).

Gyroidinoides loetterlei (Tappan)

(Pl. 16, Figs 19-23)

Gyroidina loetterlei Tappan, 1940, p. 120-121, pl. 10, fig. 10a-c.

Remarks: Gyroidinoides loetterlei morphotypes are distinguished by their small, subglobular, somewhat lobate, low trochospiral test (varying from c. 220/170µm to 230/180µm in maximum diameter/breadth ratio), subcircular in outline; equatorial periphery broadly rounded; dorsal side moderately convex; ventral side somewhat depressed around the umbilical flap; 5 to 6 chambers in the last whorl, increasing gradually in size, last chamber inflated with umbilical flap covering the aperture and umbilicus; sutures distinct, slightly depressed; surface smooth. The specimens differ from Gyoidinoides ex gr. nitida (Reuss) by having a distinctly inflated last chamber, depressed ventral side and larger umbilical flap.

Range: Campanian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Gyroidinoides ex gr. nitida (Reuss)

(Pl. 16, Figs 24-27)

Rotalina nitida Reuss, 1845, p. 35, pl. 8, fig. 52, pl. 12, figs 8, 20.

Gyroidina globosa (Hagenow). Cushman & Hedberg, 1941, p. 97, pl. 23, fig. 14a-c.

Gyroidina globosa (Hagenow). Cushman, 1946, p.140, pl. 58, fig. 8a-c (not figs 6-7).

Gyroidinoides nitida (Reuss). Hofker, 1957, p. 393-395, text-figs 437-440.

Gyroidinoides primitiva Hofker, 1957, p. 393, text-fig. 436.

Gyroidina nitida (Reuss). Trujillo, 1960, p. 331-332, pl. 48, fig. 2a-c.

Gyroidinoides nitidus (Reuss). Sliter, 1968, p. 121, pl. 22, fig.7a-c.

Gyroidinoides nitidus (Reuss). Hanzlíková, 1972, p. 129, pl. 37, fig. 99a-c.

Valvulineria angulata Magniez-Jannin, 1975, p. 243-245, pl. 16, figs 23-28.

Valvulineria/Gyroidinoides/ praestans Magniez-Jannin, 1975, p. 244-246, pl. 16, figs 32-44.

Valvulineria parva Khan f. dilatata Magniez-Jannin, 1975, p. 241, pl. 16, figs 14-17.

Gyroidinoides nitidus (Reuss). Sliter, 1977b, pl. 12, figs 7-8.

Gyroidinoides nitidus (Reuss). Dailey, 1983, pl. 7, figs 10-12.

Remarks: There is considerable morphological variation in this long ranging species-group. The morphotypes are distinguished by having a subglobular, low trochospiral test (varying from c. 240/190µm to 360/260µm in maximum diameter/breadth ratio), circular in outline; dorsal side flattened to slightly concave in the last whorl with some specimens showing a central cone of variable height; ventral side strongly convex; equatorial periphery rounded forming a distinct narrowly rounded shoulder with the dorsal side; 6 to 7 chambers in the last whorl, increasing gradually in size, somewhat inflated on the ventral side; umbilicus open, narrow; sutures distinct, slightly curved and depressed on dorsal side, nearly radial and slightly depressed on ventral side; surface smooth. The specimens differ from Gyroidinoides ex gr. globosa morphotypes in their flattened to slightly convex dorsal side and distinct peripheral shoulder. There are, however, several transitional specimens (e.g., Pl. 16, Figs 14-16) and the morphotypes may actually represent intraspecific polymorphism of a common ancestral taxon.

Range: late Aptian to early Cenomanian, late Coniacian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: deep neritic to upper bathyal (late Aptian-early Cenomanian biotopes), upper to middle bathyal (late Coniacian-Maastrichtian biotopes.

Gyroidinoides nonionoides (Bandy)

(Pl. 16, Figs 28-33)

Valvulineria cf. V. umbilicata (d'Orbigny). Cushman, 1946, p. 139, pl. 57, fig. 9a-c (not figs 10-12).

Valvulineria nonionoides Bandy, 1951, p. 504, pl. 74, fig. 5.

Gyroidina nonionoides (Bandy). Sliter, 1968, p. 117-118, pl. 21, fig. 6a-c.

Gyroidinoides sp. indet., Beckmann, 1978, p. 767, pl. 4, figs 30-32.

Remarks: Specimens of Gyroidinoides nonionoides are characterised by their nearly biconvex, low trochospiral test (varying from c. 220µm to 400µm in maximum diameter), with flattened dorsal side; equatorial periphery broadly rounded; 7 to 9 chambers in the last whorl, increasing gradually in size and becoming distinctly inflated in the last ones; sutures distinct, depressed, radial and slightly depressed; aperture an extraumbilical-umbilical interiomarginal slit; surface smooth.

Range: late Campanian to early Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-CRL-1-SE.

Palaeo-environments: upper to middle bathyal.

Gyroidinoides quadrata (Cushman & Church)

(Pl. 17, Figs 1-5)

Gyroidina quadrata Cushman & Church, 1929, p.516, pl.41, figs 7-9.

Gyroidinoides quadratus (Cushman & Church). Sliter, 1968, p. 121, pl. 22, fig. 8a-c.

Gyroidinoides quadratus (Cushman & Church). Sliter, 1977b, pl. 11, figs 4-5, 7.

Gyroidina quadrata Cushman & Church. Beckmann, 1978, p.767, pl.4, fig. 6.

Gyroidinoides quadratus (Cushman & Church). Dailey, 1983, pl. 8, figs 2-4.

Remarks: Specimens of *Gyr'des quadrata* are characterised by having a concavo-convex, trochospiral test (varying from c. 300µm to 420µm in maximum diameter), circular in outline; equatorial periphery subacute; ventral side strongly convex; dorsal side concave in the last whorl, with the first whorls forming a central cone; 5 to 6 chambers in the last whorl, increasing gradually in size, somewhat inflated on the ventral side; sutures distinct, radial, flush to slightly depressed; surface smooth.

Range: late Coniacian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to middle-lower bathyal.

Family **GLOBOROTALITIDAE** Loeblich & Tappan, 1984

Genus **GLOBOROTALITES** Brotzen, 1942

Type species: *Globorotalia multisepta* Brotzen, 1936

Globorotalites elkensis Kent

(Pl. 17, Figs 6-10)

Globorotalites elkensis Kent, 1967, p. 1451, pl. 184, figs 5-6.

Remarks: *Globlorotalites elkensis* morphotypes are distinguished by having a moderately small, plano-convex, low trochospiral test (c. 250-330µm in maximum diameter), subcircular in outline; dorsal side flattened to slightly concave; ventral side moderately convex; 8 chambers in the last whorl, increasing gradually in size, the last ones somewhat inflated; umbilicus broad and shallow; sutures distinct, slightly curved and depressed on the umbilical side, curved and flush to slightly depressed on the dorsal side; surface smooth, more coarsely perforate on the ventral side, dorsal side with only few scattered pores.

Range: late Coniacian.

Occurrence: well 1-CRL-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Globorotalites* ex gr. *micheliniana (d'Orbigny)

(Pl. 17, Figs 11-17)

Rotalina micheliniana d'Orbigny, 1840, p. 31, pl. 3, figs 1-3.

Globorotalia micheliniana (d'Orbigny). Cushman, 1946, p. 152, pl. 63, figs 2-3.

Globorotalites micheliniana (d'Orbigny). ten Dam & Magné, 1948, p. 223-224, fig. 8a-c.

Globorotalites sp. 3, ten Dam & Magné, 1948, p. 226-227.

Globorotalites michelinianus (d'Orbigny). Hofker, 1957, p. 405-408, text-figs 460-466.

Globorotalites michelinianus (d'Orbigny). Sliter, 1968, p.119, pl. 22, fig. 1a-c.

Globorotalites michelinianus (d'Orbigny). Hanzlíková, 1972, p. 128, pl. 37, figs 7-8.

Globorotalites micheliniana (d'Orbigny). Hart *et al.*, 1981, p. 200, pl. 7.14, figs 1-2.

Globorotalites micheliniana (d'Orbigny). Hart *et al.*, 1989, p. 342, pl. 7.14, figs 1-2.

Remarks: *Globorotalites* ex gr. *micheliniana* morphotypes are characterised by having a plano-convex, low trochospiral test, circular in outline and variable in size (varying from c. 240/140μm to 500/270μm in maximum diameter/breadth ratio); flattened dorsal side and strongly convex ventral side; equatorial periphery acute, carinate; 6 to 7 chambers in the last whorl, increasing gradually in size; low and slitlike interiomarginal aperture, at base of the last chamber, about midway between the umbilicus and periphery; surface smooth. This is a long ranging species-group.

Range: early to middle Albian, late Coniacian to Maastrichtian.

Occurence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: deep neritic to upper bathyal (early-middle Albian), upper to middle bathyal (late Coniacian-Maastrichtian biotopes).

Globorotalites multisepta (Brotzen)

(Pl. 17, Figs 18-23)

Globorotalia multisepta Brotzen, 1936, p. 161, pl. 11, figs 6-7, text-figs 59-61.

Globorotalites multisepta (Brotzen). ten Dam & Magné, 1948, p. 224-225, figs 1-3.

Globorotalites multiseptus (Brotzen). Hofker, 1957, p. 408-410, text-figs 467-469.

Globorotalites multiseptus (Brotzen). Hanzlíková, 1972, p. 128, pl. 37, figs 4-5.

Remarks: Specimens of Globorotalites multisepta are characterised by having a moderately small, plano-convex, low trochospiral test (c. 220-330μm in maximum diameter), circular in outline; dorsal side flattened on the last whorl with slightly convex central cone; ventral side moderately convex; equatorial periphery subacute to carinate; 8 to 9 chambers in the last whorl, increasing slowly in size; umbilicus narrow; sutures somewhat indistinct on the ventral side, oblique to curved and slightly depressed on the dorsal side; surface smooth. The specimens are somewhat similar to Globorotalites umbilicata (Loetterle) - (cf. ten Dam & Magné, 1948, p. 225-226, figs 6-7), but differ in having a narrow umbilicus and slightly convex dorsal side, rather than concave.

Range: late Coniacian.

Occurrence: well 1-CRL-1-SE (rare occurrence).

Palaeo-environments: upper bathyal.

Globorotalites sp. cf. G. multisepta (Brotzen)

(Pl. 17, Figs 24-26)

cf. Globorotalia multisepta Brotzen, 1936, p. 161, pl. 11, figs 6-7, text-figs 59-61.

Remarks: Specimens assigned to Globlorotalites sp. cf. G. multisepta have a large, plano-convex, low trochospiral test (c. 370-520μm in maximum diameter), subcircular in outline; dorsal side slightly convex; equatorial periphery carinate; 9 chambers in the last whorl, increasing gradually in size; umbilicus narrow and deep; sutures distinct, radial to curved in the ventral side, strongly curved on the dorsal side; surface smooth. The morphotypes differ from Globorotalites multisepta (Brotzen) in their larger test size, more convex ventral side, carinate equatorial periphery and more curved sutures on the dorsal side.

Range: late Aptian to middle Albian.

Occurrence: well 1-US-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Globorotalites spinea (Cushman)

(Pl. 17, Figs 27-31)

Truncatulina spinea Cushman, 1926a, p. 22, pl. 2, fig. 10a-c.
Eponides? spinea (Cushman). Cushman, 1946, p. 142, pl. 57, fig. 16
Globorotalites spineus (Cushman). Sliter, 1968, p. 119-120, pl. 22, fig. 4a-c.
Globorotalites spineus (Cushman). Sliter, 1977b, pl. 11, fig. 8.
Globorotalites spineus (Cushman). Beckmann, 1978, p. 766, pl. 4, figs 21, 27.

Remarks: Specimens of Globlorotalites spinea have a moderately small, plano-convex, low trochospiral test (c. 240-340μm in maximum diameter); equatorial periphery acute, with short spines at each suture; dorsal side flat to somewhat concave, some specimens with slightly convex central cone; ventral side moderately to strongly convex; about 6 chambers in the last whorl, increasing gradually in size; sutures distinct, flush to slightly depressed on the ventral side; surface smooth, finely perforate.

Range: late Coniacian to early Santonian.

Occurrence: wells 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Globorotalites subconica (Morrow)

(Pl. 17, Figs 32-36)

Globorotalia subconica Morrow, 1934, p. 200, pl. 30, figs 10-11.
Globorotalia subconica Morrow. Cushman, 1946, p. 153, pl. 63, fig. 4a-c.
Globorotalites subconica (Morrow). ten Dam & Magné, 1948, p. 225, figs 4-5.
Globorotalites subconicus (Morrow). Hofker, 1957, p. 404-405, text-figs 456-459.

Remarks: Globlorotalites subconica morphotypes have a small, plano-convex, subconical, low trochospiral test (c. 230-240μm in maximum diameter), circular in outline; dorsal side slightly convex or flattened; equatorial periphery subacute; umbilicus moderately narrow and deep; 6 chambers in the last whorl, increasing gradually in size; sutures distinct, flush to slightly depressed, curved; surface smooth.

Range: Campanian.

Occurrence: wells 1-CA-1-SE, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Family **OSANGULARIIDAE** Loeblich & Tappan, 1964

Genus **OSANGULARIA** Brotzen, 1940

Type species: *Osangularia lens* Brotzen, 1940.

Osangularia cordieriana (d'Orbigny)

(Pl. 18, Figs 1-3)

Rotalina cordieriana d'Orbigny, 1840, p. 33, pl. 3, figs 9-11.

Osangularia cordieriana (d'Orbigny). Hofker, 1957, p. 389, text-fig. 433a-g.

Osangularia cordieriana (d'Orbigny). Sliter, 1968, p. 118-119, pl. 21, fig. 9a-c.

Osangularia cordieriana (d'Orbigny). Hanzlíková, 1972, p. 127, pl. 36, fig. 12a-c.

Osangularia cordieriana (d'Orbigny). Sliter, 1977b, pl. 9, figs 1-3,6.

Osangularia cordieriana (d'Orbigny). Hart *et al.*, 1981, p. 212, pl. 7.20, figs 4-6.

Osangularia cordieriana (d'Orbigny). Dailey, 1983, pl. 6, figs 4,7-8.

Osangularia cordieriana (d'Orbigny). Hart *et al.*, 1989, p. 354, pl. 7.20, figs 4-6.

Remarks: Specimens of *Osangularia cordieriana* have a small, somewhat lenticular, asymmetrically biconvex, trochospiral test (c. 230-250μm in maximum diameter), with a more convex ventral side; equatorial periphery carinate; chambers increasing gradually in size; sutures distinct, depressed; surface smooth; aperture a narrow slit interiomarginal and at an acute angle to the base of the last chamber. The morphotypes differ from *Osangularia whitei* (Brotzen) in having an asymmetrically biconvex test and somewhat sigmoid periphery (cf. Hart *et al.*, 1989, p. 354).

Range: late Coniacian to Maastrichtian.

Occurrence: well 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to middle bathyal.

Osangularia navarroana (Cushman)

(Pl. 18, Figs 4-6)

Pulvinulinella navarroana Cushman, 1938b, p. 66, pl. 11, fig. 5.

Pulvinulinella navarroana Cushman. Cushman, 1946, p. 144, pl. 60, fig. 1a-c.

Osangularia navarroana (Cushman). Hart et al., 1981, p. 212, pl. 7.20, figs 7-8.

Osangularia navarroana (Cushman). Hart et al., 1989, p. 354, pl. 7.20, figs 7-8.

Remarks: The species has a large, biconvex, trochospiral test (c. 530-570µm in maximum diameter); equatorial periphery carinate; 8 to 10 chambers in the last whorl, increasing slowly in size; sutures distinct, nearly radial on the ventral side and strongly oblique on the dorsal view; aperture a narrow interiomarginal slit extending up the face of the last chamber on the ventral side; surface smooth. It differs from Osangularia velascoensis (Cushman) in having a larger test size and smooth dorsal side, with flush sutures.

Range: late Coniacian to early Campanian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3.

Palaeo-environments: upper to middle bathyal.

Osangularia schloenbachi (Reuss)

(Pl. 18, Figs 7-11)

Rotalia schloenbachi Reuss, 1863, p. 84, pl. 10, fig. 5.

Eponides utaturensis Sastri & Sastry, 1966, p. 292, pl. 19, fig. 6a-c.

Osangularia californica Dailey, 1970, p. 108-109, pl. 13, figs 3-4.

Osangularia utaturensis (Sastri & Sastry). Scheibnerovà, 1974a, p. 714, pl. 4, figs 27-28, pl. 5, figs 1-9, pl. 11, figs 4-5.

Osangularia utaturensis (Sastri & Sastry). Gradstein, 1978, p. 676, pl. 7, figs 5-12.

Osangularia schloenbachi (Reuss). Crittenden, 1983b, p. 42-43, pl. figs 5.1-14, 6.1-14, 7.1-10.

Remarks: Osangularia schloenbachi morphotypes are characterised by having a moderately large, compressed, biconvex, low trochospiral test (c. 360-400µm in maximum diameter), circular in outline; equatorial periphery acute; 10 to 12 chambers in the last whorl, increasing slowly in size; sutures distinct, curved and raised; surface smooth, finely perforate. The early record of Osangularia schloenbachi in the lower Albian strata of Sergipe recalls previous reports of coeval occurrences in the North Atlantic and western Tethyan realms. For instance: specimens reported by Gradstein (1978) from the upper Aptian-upper Albian sediments of the Blake Nose, western North Atlantic; specimens of Osangularia sp. aff. brotzeni (Gandolfi) (morphotypes identical with Osangularia schloenbachi; cf. Gradstein, op. cit., p. 676) described by Moullade (1966, p. 77-79) from the uppermost Aptian-middle Albian in the "Fosse vocontienne" of southeast France; and specimens reported by Crittenden (1983b) from the southern North Sea Basin.

Range: early to middle-late Albian.

Occurrence: wells 1-SES-1A, 1-SES-3 (rare occurrence).

Palaeo-environment: deep neritic to upper bathyal.

Osangularia velascoensis (Cushman)

(Pl. 18, Figs 12-16)

Truncatulina velascoensis Cushman, 1925, p. 20, pl. 3, fig. 2.

Pulvinulinella velascoensis (Cushman). Cushman, 1946, p. 145, pl. 60, fig. 3a-c.

Osangularia velascoensis (Cushman). Hanzlíková, 1972, p. 127, pl. 37, fi. 6a-c.

Remarks: Specimens of Osangularia velascoensis have a moderately large, lenticular, nearly symmetrical, biconvex, trochospiral test (c. 360-370µm in maximum diameter), circular in outline; equatorial periphery carinate, with a very thin broad keel; 10 chambers in the last whorl, increasing slowly in size; sutures distinct, raised and oblique on the dorsal side, flush to slightly depressed and somewhat curved on the ventral side; surface smooth, with raised and thickened sutures on the dorsal view; aperture an elongate narrow slit, at an acute angle to the base of the last chamber face.

Range: late Santonian to Maastrichtian.

Occurrence: wells 1-SES-3, 1-SES-9

Palaeo-environments: upper to middle bathyal.

Family **GAVELINELLIDAE** Hofker, 1956

Subfamily **GAVELINELLINAE** Hofker, 1956

Remarks: Most of the Cretaceous shelf and upper to middle slope sediments from Sergipe contain rare to abundant occurrences of specimens of several taxa of gavelinellids. Several closed related specimens show features of the genera Gavelinella, Lingulogavelinella and Orithostella (sensu Malapris, 1965; Malapris-Bizouard, 1967; Michael, 1966; Eicher & Worstell, 1970; and Scheibnerovà, 1971b, 1974).

Genus **GAVELINELLA** Brotzen, 1942

Type Species: Discorbina pertusa Marsson, 1878.

Remarks: Specimens of Gavelinella have a highly variable morphology. The morphotypes are characterised by having a biconvex to plano/concavo-convex, trochospiral test; dorsal side evolute, ventral side involute; umbilicus partially closed by subtriangular flaps projecting from umbilical margins of each chamber, most specimens with a small umbilical boss; dorsal boss of variable height may be present; aperture a low interiomarginal slit extending from near periphery to the umbilicus. The most diagnostic characteristics of the Gavelinella, which readily distinguishes them from the Lingulogavelinella forms, is an evolute dorsal side, rather than partially evolute or involute, and a distinct umbilicate ventral side with no umbilical boss.

Gavelinella barremiana Bettenstaedt-**Gav. flandrini** Moullade **plexus**, emended

(Pl. 18, Figs 17-20)

Gavelinella barremiana Bettenstaedt, 1952, p. 275-276, pl. 2, figs 26-29.
Gavelinella barremiana Bettenstaedt. Moullade, 1960, p. 137, pl. 2, figs 6-8
Gavelinella flandrini Moullade, 1960, p. 137-138, pl. 2, figs 10-14.

Gavelinella barremiana Bettenstaedt. Flandrin, Moullade & Porthault, 1961, p. 220-221, pl. 3, figs 14-16.
Gavelinella flandrini Moullade. Flandrin, Moullade & Porthault, 1961, p. 221, pl. 3, figs 11-13.
Gavelinella barremiana Bettenstaedt. Malapris-Bizouard, 1974, p. 13-19, pl. 1, figs 6-10

Gavelinella brielensis Malapris-Bizouard, 1974, p. 19-21, pl. 1, figs 11-16.
Gavelinella barremiana Bettenstaedt. Bartenstein & Bolli, 1977, p. 558, pl. 2, fig. 38, pl. 3, figs 1-3.
Gavelinella barremiana Bettenstaedt. Gradstein, 1978, p. 674, pl. 6, figs 14-17.
Gavelinella barremiana Bettenstaedt. Bartenstein & Kodatcheva, 1982, p. 649, pl. 4, figs 18-19.

Remarks: This gavelinellid plexus is distributed worldwide from the middle Barremian to Albian in the central North Atlantic-western Tethyan and Boreal realms (e.g., Bartenstein & Kodatcheva, 1982; Flandrin *et al.*, 1961). The morphotypes are moderately small, flattened, nearly biconvex to slightly plano/concavo-convex, nearly planispiral/low trochospiral test (c. 330-370um in maximum diameter), subcircular in outline; equatorial periphery acute; 9 to 12 chambers in the last whorl, increasing slowly in size; sutures distinct, slightly depressed, strongly curved backwards; ventral side more involute. The morphotype *Gavelinella flandrini* was distinguished from *Gavelinella barremiana* by Moullade (1960, p. 137-138) in having a more compressed, nearly biconvex test, rather than plano-convex. *Gavelinella brielensis* was proposed by Malapris-Bizouard (1974, p. 19-21) as an intermediate form between *Gavelinella barremiana* and *Gavelinella intermedia* (Bertehelin), but also falls within the morphological variability of the plexus. The morphotypes may actually represent ontogenetic or ecophenotypic polymorphs of a single taxon.

Range: late Aptian to early Albian.

Occurrence: well 1-US-1-SE (rare occurence).

Palaeo-environments: deep neritic to upper bathyal.

Gavelinella ex gr. beccariiformis (White)

(Pl. 18, Figs 21-26)

Rotalia beccariiformis White, 1928b, p. 287, pl. 39, figs 2a-c, 3a-4c (var.).

Anomalina beccariiformis (White). Cushman & Renz, 1946, p. 48, pl. 8, figs 21-22.

Gavelinella beccariiformis (White). von Hillebrandt, 1962, p. 101, pl. 8, fig. 2a-c.

Anomalina whitei Martin, 1964, p. 106, pl. 16, figs 4a-c.

Gavelinella whitei (Martin). Sliter, 1968, p. 126, pl. 24, fig. 1.

Gavelinella beccariiformis (White). Dailey, 1983, p. 766, pl. 9, figs 4, 9.

Gavelinella whitei (Martin). Hanzlíková, 1972, p. 133, pl. 38, fig. 5a-c, pl. 39, fig. 9a-c.

Gavelinella whitei (Martin). Sliter, 1977, pl. 13, figs 2-5.

Gavelinella beccariiformis (White). Beckmann, 1978, p. 766, pl. 5, figs 1-2, 3 (conical variety).

Gavelinella sp. aff. G. daini (Scijfsma). Beckmann, 1978, p. 766, pl. 5, figs 9-11.

Gavelinella beccariiformis (White). Tjalsma & Lohman, 1983, p. 12, pl. 6, figs 1a-3b.

Remarks: This species-group is characterised by having a nearly biconvex, inflated, low trochospiral test, moderately variable in size (c. 250-400μm in maximum diameter) with somewhat flattened sides; evolute flattened dorsal side; ventral side involute, slightly more convex, umbilicate; equatorial periphery broadly rounded; 9 to 11 chambers in the last whorl; sutures distinct, curved on dorsal side, indistinct, radial on ventral side; wall rather coarsely perforated; surface smooth to granular, umbilical area with small pustules arranged in depressed threadlike lines radiating from umbilicus; aperture a low interiomarginal slit extending from periphery to umbilicus.

Range: late Coniacian to Maastrichtian.

Occurrence: locality A-18, wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to lower bathyal.

Gavelinella berthelini (Keller)-**Gav. plummerae** (Tappan)-
Gav. reussi (Khan) **plexus**, emended

(Pl. 18, Figs 27-32; Pl. 19, Figs 1-4)

This gavelinellid morphogroup seems to have had an extensive global distribution in the mid-Cretaceous succession. The following is an attempt to give a comprehensive account of the reported occurrences and synonymies:

non Anomalina complanata Berthelin (non Reuss), 1880, p. 66-67, pl. 4, figs 12-13 (Montcley, France; Albian).

Anomalina berthelini Keller, 1935, p. 552-553, pl. 2, figs 25-27 (Dnjepr-Donez Basin, USSR).

Anomalina plummerae Tappan, 1940, p. 124, pl. 18, figs 15-16.

Anomalina berthelini Kellet. ten Dam, 1950, p. 56, pl. 4, figs 9a-c (eastern Netherlands; Albian).

Anomalina complanata Reuss var. reussi Khan, 1950, p. 277, pl. 2, figs 17-18 (Gault Clay Formation, southeast England; upper Albian).

Planulina dakotensis Fox, 1954, p. 119-129, pl. 26, figs 19-21 (Greenhorn Formation, South Dakota and Wyoming; upper Cenomanian -middle Turonian).

Gavelinopsis infracretacea Hofker, 1957, p. 320-321, figs 369a-e (Netherlands, middle Albian).

Anomalina complanata Reuss. Trujillo, 1960, p. 334-335, pl. 49, fig. 1a-c (California; middle Turonian).

Anomalina (Brotzenella) belorussica Akimez, 1961, p. 160-161, pl. 16, figs 1a,b,w (Byelorussia, U.S.S.R.; Albian, Cenomanian).

Gavelinopsis berthelini (Keller). Bach, 1965, p. 25-26, pl. 6, figs 3a-d (Kleinen Fallstein, east Germany; middle Albian-lower Cenomanian).

Anomalina complanata Berthelin. Malapris, 1965, pl.1, figs 1a-d (Paris Basin, Courcelles, Aube, France; Albian).

Gavelinella (Berthelina) intermedia (Berthelin). Malapris, 1965, pl. 1, fig. 5; pl. 2, figs 1a-c, 6a-c (Paris Basin, Courcelles, Aube, France; Albian).

Gavelinella tourainensis Butt, 1966, p. 176, pl. 4, figs 1-3 (Touraine, Central France; Turonian).

Gavelinopsis berthelini (Keller). Michael, 1966, p. 437-438, pl. 50, figs 18-19 (northwest Germany; lower Albian-Cenomanian).

Gavelinella intermedia (Berthelin). Michael, 1966, pl. 50, figs 12-13 (northwest Germany; lower Albian-Cenomanian).

Gavelinella berthelini (Keller). Fuchs, 1967, p. 336, pl. 18, figs 8a-c (Netherlands; middle Albian).

Gavelinella plummerae (Tappan). Eicher & Worstell, 1970, p. 293, pl. 6, figs 4-5 (Greenhorn Formation, Colorado and western Kansas; upper Cenomanian-middle Turonian).

Gavelinella (Berthelina) belorussica (Akmiez). Gawor-Biedowa, 1972, p. 116-118, pl. 16, figs 5-6, text-fig. 10 (Poland; upper Albian to lower Turonian).

Gavelinella (Berthelina) ex gr. berthelini (Keller). Malumian & Masiuk, 1976, p. 200-201, pl. 5, figs 3-5 ('Arroyo Alfa' and 'Cabeza de León' Formations, Tierra del Fuego, Argentina; Albian to lower Turonian).

Gavelinella plummerae (Tappan). Olsson, 1977, pl. 3, figs I-K (western Central North Atlantic; Turonian).

Anomalinoides berthelini (Keller). Haig, 1982, p.65, pl. 13, figs 6-8 (northern Carpentaria Basin, Queensland, Australia; upper Albian).

Gavelinella intermedia (Berthelin) var. à umbo. Juignet, Damotte, Fauconnier, Kennedy, Magniez-Jannin, Monciardini & Odin, 1983, pl. 4, figs 18-20 (Cormes and Ballon, NE France; upper Albian).

Gavelinella sp. aff. plummerae Tappan. Juignet et al., 1983, pl. 4, figs 23-26 (Courgenard, NW France; middle Cenomanian).

Gavelinella reussi (Khan). Hart & Swiecicki, 1987, fig. 8.9 (Gault Clay Formation, southeast England; upper Albian).

Gavelinella tourainensis Butt. Hart & Swiecicki, 1987, fig. 8.9 (chalk facies of southeast England; Turonian-Coniacian).

Gavelinella berthelini (Keller). Jarvis et al., 1988a, figs 11.k-l.

Gavelinella berthelini (Keller). Hart & Swiecicki, 1988, fig. 2 (Gault Clay Formation and chalk facies of southeast England; Albian).

Remarks:

The synonymy list exemplifies the morphological variability of this Gavelinella plexus. The morphotypes are characterised by having a low asymmetrically biconvex to plano-convex trochospiral test, of variable size (varying from c. 100μm to 370μm in maximum diameter), circular in outline; dorsal side convex with distinct central boss, of variable height; equatorial periphery subacute; about 7 to 10 chambers in the last whorl, increasing slowly in size; ventral side moderately convex to nearly flattened, with central umbilical thickening in the form of a small boss or hook; narrow and short, periumbilical lamellar flaps; sutures distinct, radial to slightly curved on the ventral side, slightly arcuate in the dorsal side; aperture a low interiomarginal arch extending from the periphery onto the ventral side, under the lamellar flaps.

These gavelinellid morphotypes (low asymmetrically biconvex to nearly plano-convex tests depicting a central rounded dorsal boss of variable height) are the most common benthonic foraminifera to be found associated with Cenomanian-Turonian low-oxygen neritic environments (see Chapter 5, section 5.5.2). In sections deposited under dysaerobic/quasi-anaerobic bottom conditions, the assemblages are dominated (about 30-40% of the total foraminiferal assemlage) by specimens of minute test size (c. 100-200um in maximum diameter), with lower dorsal height.

Range: late Albian to Turonian.

Occurrence: localities A-1, A-2, A-8, A-9, A-15, A-46, Pati 1, Itaporanga 2, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3.

Palaeo-environments: shallow middle neritic to upper bathyal.

Gavelinella clementiana (d'Orbigny)

(Pl. 19, Figs 5-7)

Rosalina clementiana d'Orbigny, 1840, p. 37, pl. 3, figs 23-25.

Gavelinella clementiana (d'Orbigny). Hofker, 1957, p. 294-295, text-figs 350, 352.

Gavelinella clementiana clementiana (d'Orbigny). Edwards, 1981, p. 394-395, pl. 58, figs 3-5.

Remarks: Specimens of Gavelinella clementiana are distinguished by their small, concavo-convex, trochospiral test (c. 220µm in maximum diameter), circular in outline; equatorial periphery broadly rounded; about 8 chambers in the last whorl, increasing gradually in size; dorsal side evolute, concave; ventral side involute; umbilicus covered by imperforate portici; sutures distinct, radial to slightly curved; surface finely perforate on the dorsal side and coarsely perforate ventrally.

Range: late Maastrichtian.

Occurrence: well 1-SES-1A (rare occurrence).

Palaeo-environments: upper to middle bathyal.

Gavelinella correcta (Carsey)

(Pl. 19, Figs 8-14)

Discorbis correcta Carsey, 1926, p. 45, pl. 3, fig. 5.

Planulina correcta (Carsey). Cushman & Hedberg, 1941, p. 99-100, pl. 23, fig. 10a-c.

Planulina correcta (Carsey). Cushman, 1946, p. 158, pl.65, fig. 1a-c.

Gavelinella sandidgei (Brotzen). Sliter, 1968, p. 124, pl. 23, fig. 8a-c (not fig. 7a-c).

Remarks: Specimens of Gavelinella correcta are characterised by having a moderately small (c. 250-290μm in maximum diameter), compressed, concavo-convex, low trochospiral test, subcircular in outline and lobate in the last chambers; equatorial periphery narrowly rounded to subacute, perforate; dorsal side slightly convex, with a distinct small boss, sometimes obscured by thickened sutures (Pl. 19, Figs 8-9); 7 to 9 chambers in the last whorl, increasing gradually in size, the later ones somewhat inflated; umbilicus narrow and shallow, partially closed by periumbilical flaps projecting from each chamber; sutures distinct, curved, raised or flush in the early stage on the dorsal side, later depressed; aperture a low interiomarginal arch extending from periphery to umbilicus; surface smooth, finely perforate. The specimens somewhat resemble low trochospiral morphotypes of the Gavelinella berthelini (Keller)-Gav. plummerae (Tappan)-Gav. reussi (Khan) plexus, but differ in having a more asymmetrical, compressed, concavo-convex test, subcircular outline, with chambers increasing more rapidly in size, lower dorsal boss and an umbilicus partially to completely closed by periumbilical imperforate flaps, with no clearly defined umbilical boss.

Range: late Coniacian-Santonian to Campanian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE.

Palaeo-environments: deep neritic to upper bathyal.

Gavelinella lorneiana (d'Orbigny)

(Pl. 19, Figs 15-19)

Rosalina lorneiana d'Orbigny, 1840, p. 36, pl. 3, figs 20-22.

Cibicides mendesi Petri, 1962, p. 131-132, pl. 21, fig. 2a-c -paratype (not figs 1, 3).

Gavelinella lorneiana (d'Orbigny) var. A. Edwards, 1981, p. 397, pl. 56, fig. 6.

Remarks: Gavelinella lorneiana is characterised by having a small, low, concavo-convex, trochospiral test (c. 280-300µm in maximum diameter), nearly circular in outline; equatorial periphery subacute; ventral side concave; about 10 chambers in the last whorl, increasing slowly in size; last chamber moderately inflated; sutures distinct, depressed, strongly curved; surface smoth, finely perforate.

Range: Campanian.

Occurrence: locality A-18, well 1-CN-1-SE.

Palaeo-environments: middle-deep neritic to upper bathyal.

Gavelinella ex gr. monterelensis (Marie)

(Pl. 19, Figs 20-27)

Anomalina monterelensis Marie, 1941, p.243, pl.37, fig. 342a-c.

Gavelinella monterelensis (Marie). Dailey, 1983, p. 766, pl. 8, figs 9, 13.

Gavelinella monterelensis (Marie). Hanzlíková, 1972, p. 131, pl. 39, fig. 3a-c.

Gavelinella monterelensis (Marie). Edwards, 1981, p. 397, pl. 58, figs 15-17.

Gavelinella monterelensis (Marie). Hart et al., 1981, p. 196, pl. 7.12, figs 1-3.

Gavelinella monterelensis (Marie). Hart et al., 1989, p. 338, pl. 7.12, figs 1-3.

Remarks: Gavelinella ex gr. monterelensis morphotypes are distinguished by their nearly biconvex, moderately low trochospiral test, circular in outline and variable in size (varying from c. 300µm to 490µm in maximum diameter); equatorial periphery acute; dorsal side more strongly convex, with distinct boss of variable size and height; ventral side involute, with small umbilical boss; 10 to 11 chambers in the last whorl, increasing slowly in size; sutures distinct, curved, slightly raised on the early stage of the last whorl, later flush to somewhat depressed; aperture a low equatorial, interiomarginal slit, at base of final chamber, extending to umbilicus; surface smooth, finely perforate.

Range: late Campanian to Maastrichtian.

Occurrence: locality A-18, wells 1-CA-1-SE, 1-SES-1A, 1-SES-3.

Palaeo-environments: deep neritic to upper-middle bathyal.

Gavelinella nacatochensis (Cushman)

(Pl. 19, Figs 28-31)

Planulina nacatochensis Cushman, 1938, p. 50, pl. 8, fig. 9.

Planulina nacatochensis Cushman. Cushman, 1946, p. 158, pl. 65, fig. 2a-c.

Gavelinella talaria (Nauss). Kent, 1967, p.1453-1454, pl. 184, fig. 10a-c.

Gavelinella nacatochensis (Cushman). Sliter, 1968, p. 124, pl. 23, figs 4-5.

Gavelinella nacatochensis (Cushman). Dailey, 1983, p. 766, pl. 10, figs 4,7-8.

Gavelinella nacatochensis (Cushman). Sliter, 1977b, pl. 12, fig. 6.

Remarks: Specimens of Gavelinella nacatochensis have a small, compressed, biconvex, low trochospiral test (c. 200-240μm in maximum diameter), subcircular in outline; equatorial periphery narrowly rounded; ventral side nearly involute; 7 to 9 chambers in the last whorl, increasing gradually in size; umbilicus small, shallow; sutures distinct, slightly raised in early stage of last whorl, later depressed, curved on both sides; aperture a low interiomarginal arch extending from the peripheral margin to the umbilicus; surface smooth, finely perforate.

Range: Campanian to Maastrichtian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-1A, 1-SES-9, 1-SES-3, 1-SES-24.

Palaeo-environments: deep neritic to middle bathyal.

Gavelinella sandidgei (Brotzen)

(Pl. 19, Figs 32-36)

Cibicides sandidgei Brotzen, 1936, p. 191, pl. 14, figs 2-4.

Gavelinella sandidgei (Brotzen). Hofker, 1957, p. 315-316, text-fig. 358.

Gavelinella sandidgei (Brotzen). Sliter, 1968, p. 124, pl. 23, fig. 7a-c (not fig. 8a-c).

Gavelinella sandidgei (Brotzen). Hanzlíková, 1972, p. 132, pl. 39, fig. 4a-c.

Remarks: Gavelinella sandidgei morphotypes are distinguished by their small, somewhat compressed, plano-convex, low trochospiral test (c. 220-250μm in maximum diameter), nearly circular in outline; equatorial periphery subacute; dorsal side convex, with small central boss; ventral side flat, involute, with umbilical boss; 8 chambers in the last whorl, increasing rather gradually in size; sutures distinct, curved, flush to slightly depressed; aperture a low interiomarginal arch extending from periphery to umbilicus; imperforate, subtriangular flaps projecting from each chamber; surface smooth, ventral side finely perforate, dorsal side with only few scattered pores. The specimens are somewhat similar to Gavelinella correcta (Carsey), but differ in their less compressed, distinct plano-convex tests, smaller in size, with a scattered perforate dorsal side.

Range: late Coniacian to Campanian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-9.

Palaeo-environments: middle neritic to upper bathyal.

Gavelinella spissocostata (Cushman)

(Pl. 20, Figs 1-4)

Planulina spissocostata Cushman, 1938, p. 69, pl. 12, fig. 4.

Planulina spissocostata Cushman. Cushman & Hedberg, 1941, pl. 99, pl. 23, fig. 24.

Planulina spissocostata Cushman. Cushman, 1946, p. 157-158, pl. 64, fig. 13a-c.

Gavelinella spissocostata (Cushman). Olsson & Nyong, 1984, pl. 3, figs 11-13.

Remarks: Specimens of Gavelinella spissocostata are characterised by their moderately large, compressed, plano-convex, nearly planispiral/low trochospiral test (c. 470-530µm in maximum diameter), circular to subcircular in outline; equatorial periphery carinate; dorsal side slightly convex, somewhat evolute, with small rounded boss in the centre; ventral side flattened, involute, with umbilical boss, hook-shaped; 12 to 14 chambers in the last whorl, increasing gradually in size; sutures distinct, curved, strongly raised and thickened on both sides; surface finely perforate, smooth, except for the thickened sutures.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-24.

Palaeo-environments: upper to middle bathyal.

Gavelinella thalmanni (Brotzen).

(Pl. 20, Figs 5-10)

Cibicides thalmanni Brotzen, 1936, p. 190-191, pl. 4, fig. 7a-c.

Gavelinella clementiana (d'Orbigny) var. thalmanni (Brotzen). Hofker, 1957, p. 295-297, text-fig. 351.

Gavelinella thalmanni (Brotzen). Edwards, 1981, p. 404, pl. 58, figs 7-11.

Remarks: Specimens of Gavelinella thalmmanni are distinguished by their small, plano-convex to somewhat biconvex, low trochospiral test (c. 200-230µm in maximum diameter), subcircular in outline; equatorial periphery rounded, imperforate along the early chambers of the last whorl; about 7 chambers in the last whorl, increasing gradually in size; sutures somewhat indistinct, slightly raised to depressed in the later chambers; surface finely perforate.

Range: late Coniacian.

Occurrence: well 1-CRL-1-SE (rare occurrence).

Palaeo-environments: deep neritic to upper bathyal.

Gavelinella ex gr. velascoensis (Cushman)

(Pl. 20, Figs 11-16)

Anomalina velascoensis Cushman, 1925, p. 21, pl. 3, fig. 3.

Anomalina rubiginosa Cushman, 1926b, p. 607, pl. 21, fig. 6a-c.

Anomalina rubiginosa Cushman. Cushman, 1946, p. 156, pl. 64, figs 4-6.

Anomalinoides pinguis (Jennings). Graham & Church, 1963, p. 65, pl. 8, fig. 2.

Gavelinella rubiginosa (Cushman). Hanzlíková, 1972, p. 132, pl. 38, figs 7-8.

Gavelinella velascoensis (Cushman). Sliter, 1977b, pl. 13, fig. 1.

Anomalinoides pinguis (Jennings). Olsson, 1977, pl. 4, figs F-G.

Gavelinella cf. velascoensis (Cushman). Beckmann, 1978, p. 766, pl. 5, figs 19-22.

Remarks: Gavelinella ex gr. velascoensis morphotypes are characterised by their large, nearly biconvex to plano-convex, closely coiled, low trochospiral test (c. 350-380µm in maximum diameter -neanic/early ephebic stage; c. 500-560µm -gerontic stage), circular to subcircular in outline; equatorial periphery broadly rounded; dorsal side partially evolute, nearly flattened, with irregularly thickened sutures and hook-shaped boss; ventral side convex, involute; about 7 to 8 somewhat inflated chambers in the last whorl, increasing gradually in size; sutures rather indistinct, slightly depressed in the last few chambers; surface coarsely perforate in neanic/early ephebic forms, pores rather scattered and obscured by wall thickening on gerontic specimens.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9.

Palaeo-environments: upper to middle bathyal.

Gavelinella sp. A

(Pl. 20, Figs 17-25)

Remarks: Gavelinella sp. A morphotypes are characterised by having a small, plano/concavo-convex, low trochospiral test (c. 200-300µm in maximum diameter), subcircular in outline and moderately lobate in the last chambers; equatorial periphery narrowly rounded, imperforate; dorsal side convex, with small central boss; ventral side flat to slightly concave, involute; 7 to 8 chambers in the last whorl, increasing rather rapidly in size, slightly inflated in the last ones; sutures distinct, curved, flush to slightly depressed; aperture a low interiomarginal arch extending from periphery to umbilicus; imperforate, subtriangular flaps projecting from each chamber, partially closing the umbilicus; surface smooth, ventral side coarsely perforate, dorsal side with only few scattered pores. They differ from Gavelinella sandidgei (Brotzen) by having a plano/concavo-convex test, subcircular and moderately lobate in outline, narrowly rounded periphery, rather than subacute, and less distinct dorsal boss. The specimens somewhat resemble plano/concavo-convex gavelinellids described as Lingulogavelinella(?) cibicidoides by Malapris (1965, p. 144, 146, pl. 4, figs 9-11), from the lower-middle Albian of Aube, France. However, the taxonomic affinity between these morphotypes can only be assessed after further examination of holotypes and topotype material.

Range: Cenomanian to early Coniacian (the greatest abundance in the early Coniacian).

Occurrence: localities A-1, A-9, A-10, A-11, Mata 10, Tabocas 2

Palaeo-environments: shallow to middle neritic.

Genus **LINGULOGAVELINELLA** Malapris, 1965

Type Species: Lingulogavelinella albiensis Malapris, 1965

Remarks: Lingulogavelinella morphotypes are characterised by a low, almost flat, trochospiral test; ventral side concave, flat or slightly convex, with a closed umbilicus and characteristic tongue-like extensions of the chamber walls forming a stellate umbilical pattern. Aperture an interiomarginal equatorial arch, extending from the periphery to the umbilicus (cf. Loeblich & Tappan, 1988, p. 641).

Lingulogavelinella ciryi Malapris-Bizouard

(Pl. 20, Figs 26-31)

Lingulogavelinella ciryi ciryi Malapris-Bizouard, 1967, p. 137-138, pl. 1, figs 16-19, pl. 2, figs 16-20.

Lingulogavelinella aff. ciryi ciryi Malapris-Bizouard. Maync, 1973, p. 1099, pl. 4, figs 6-11.

Lingulogavelinella ciryi Malapris-Bizouard. Gradstein, 1978, pl. 5, figs 9, 13-17.

Remarks: Abundant specimens of minute gavelinellids (c. 130-160µm in maximum diameter) occur in the lowermost marine section (upper Aptian to early Albian) of Sergipe. They are characterised by their very small size, compressed, nearly biconvex, low trochospiral test, circular to subcircular in outline; equatorial periphery narrowly rounded; 6 to 8 chambers in the last whorl, increasing gradually in size; ventral side with well developed imperforate apertural flaps, each partially overlapping and concealing the previous one.

Range: late Aptian to early Albian.

Occurrence: locality A-38, wells 7-CP-252-SE, 1-US-1-SE.

Palaeo-environments: shallow to middle neritic (rare specimens occur in deep neritic-upper bathyal environments drifted by bottom currents).

Lingulogavelinella(?) sp. cf. L. thalmanniformis (Plotnikova)

(Pl. 21, Figs 1-7)

cf. Anomalina (Pseudovalvulineria) thalmanniformis Plotnikova, 1962, p. 53, pl. II, fig. 2.

Lingulogavelinella(?) sp. aff. L. thalmanniformis. Malapris, 1965, p. 142, 143, pl. 3, figs 7-13.

Remarks: Lingulogavelinella(?) sp. cf. L. thalmanniformis morphotypes are characterised by having a minute, concavo-convex, low trochospiral test (c. 200-330µm in maximum diameter), subcircular in outline and lobate in the last 2 or 3 chambers; equatorial periphery narrowly rounded; dorsal side slightly convex and evolute; 6 to 7 chambers in the last whorl, increasing rather rapidly in size; the last chamber somewhat inflated and the penultimate one is partially overlapped; umbilicus completely masked by periumbilical flaps; sutures distinct, depressed, slightl curved; surface smooth, finely perforate. The specimens resemble forms of Valvulineria in chamber arrangement and wall structure (cf. Malapris, 1965, p. 144).

Range: Cenomanian to early Turonian.

Occurrence: localities A-1, A-2, A-9, A-22, A-35, well 1-US-1-SE.

Palaeo-environments: middle neritic to upper bathyal.

Ligulogavelinella tormarpensis (Brotzen)

(Pl. 21, Figs 8–13)

Gavelinella tormarpensis Brotzen, 1942, p. 52, pl. 1, fig. 6.
Gavelinella tormarpensis Brotzen. Malapris, 1965, p. 148, pl. 3, figs 1–4.
Gavelinella tormarpensis Brotzen. Carter & Hart, 1977, p.48, pl. 1, figs 31–32.

Remarks: Specimens of *Lingulogavelinella tormarpensis* are characterised by their minute, compressed, biconvex, low trochospiral test (c. 160–210μm in maximum diameter), nearly circular in outline; equatorial periphery narrowly rounded; dorsal side evolute; ventral side involute, with a slightly opened umbilicus; 6 to 7 chambers in the last whorl, increasing gradually in size; each chamber projects a more or less large imperforate flap towards the umbilicus, partially covering it; aperture a low interiomarginal equatorial arch extending onto the ventral side; surface smooth, finely perforate. The morphotypes somewhat resemble *Lingulogavelinella*(?) sp. cf. *L. thalmanniformis* (Plotnikova), with which *Lingulogavelinella tormarpensis* is linked by intermediate forms (cf. Malapris, 1965, p. 146). They differ, however, in having a more laterally compressed, biconvex test, nearly circular in outline, distinct imperforate periumbilical flaps and slightly opened umbilicus. The species is placed in *Lingulogavella* Malapris on the basis of its apertural characteristics, which are apparently more closely related to *Lingulogavelinella* morphotypes than to *Gavelinella*.

Range: Cenomanian to early Coniacian.

Occurrence: localities A-1, A-6, A-10, Cruzes 15, well 1-US-1-SE.

Palaeo-environments: middle to deep neritic.

Genus **ORITHOSTELLA** Eicher & Worstell, 1970

Type species: *Orithostella viriola* Eicher & Worstell, 1970
(= *Cibicidina halfeldi* Petri, 1962)

Orithostella ex gr. halfeldi (Petri)

(Pl. 21, Figs 14-19)

Cibicidina halfeldi Petri, 1962, p. 132-134, pl. 20, figs 4-5, pl. 21, figs 4-6.
Orithostella viriola Eicher & Wortell, 1970, p. 295, pl. 6, figs 6-8, 10.

Remarks: Specimens of Orithostella ex gr. halfeldi are distinguished by having a small, plano-convex, trochospiral test (c. 170-250µm in maximum diameter), circular to subcircular in outline; equatorial periphery subacute; dorsal side strongly convex to subconical (c. 80-100µm in height), nearly involute, the last whorl entirely covers the preceding ones, some specimens with a small central boss; ventral side flattened, involute, commonly with a thickened umbilical boss; 7 to 8 chambers in the last whorl, increasing slowly to gradually in size; sutures distinct, curved, flush to slightly depressed; aperture an interiomarginal equatorial arch extending onto the flat ventral side around the apertural flaps, with the open sutural apertures of previous chambers forming a stellate periumbilical pattern; surface smooth, finely perforate. The late Coniacian-Maastrichtian specimens of Sergipe are closely similar to Orithostella viriola, described by Eicher & Worstell (1970, p. 294, pl. 6, figs 6-8, 10) from the upper Cenomanian-middle Turonian of the Greenhorn Formation, western interior of the United States. Orithostella ex gr. halfeldi differ mostly in having smaller tests with somewhat less steeper sides. However, transitional morphotypes are recorded, which suggest more likely an intraspecific relationship. Therefore, on this basis and until further evidence is produced, Orithostella viriola is placed as a junior synonym of the Orithostella halfeldi species-group.

Range: late Coniacian to Campanian.

Occurrence: locality A-18, wells 1-CA-1-SE, 1-SES-3.

Palaeo-environments: deep neritic to upper-middle bathyal.

Genus **STENSIOEINA** Brotzen, 1936

Type species: Rotalia exsculpta Reuss, 1860

Stensioeina sp. A

(Pl. 21, Figs 20-25)

Remarks: Specimens of Stensioeina sp. A are characterised by having a moderately large, plano-convex, low trochospiral test (c. 390µm in maximum diameter), subcircular in outline; equatorial periphery broadly to narrowly rounded; about 7 to 8 chambers in the last whorl, increasing gradually in size; dorsal side flat and evolute, with limbate sutures that are strongly raised in somewhat irregular ridges; ventral side involute, strongly convex, with more nearly radial sutures; aperture a low interiomarginal opening between the umbilicus and periphery. The morphotypes are probably related to the Stensioeina exsculpta (Reuss) species-group.

Range: late Santonian.

Occurrence: well 1-SES-3 (rare occurrence).

Palaeo-environments: middle bathyal.

Family **KARRERIIDAE** Saidova, 1981

Genus **KARRERIA** Rzehak, 1891

Type species: Karreria fallax Rzehak, 1891

Karreria sp. A

(Pl. 21, Figs 26-29)

Remarks: A single specimen assigned to Karreria sp. A was recovered from the upper Campanian. It is characterised by having a very large, elongate test (c. 870µm in maximum length; c. 450µm in maximum width); early portion with short trochospiral coil of one whorl, followed by a rectilinear uniserial stage, with broad and low chambers; aperture terminal, elliptical, bordered by a slight lip and produced on short neck; sutures distinct, slightly depressed; surface finely perforate, ornamented with numerous fine longitudinal striae (Pl. 21, Fig. 29).

Range: late Campanian.

Occurrence: well 1-SES-9 (rare occurence).

Palaeo-environments: upper to middle bathyal.

Suborder **GLOBIGERININA**
Delage & Hérouard, 1896

Superfamily **HETEROHELICACEA**
Cushman, 1927

Family **GUEMBELITRIIDAE**
Montanaro Gallitelli, 1957

Genus **GUEMBELITRIA** Cushman, 1933
Type species: Guembelitria cretacea Cushman, 1933

Guembelitria cenomana (Keller)
(Pl. 22, Figs 1-3)

Guembelina cenomana Keller, 1935, p. 547-548, pl. 2, figs 13, 14.
Guembelitria harrisi Tappan, 1940, p. 115, pl. 19, figs 2a-b.
Guembelitria harrisi Tappan. Pessagno, 1967, p. 258, pl.48, figs 12-13.
Guembelitria cenomana (Keller). Masters, 1977, p. 481-482, pl. 27, figs 1, 3.

Remarks: Guembelitria cenomana differs from Guembelitria cretacea Cushman by having less inflated chambers and a low, slightly arched aperture, with a test often tending to appear somewhat less elongate than that of Guembelitria cretacea. All specimens are very small (around 150-210µm in maximum length).

Range: latest Albian to Turonian.

Occurrence: localities A-2, A-9, A-17, A-21, wells 1-US-1-SE, 1-SES-24.

Guembelitria cretacea Cushman
(Pl. 22, Figs 4-5)

Guembelitria cretacea Cushman, 1933a, p. 37-38, pl.4, figs 12a-b.
Guembelitria cretacea Cushman. Loeblich & Tappan, 1964, p. C652, fig.523: 1a-b.
Guembelitria cretacea Cushman. Pessagno, 1967, p. 258, pl. 87, figs 1-3.

Guembelitria cretacea Cushman. Smith & Pessagno, 1973, p.15, pl.1, figs 1-8.

Remarks: This species is distinguished by its small, elongate, triserial test (c. 210-220µm in maximum length), with sphaerical chambers, depressed sutures and highly arched aperture.

Range: late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-24.

Family **HETEROHELICIDAE** Cushman, 1927

Subfamily **HETEROHELICINAE** Cushman, 1927

Genus **HETEROHELIX** Ehrenberg, 1843

Type species: *Textilaria americana* Ehrenberg, 1843

Heterohelix americana (Ehrenberg)

(Pl. 22, Fig. 6)

Textilaria americana Ehrenberg, 1843, p. 366, 398, 428.

Heterohelix americana (Ehrenberg). Bergstresser & Frerichs, 1982, p. 355-356, pl. 1, figs 1-2.

Remarks: Specimens of *Heterohelix americana* are characterised by having a small (c. 300µm in maximum length), compressed, biserial test; chambers increasing gradualy in size, with the last one to two pairs of chambers subtriangular in outline, pointed upward at outer margin; numerous fine discontinuous costae.

Range: late Campanian.

Occurrence: well 1-CA-1-SE.

Heterohelix* ex gr. *globulosa (Ehrenberg)

(Pl. 22, Figs 7-8)

Textularia globulosa Ehrenberg, 1840 (1838), p. 135, pl. 4, figs 2 beta, 4 beta, 5 beta, 7 beta, 8 beta.

Guembelina globulosa (Ehrenberg). Egger, 1899, p. 32, fig. 43.

Heterohelix globulosa (Ehrenberg). Gallitelli, 1957, p. 137, pl. 31, figs 12-15.

Heterohelix globulosa (Ehrenberg). Pessagno, 1967, p. 260, pl. 87, figs 5-9, 11-13.

Remarks: This species group (c. 270-300µm in maximum length) is characterised by its inflated, rapidly expanding chambers, and presence of numerous faint discontinuous striae.

Range: Cenomanian to Maastrichtian.

Occurrence: localities A-17, A-18, A-21, A-45, Cruzes 15, Tabocas 2, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Heterohelix moremani (Cushman)

(Pl. 22, Figs 9-11)

Guembelina moremani Cushman, 1938, p. 10, pl. 2, figs 1-3.

Heterohelix moremani (Cushman). Pessagno, 1967, p. 260-261, pl. 48, figs 10-11; pl. 89, figs 1-2.

Remarks: All the specimens of Heterohelix moremani have a smooth, finely perforate test (c. 230-330µm in maximum length) with no striae.

Range: latest Albian to middle-late Turonian.

Occurrence: localities A-2, Cruzes 15, wells 1-CA-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-24.

Heterohelix planata (Cushman)

(Pl. 22, Figs 12-13)

Guembelina planata Cushman, 1938, p. 12, fig. 13, 14.

Hetrohelix planata (Cushman). Pessagno, 1967, p. 261, pl. 86, figs 3, 4; pl. 89, figs 6, 7.

Remarks: Hetohelix planata (Cushman) - (c. 190µm in maximum diameter) resembles Heterohelix pulchra (Brotzen), from which it differs in having tear-drop shaped ephebic chambers (not reniform), and from Heterohelix striata (Ehrenberg) by its test-surface either smooth or covered by fine striae.

Range: Campanian to Maastrichtian.

Occurrence: wells 1-CN-1-SE, 1-SES-1A, 1-SES-24.

Heterohelix pulchra (Brotzen)

(Pl. 22, Figs 14-15)

Guembelina pulchra Brotzen, 1936, p. 121, pl. 9, figs 3a-b.
Heterohelix pulchra (Brotzen). Gallitelli, 1957, p. 137, pl. 31, fig.20.
Heterohelix pulchra (Brotzen). Pessagno, 1962, p. 358, pl. 1, fig. 3.
Heterohelix pulchra (Brotzen). Pesagno, 1967, p. 262, pl. 87, fig.4.

Remarks: The species (c. 200-300μm in maximum length) is characterised by the broadened and reniform nature of its last two or three chambers in side view; test-surface either smooth or covered by fine striae on all but the the last one to two chambers.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-24.

Heterohelix reussi (Cushman)

(Pl. 22, Figs 16-18)

Guembelina reussi Cushman, 1938, p. 11, pl. 2, figs 6-9.
Guembelina reussi Cushman. Cushman, 1946, p. 104, pl. 44, figs 18-19.
Heterohelix reussi (Cushman). Pessagno, 1967, p. 263, pl. 85, figs 1-9; pl. 86, figs 1-2.

Remarks: *Heterohelix reussi* (Cushman) shows well-developed fine discontinuous costae on all chambers of its test (c. 300-480μm in maximum length), less inflated chambers, and large depressed triangular areas between the last several chambers, which are distinctly set apart.

Range: Turonian to early Campanian.

Occurrence: localities A-2, A-11, A-21, A-22, Tabocas 2, wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-24.

Heterohelix striata (Ehrenberg)

(Pl. 22, Fig. 19)

Textularia striata Ehrenberg, 1840, p. 135, pl. 4, figs 1 alpha, 1 alpha prime, 2 alpha, 3 alpha, not 9 alpha.
Guembelina striata (Ehrenberg). Egger, 1899, p. 33, pl. 14, figs. 37-39.
Guembelina striata (Ehrenberg). Cushman, 1946, pp. 104-105, pl. 45, figs 4-5.

Pseudoguembelina striata (Ehrenberg). Bronnimann & Brown, 1953, p. 154, text-fig. 6 (p. 151).

Heterohelix striata (Ehrenberg). Pessagno, 1962, p. 358, pl. 1, fig.5.

Heterohelix striata (Ehrenberg). Pessagno, 1967, p. 264, pl. 78, figs 4,5; pl. 88, figs 3-7; pl. 98, fig. 16.

Heterohelix striata (Ehrenberg). Smith & Pessagno, 1973, p. 19, pl.3, fig. 8; pl. 4, figs 1-4.

Remarks: Heterohelix striata (Ehrenberg) - (c. 290µm in maximum length) differs from Heterohelix ex gr. globulosa (Ehrenberg), which is similar in terms of chamber shape and arrangement, inhaving well-developed costae in the ephebic stage. Some early ontogenetic forms of Heterohelix striata have really just striae and, thus, may be difficult to be distinguished from Heterohelix ex gr. globulosa morphotypes.

Range: Santonian to Maastrichtian.

Occurrence: locality A-18, wells 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Genus **PLANOGLOBULINA** Cushman, 1927

Type species: Guembelina acervulinoides Egger, 1902

Planoglobulina varians (Rzehak)

(Pl. 22, Figs 20-21)

Pseudotextularia varians Rzehak, 1895, p. 217, pl. 7, figs 2, 3.

Guembelina acervulinoides Egger, 1899, p. 35, pl. 14, figs 20-22.

Guembelina fructicosa Egger, 1899, p. 35, pl. 14, figs 8, 9, 24.

Pseudotextularia varians (Rzehak) var. mendezensis White, 1929, p. 41, pl.4, figs 16a,b.

Pseudotextularia varians Rzehak. Cushman, 1946, p. 110, pl. 47, figs 4, 6, 7, 9.

Racemiguembelina fructicosa (Egger). Gallitelli, 1957, p. 142, pl. 32, figs 14-15.

Racemiguembelina fructicosa (Egger). Loeblich & Tappan, 1964, p. C656, fig. 525: 8a-b.

Racemiguembelina fructicosa (Egger). Pessagno, 1967, p. 270, pl.90, figs 14, 15.

Planoglobulina varians (Rzehak). Masters, 1977, p. 361-363, pl. 4, figs 1-2.

Remarks: Planoglobulina varians is characterised by having a large, thick conical test (c. 600-630µm in maximum length) with coarse and widely spaced costae.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-MO-1-SE, 1-SES-24.

Genus **PSEUDOTEXTULARIA** Rzehak, 1891

Type species: Cuneolina elegans Rzehak, 1891

Pseudotextularia browni Masters

(Pl. 22, Figs 22-23)

Pseudotextularia browni Masters, 1976, p. 321, pl. 1, figs 10-12.

Pseudotextularia browni Masters, 1977, p. 380-381, pl.5, figs 3-4.

Remarks: Pseudotextularia browni is characterised by possessing an inflated, biserial test (c. 280-380µm in maximum length), with chambers which rapidaly increase in width and thickness; thickness exceeding the other dimensions.

Range: Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-SES-1A.

Pseudotextularia carseyae (Plummer)

(Pl. 22, Figs 24-25)

Ventilabrella carseyae Plummer, 1931, p. 178-179, pl. 9, figs 7-9.

Ventilabrella carseyae Plummer. Cushman, 1946, p.112, pl. 48, figs 1-4.

Pseudotextularia elegans (Rzehak). Pessagno, 1967, p. 268-269, pl. 75, figs 12-17.

Pseudotextularia eggeri Rzehak. Sliter, 1968, p. 98, pl. 14, fig. 15.

Pseudotextularia carseyae (Plummer). Masters, 1977, p. 381-383, pl. 6, figs 1-2.

Remarks: Pseudotextularia carseyae - (c. 450µm in maximum length) - is characterised by having chambers increasing rapidly in width and thickness; lobate periphery in chambers of the ephebic stage.

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9.

Pseudotextularia elegans (Rzehak)

(Pl. 22, Figs 26-28)

Cuneolina elegans Rzehak, 1891, p. 2.

Pseudotextularia varians Rzehak, 1895, p. 217, pl. 7, figs 1a-b.

Guembelina elegans (Rzehak). White, 1929, p. 34-35, pl. 4, fig. 8.

Pseudotextularia elegans (Rzehak). Gallitelli, 1957, p. 138, pl. 33, figs 6a-c.

Pseudotextularia elongata Seiglie, 1959, p. 58-59, pl.1, figs 2a-b, 4a-b; pl. 2, figs 1a-b, 2a-b, 4a-b, 6a-b; pl. 3, figs 1a-b; text-fig.4.

Pseudotextularia elegans (Rzehak). Pessagno, 1962, p. 356, pl. 1, figs 7, 9.

Pseudotextularia elegans (Rzehak). Loeblich & Tappan, 1964, p.C656, fig. 525: 7a-c.

Pseudotextularia elegans (Rzehak). Pessagno, 1967, p. 268, pl. 75, figs 12-17; pl. 85, figs 10-11; pl. 88, figs 14-16; pl.89, figs 10-11; pl. 97, fig. 18; pl. 98, figs 19-20.

Pseudotextularia elegans (Rzehak). Smith & Pessagno, 1973, p. 30-32, pl. 9, figs 5-15; pl. 10, figs 2-6.

Pseudotextularia elegans (Rzehak). Masters, 1977, p. 383-386, pl.6, figs 3-4

Remarks: Specimens of Pseudotextularia elegans (Rzehak) - (c. 390-450µm in maximum length) - are characterised by possessing chambers that rapidly increase in width and thickness, and which sometimes may be as long as they are wide; lobate periphery in later stages of test growth; and by having moderate to coarse costae.

Range: late Campanian to Maastrichtian.

Occurrence: locality A-19, wells 1-SES-1A, 1-SES-9, 1-SES-24.

Genus **VENTILABRELLA** Cushman, 1928

Type species: Ventilabrella eggeri Cushman

Ventilabrella austinana Cushman.

(Pl. 22, Fig. 29)

Ventilabrella austinana Cushman, 1938, p. 26, pl. 4, fig. 19.
Ventilabrella austinana Cushman. Cushman, 1946, p. 111, pl. 47, fig. 16.
Ventilabrella austinana Cushman. Masters, 1977, p. 389–390, pl. 6, fig. 5.

Remarks: Ventilabrella austinana is characterised by its moderately large, fan-shaped test (c. 380/360µm in maximum length/breadth ratio), with an initial biserial stage, later developing supplementary chambers in the plane of symmetry; chambers gradually increasing in size; numerous fine costae.

Range: early Santonian.

Occurrence: well 1-CRL-1-SE (rare occurrence).

Subfamily **PSEUDOGUEMBELININAE** Aliyulla, 1977

Genus **PSEUDOGUEMBELINA** Bronnimann & Brown,1953

Type species: Guembelina excolata Cushman, 1926

Pseudoguembelina costata (Carsey)

(Pl. 22, Fig. 30)

Textularia costata Carsey, 1926, p. 26, pl. 1, fig. 4.
Guembelina costulata Cushman. Cushman, 1938, p. 16–17, pl. 3, figs 7–9.
Guembelina costulata Cushman. Cushman, 1946, p. 108, pl. 46, figs 11-12.
Pseudoguembelina costulata (Cushman). Bronnimann & Brown, 1953, p. 153–154, text-fig. 5.
Pseudoguembelina costulata (Cushman). Pessagno, 1962, p. 537, pl.1, fig. 6.
Pseudoguembelina costulata (Cushman). Pessagno, 1967, p. 266, pl.79, fig. 1; pl. 88, figs 8–9; pl. 90, fig. 3.
Pseudoguembelina costulata (Cushman). Smith & Pessagno, 1973, p. 24–25, pl. 6, figs 1–5.
Pseudoguembelina costata (Carsey). Masters, 1977, p. 369–370, pl. 4, fig. 6.

Remarks: Pseudoguembelina costata is characterised by its small, biserial test (c. 300-310μm in maximum length), possessing numerous fine costae. It differs from Pseudoguembelina excolata (Cushman) in having a smaller test, narrower outline in side view and finer costae.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-24.

Pseudoguembelina excolata (Cushman)

(Pl. 22, Figs 31-32)

Guembelina excolata Cushman, 1926a, p. 20, pl. 2, fig. 9.

Guembelina excolata Cushman. Voorwijk, 1937, p. 194, pl.1, figs 7-8.

Guembelina excolata Cushman. Cushman, 1946, p.108-109, pl. 46, figs 16a-b.

Pseudoguembelina excolata (Cushman). Bronnimann & Brown, 1953, p. 153, text-figs 1-4.

Pseudoguembelina excolata (Cushman). Pessagno, 1967, p.266-267, pl. 68, figs 4-5; pl. 90, fig. 5.

Pseudoguembelina excolata (Cushman). Smith & Pessagno, 1973, p.25-26, pl. 6, figs 6-10.

Pseudoguembelina excolata (Cushman). Masters, 1977, p. 371-373, pl. 4, figs 7, 8.

Remarks: Pseudoguembelina excolata is distinguished from Pseudoguembelina costata (Carsey) by its larger, biserial test (c. 310-540μm in maximum length), with less numerous and coarser costae.

Range: Santonian to Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-24.

Pseudoguembelina palpebra Bronnimann & Brown

(Pl. 23, Figs 1-2)

Pseudoguembelina palpebra Bronnimann & Brown, 1953, p. 155, text-figs 9-10.

Pseudoguembelina palpebra Bronnimann & Brown. Caron, 1985, p. 65, figs 24.18-19.

Remarks: Specimens of *Pseudoguembelina palpebra* are characterised by having a large, broad, elongate test (c. 300-480µm in maximum length), with numerous fine striae/coastae. It differs from *Pseudoguembelina excolata* (Cushman) in its broader outline in side view and finer and more numerous striae/coastae.

Range: Maastrichtian.

Occurrence: well 1-SES-1A.

Superfamily **PLANOMALINACEA** Bolli, Loeblich & Tappan, 1957

Family **GLOBIGERINELLOIDIDAE** Longoria, 1974

Subfamily **GLOBIGERINELLOIDINAE** Longoria, 1974

Genus **GLOBIGERINELLOIDES** Cushman & ten Dam, 1948

Type species: *Globigerinelloides algeriana*
Cushman & ten Dam, 1948.

Globigerinelloides abberanta (Netskaya)

(Pl. 23, Figs 3-6)

Globigerinella abberanta Netskaya, 1948, p. 220, pl. 2, figs 3a, b.

Biglobigerinella multispina Lalicker, 1948, p.624, pl.92, figs 1a-3c.

Planomalina mauryae Petri, 1962, p. 116-119, pl. 16, figs. 1a, b.

Globigerinelloides multispina (Lalicker). Pessagno, 1967, p. 276-277, pl. 70, figs. 1-2, pl. 82, figs. 10-11, pl. 91, figs. 1-2.

Globigerinelloides multispina (Lalicker). Bertels, 1970, p. 34-35, pl. 3, figs 1a-2b, text-figs. 8-10.

Globigerinelloides abberanta (Netskaya). Masters, 1977, p. 401-403, pl. 8, figs. 3-5, pl. 9, figs 1-2.

Remarks: *Globigerinelloides abberanta* is characterised by its partially evolute planispiral test (c. 230-300µm in maximum diameter), with equatorial periphery slightly lobate; 6 to 7 subspherical, inflated, chambers in the last whorl, gradually increasing in size; last two chambers tending to increase in thickness.

Range: late Santonian to early Maastrichtian.

Occurrence: localities A-19, wells 1-CA-1-SE, 1-SES-9.

Globigerinelloides aptiense Longoria
(Pl. 23, Figs 7-9)

Globigerinelloides aptiense Longoria, 1974, p. 79-80, pl. 4, figs 9-10, pl. 8, figs 4-6, 17-18.

Remarks: Globigerinelloides aptiense is characterised by its minute planispiral test (c. 180-220μm in maximum diameter); lobate periphery; 6 to 7 sphaerical to petalloid chambers in the last whorl, gradually increasing in size; umbilicus wide. It differs from Globigerinelloides ferreolensis (Moullade) in having fewer chambers in the last whorl and a more lobate periphery.

Range: late Aptian.

Occurrence: well 1-CA-1-SE.

Globigerinelloides barri (Bolli, Loeblich & Tappan)
(Pl. 23, Figs 10-14)

Biglobigerinella barri Bolli, Loeblich & Tappan, 1957, p.25, pl. 1, figs 13-18.
Globigerinelloides barri (Bolli, Loeblich & Tappan). Longoria, 1974, p. 80-82, pl. 4, figs 1-3, 8, 14; pl. 5, figs 9-16; pl. 27, fig. 19.
Globigerinelloides barri (Bolli, Loeblich & Tappan). Leckie, 1984, p.593, pl. 2, figs 1-4.

Remarks: Globigerinelloides barri is characterised by its small, planispiral test (c. 240-320μm in maximum diameter); circular peripheral outline; 6 to 10 ovate to nearly spherical chambers in the last whorl; smaller and low but broad last single chamber or biserial, with paired contiguous supplementary ones added in the gerontic stage and positioned laterally to the plane of coiling, at each side of the periphery.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE.

Globigerinelloides bentonensis (Morrow)

(Pl. 23, Figs 15-20)

non Anomalina eaglefordensis Moreman, 1927, p. 99, pl. 16, fig. 9 (fide Carter & Hart, 1977).

Anomalina bentonensis Morrow, 1934, p. 201, pl. 30, fig. 4.

Planomalina caseyi Bolli, Loeblich & Tappan, 1957, p.24, pl. 1, figs 4-5.

non Globigerinelloides eaglefordensis (Moreman). Loeblich & Tappan, 1961, p. 268-269, pl. 2, figs 3-7.

Globigerinelloides bentonensis (Morrow). Eicher & Worstell, 1970, p. 297, pl. 8, figs 17, 19; pl. 9, fig. 3.

Globigerinelloides bentonensis (Morrow). Leckie, 1984, p. 593, pl. 10, figs 5-11.

Globigerinelloides bentonensis (Morrow). Carter & Hart, 1977, p.27-28, pl. 1, fig. 11, pl. 2, figs 19, 20.

Remarks: Globigerinelloides bentonensis is distinguished by its large planispiral test (c. 300-510μm in maximum diameter); equatorial periphery slightly lobate, axial periphery rounded; 6 to 7 inflated chambers, gradually to rapidly increasing in size; aperture a low, interiomarginal, umbilical-equatorial arch with bordering imperforate lip; narrow to moderately wide shallow umbilicus; sutures depressed, radial in the last one to two chambers. The specimens illustrated by Bolli, Loeblich & Tappan (1957) and described as Planomalina caseyi are identical to Globigerinelloides bentonensis (Morrow). It is a common component of the Cenomanian planktonic assemblages from the Sergipe Basin and is particularly abundant in the latest Cenomanian [Globigerinelloides bentonensis-Hedbergella (W.) aprica Zone - Chapter 4, section 4.2.1.(i)].

Range: middle Albian to Cenomanian.

Occurrence: localities A-1, A-9, wells 1-CA-1-SE, 1-US-1-SE, 1-SES-24.

Globigerinelloides cushmani (Tappan)

(Pl. 23, Figs 21-24)

Globigerinella cushmani Tappan, 1943, p. 513, pl. 83, figs 5a, b.

Globigerinelloides cushmani (Tappan). Masters, 1977, p. 10, fig. 4; pl. 11, figs 1, 2.

Remarks: Globigerinelloides cushmani is characterised by having a small, planispiral test (c. 260–320μm in maximum diameter; circular equatorial periphery moderately lobate, rounded axial periphery; 7 inflated chambers in the last whorl, gradually increasing in size; last chambers rapidly increase in thickness; low interiomarginal, umbilical-extraumbilical to extraumbilical aperture with a narrow imperforate lip; umbilicus shallow and narrow. It differs from from Globigerinelloides bentonensis (Morrow) in having a more lobate equatorial profile and a circular equatorial periphery. Globigerinelloides cushmani is similar to Globigerinelloides barri (Bolli, Loeblich & Tappan) from which it differs by having fewer chambers, a laterally broader (thicker) test and a single-chambered last stage.

Range: early to middle Albian.

Occurrence: locality A-27 and wells 1-CA-1-SE, 1-US-1-SE.

Globigerinelloides escheri (Kaufmann)

(Pl. 23, Figs 25–28)

Nonionina escheri Kaufmann, 1865, p. 198.

Globigerinelloides escheri (Kaufmann). Marianos & Zingula, 1966, p. 334–335, pl. 37, figs. 3a, b.

Globigerinelloides asperus (Ehrenberg). Pessagno, 1967, p. 274–275, pl. 60, figs 4–5.

Globigerinelloides prairiehillensis Pessagno, 1967, p.277–278, pl. 60, figs 2–3, pl. 83, fig. 1, pl. 90, figs 1–2, 4.

Globigerinelloides volutus (White). Pessagno, 1967, p. 278–279, pl. 62, figs 10–11.

Globigerinelloides escheri (Kaufmann). Masters, 1977, p. 409–412, pl. 11, figs 4–5.

Remarks: This species is distinguished by its small planispiral test (c. 220–230μm in maximum diameter); circular equatorial periphery very lobate; 5 to 6 subspherical, inflated, chambers in the last whorl, rapidly increasing in size; umbilicus narrow and shallow; pustulose surface. It differs from Globigerinelloides abberanta (Netskaya) by its smaller size, being more loosely coiled and having fewer number of chambers in the last whorl.

Range: Santonian to Maastrichtian.

Occurrence: localities A-18, A-19, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Globigerinelloides ferreolensis (Moullade)

(Pl. 23, Figs 29–30)

Biticinella ferreolensis Moullade, 1961, p. 214, pl. 1, figs 1-5.
Globigerinelloides ferreolensis (Moullade). Longoria, 1974, p.84-85, pl. 5, figs 7, 8; pl. 8, figs 1-3, 8-15; pl. 14, figs 7-8; pl. 27, figs 3, 5, 12.
Globigerinelloides ferreolensis (Moullade). Leckie, 1984, p. 593, pl. 2, figs 9-12.

Remarks: This species is distinguished by its small planispiral test (c. 250-330μm in maximum diameter), with an elliptical equatorial periphery; 7 to 9 subspherical chambers in the last whorl, increasing slowly in size; relatively wide and shallow umbilicus. It differs from Glonbigerinelloides aptiense Longoria in having more chambers in the last whorl, and from Globigerinelloides barri (Bolli, Loeblich & Tappan) in being elliptical in outline rather than circular and having a thinner test.

Range: late Aptian.

Occurrence: wells 1-US-1-SE, 1-SES-9, 1-SES-3.

Globigerinelloides macrocamerata Longoria

(Pl. 24, Figs 1-4)

Globigerinelloides macrocameratus Longoria, 1974, p. 85-86, pl. 5, figs 1-6.

Remarks: Specimens of Globigerinelloides macrocamerata are characterised by having a moderately small (c. 300-330μm in maximum diameter) planispiral test; slightly lobate equatorial periphery; 7 spherical chambers in the last whorl, increasing gradually in size, with a large last chamber; sutures depressed and radial. It differs from Globigerinelloides ferreolensis (Moullade) by its more inflated last chambers, more lobate equatorial periphery and large last chamber.

Range: late Aptian.

Occurrence: well 1-US-1-SE.

Globigerinelloides ex gr. maridalensis (Bolli)

(Pl. 24, Figs 5-15)

Planomalina maridalensis Bolli, 1959, p. 261, pl. 20, figs 4-6.
Globigerinella duboisi Chevalier, 1961, p. 33, pl. 1, figs 14, 15-18.

Globigerinella gottisi Chevalier, 1961, p. 33-34, pl.1, figs 9-11, 13.
Globigerinelloides duboisi (Chevalier). Longoria, 1974, p. 83-84.
Globigerinelloides maridalensis (Bolli). Longoria, 1974, p. 86-88, pl. 9, figs 4-7, 10-13, pl. 27, fig. 18.
Blowiella duboisi (Chevalier). Banner & Desai, 1988, p. 172, pl. 8, figs 10-12.
Blowiella gottisi (Chevalier). Banner & Desai, 1988, p. 172, pl. 8, figs 13-15.
Blowiella maridalensis (Bolli). Banner & Desai, 1988, p. 172-173, pl. 9, figs 1-3.

Remarks: Specimens of Globigerinelloides ex gr. maridalensis are distinguished by their small (c. 220-250µm in maximum diameter), nearly involute to semi-evolute test, laterally compressed to inflated; equatorial periphery lobate; 4 to 5 ovoid to petalloid, subspherical chambers in the last whorl, increasing rapidly in size; last chamber comprising one-third to one-half of the test; wall finely perforated. The synonymy list exemplifies the variability of morphotypes here considered to belong to this species group.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-SES-3.

Globigerinelloides texomaensis Michael.

(Pl. 24, Figs 16-20)

Globigerinelloides texomaensis Michael, 1972, p. 209, pl. 6, figs 9-11.
Globigerinelloides texomaensis Michael. Caron, 1978, p. 658, pl. 2, figs 7-8.

Remarks: Globigerinelloides texomaensis is distinguished by its small planispiral test (c. 290-300µm in maximum diameter), with a very large and broad last chamber, compressed laterally; 5 to 6 subspherical chambers in the last whorl, gradually increasing in size; lobate equatorial periphery; narrow umbilicus. It differs from Globigerinelloides cushmani in having a slightly larger test with fewer chambers, a large and broad last chamber and a more lobate equatorial periphery.

Range: late Albian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-US-1-SE.

Globigerinelloides ultramicra (Subbotina)

(Pl. 24, Figs 21-22)

Globigerinella ultramicra Subbotina, 1949, p. 33, pl. 2, figs 17,18.
Globigerinelloides ultramicra (Subbotina). Masters, 1977, p.413-416, pl. 12, figs 3-5.

Remarks: Globigerinelloides ultramicra is characterized by its small (c. 290µm in maximum diameter), compressed, loosely coiled planispiral test; 7 to 8 subspherfical chambers in the last whorl, gradually increasing in size; umbilicus wide and shallow. It differs from Globigerinelloides escheri (Kaufmann) in being more loosely coiled and having more chambers in the last whorl.

Range: late Santonian to Maastrichtian.

Occurrence: locality A-18, wells 1-SES-1A, 1-SES-3.

Family **PLANOMALINIDAE**

Bolli, Loeblich & Tappan, 1957

Genus **PLANOMALINA**

Loeblich & Tappan, 1946

Type species: Planomalina apsidostroba Loeblich & Tappan

Planomalina sp. cf. P. praebuxtorfi Wonders

(Pl. 24, Figs 23-28)

cf. Planomalina praebuxtorfi Wonders, 1975, p. 90-91, pl. 1, figs 1a-c, 2a-c, text-fig. 4: 2a-b.
cf. Planomalina praebuxtorfi Wonders. Robaszynski & Caron, 1979, p. 50, pl. 1, fig. 1a-c.
cf. Planomalina praebuxtorfi Wonders. Wonders, 1980, pl. 1, p.123, fig. 1a-c.
cf. Planomalina praebuxtorfi Wonders. Leckie, 1984, p. 598, pl. 10, figs 1-2.

Remarks: Several specimens tentatively referable to *Planomalina* sp. cf. *P. praebuxtorfi* were recovered from the lowermost Cenomanian section (*Rotalipora brotzeni* Zone; well 1-CN-1-SE, core 5: 537.00m), and seem to be transitional forms between *Globigerinelloides bentonensis* (Morrow) and *Planomalina praebuxtorfi*. They are distinguished by having a planispiral test, biumbilicate, and symmetrical; 6 to 8 (generally 7) globular to crescent-shaped chambers in the last whorl, increasing gradually in size; the last one or two chambers laterally compressed. The specimens from Sergipe differ from the typical *Planomalina praebuxtorfi* species (*sensu* Wonders, 1975, p. 90-91, pl. 1, figs 1-2) in having an overall smooth test surface and only the last 1 or 2 chambers laterally compressed.

Range: latest Albian to earliest Cenomanian.

Occurrence: wells 1-CN-1-SE (core 5: 537.80m), 1-CRL-1-SE (core 1: 1182.50m, rare occurrence).

Superfamily **ROTALIPORACEA**

Sigal, 1958

Family **GLOBULIGERINIDAE**

Loeblich & Tappan, 1984

Remarks: Specimens of the genera *Conoglobigerina* Morozova (Middle to Upper Jurassic) and *Globuligerina* Bignot have been reported elsewhere from Jurassic to lower-upper Aptian strata (cf. Masters, 1977; Caron, 1985; Sliter, 1989). The occurrence of "globuligerinid" morphotypes in the upper Aptian-lowermost Albian of Sergipe may suggest, therefore, either a probable higher (younger) last appearance datum (in the late Aptian/earliest Albian) at low-latitudes or, most likely, new taxa placed within the phylogenetic lineage of *Conoglobuligerina* - *Globuligerina* - *Hedbergella* (*Favusella*) (e.g., Grigelis & Gorbatchik, 1980, p. 189).

Genus **CONOGLOBIGERINA** Morozova, 1961

Type species: *Globigerina* (*Conoglobigerina*) *dagestanica* Morozova,
in Morozova & Moskalenko, 1961

Conoglobigerina(?) sp. A

(Pl. 24, Figs 29–33)

Remarks: Specimens of Conoglobigerina(?) sp. A are distinguished by having a minute trochoid test, with a moderately high trochospire (varying from c. 110/130µm to 180/180µm in maximum diameter/height ratio); 3 rapidly enlarging globular chambers in the last whorl; umbilicus small; periphery rounded; test surface with imperforate small rounded or elongated tubercles, some forming elongated quadrangles (= ridges); aperture a low umbilical arch, bordered by a narrow lip. The morphotypes are somewhat similar in chamber arrangement to Jurassic topotypes of Conoglobigerina bathoniana (Pazdrowa), refigured by Masters (1977, pl.22, figs 1-3), and Conoglobigerina dagestanica Morozova, illustrated by Grigelis & Gorbatchik (1980, pl. 1, figs 1-2). It differs from Globuligerina sp. cf. G. hoteriva in having a more regular trochoid test with a higher trochospire (diameter/height ratio < 1).

Range: late Aptian to earliest Albian (?).

Occurrence: Rare specimens were recovered from well 1-CA-SE (upper Aptian: 1095-1110m, 1125-1140m, 1245-1260m; lowermost Albian: 1035-1050m). The stray occurrence in the lowermost Albian may actually represent reworking from the upper Aptian, although the few specimens recovered are all well preserved.

Genus **GLOBULIGERINA** Grigyalis

Type species: Globigerina oxfordiana Grigyalis, 1958

Globuligerina sp. cf. G. hoterivica (Subbotina)

(Pl. 24, Figs 34-35)

cf. Globigerina hoteriva Subbotina, 1953, p. 50, pl. 1, fig. 1a-c.

cf. Globuligerina hauterivica (Subbotina). Gregelis & Gorbatchik, 1980, pl. 1, fig. 7 a-b.

cf. Globuligerina hoterivica (Subbotina). Caron, 1985, p. 57, figs 25.1-3.

Remarks: A single specimen tentatively referred to *Globuligerina* sp. cf. *G. hoterivica* was recovered from an uppermost section of the Oiterinhos Member, Muribeca Formation (well 1-CPB-1R-SE, core 7: 370.90m). The specimen is characterised by having a minute test with a moderately small trochospire (c. 217/154µm in maximum diameter/height ratio); 4 subglobular chambers in the last whorl; very recrystalised test.

Range: early(?)-late Aptian.

Occurrence: well 1-CPB-1R-SE (rare occurrence).

Family **HEDBERGELLIDAE**
Loeblich & Tappan, 1961

Subfamily **HEDBERGELLINAE**
Loeblich & Tappan, 1961

Genus **HEDBERGELLA**
Bronnimann & Brown, 1958;
emended, Longoria, 1974; re-emended
Type species: *Anomalina lorneiana* d'Orbigny var. *trochoidea*
Gandolfi, 1942

Remarks:

The emended definition of the genus *Hedbergella* as given by Longoria (1974, p. 51-53) is re-emended in here to include forms which have been previously grouped under the generic name *Favusella* by Michael (1972, p. 53), proposed as a subgenus of *Hedbergella* by Koutsoukos *et al.* (1989), and *Whiteinella* by Pessagno (1967, p. 298). The various published favusellid taxa have been shown to be ecophenotypic expressions of a *Hedbergella* stock suited to shallow, warm, hypersaline, carbonate-saturated environments (see Chapter 6 and Koutsoukos *et al.*, op. cit.), and therefore lack the taxonomic status of a separate genus. Typical favusellid morphotypes have the test surface covered by a variable sculptural ornamentation, progressively evolving from fine rounded tubercles and well-defined rounded or elongated tubercles (some forming elongated quadrangles = ridges), to a reticulate system of fine to coarse ridges forming irregular polygonal cells (honeycomb pattern) in the adult stage. On the other hand, the morphological characteristics - used by several authors (e.g., Pessagno, op.

cit., p. 298; Robaszynski & Caron, 1979; Loeblich & Tappan, 1988) - to differentiate the genus Whiteinella from Hedbergella (much larger portici with infralaminal accessory apertures, larger umbilicus, and the more umbilical position of the primary aperture), and the presence of several interspecific variations (probably reflecting pelagic ecophenotypic differentiation) between the two groups, does not have enough taxonomic stability to support the proposal of a different genus. As already noted by Robaszynski & Caron (1979, v.1, p. 155) 'The presence of transitional forms prevents a firm separation of the two genera'. Therefore, until further evidence is produced, it is recommended that the generic designations of Favusella and Whiteinella be kept at the subgeneric level, within the genus Hedbergella.

Subgenus **HEDBERGELLA**

Type species: Anomalina lorneiana d'Orbigny var. trochoidea
Gandolfi, 1942

Remarks: The definition of the subgenus follows herein the original descripton of Hedbergella given by Bronnimann & Brown, 1958, p. 16.

Hedbergella (Hedbergella) ex gr. delrioensis (Carsey)

(Pl. 25, Figs 1-7)

Globigerina cretacea d'Orbigny var. delrioensis Carsey, 1926, p.43, no figures.

Globigerina portsdownensis Williams-Mitchell, 1948, p. 96-97, pl. 8, figs 4a-c.

Praeglobotruncana (Hedbergella) delrioensis (Carsey). Banner & Blow, 1959, p.8.

Hedbergella portsdownensis (Williams-Mitchell). Loeblich & Tappan, 1961, p. 277, pl. 5, figs 3a-c.

Hedbergella delrioensis (Carsey). Renz, Luterbacher & Schneider, 1963, p. 1083, pl. 9, figs 5a-c.

Hedbergella delrioensis (Carsey). Pessagno, 1967, p. 282-283, pl. 48, figs 1-2, 3-5.

Hedbergella libyca Barr, 1972, p. 14, pl. 10, figs 10a-c.

Hedbergella costellata Saint-Marc, 1973, p. 11-12, pl. 1, figs 1-2, pl. 2, figs 1-3.

Hedbergella costellata Saint-Marc. Caron, 1978, p. 658, pl. 4, figs 1-3, 8-9.
Hedbergella delrioensis (Carsey). Robaszynski & Caron, 1979, v. 1, p. 123, 128, pl. 22, figs 1-2, pl. 23, figs 1-3.
Hedbergella libyca Barr. Leckie, 1984, p. 598, pl. 11, figs 5-9.

Remarks: Morphotypes of this species group are characterised by a moderately small test (c. 200-330μm in maximum diameter) coiled in a very low, almost flat, trochospire; 4 to 6 (generally 5) inflated, spherical to ovoid chambers in the last whorl, increasing gradually or rapidly in size; the last chamber may extend over the umbilicus in the gerontic stage; lobate equatorial periphery; umbilicus deep and small; primary aperture a large interiomarginal arch, extraumbilical-umbilical in position.

Hedbergella (*H.*) ex gr. *delrioensis* is a moderately variable species. Variation is represented by the degree of chamber enlargement as added to the whorl, development of an apertural lip, and surface texture, which can probably be explained as ecophenotypic differentiation. The latest Aptian to middle-late Albian specimens tend to be smoother, smaller (<300um in maximum diameter), and with a less pronounced apertural lip, while the latest Albian-Turonian specimens tend to be slightly larger, some with a more pustulose/rugose (pustules and/or costellae) surface ornamentation. The pustulose/rugose morphotypes, described as *Hedbergella libyca* Barr or *Hedbergella costellata* Saint-Marc, and *Hedbergella portsdownensis* (Williams-Mitchell), from latest Albian-Cenomanian sediments (Pl. 25, Figs 5-7), appear to represent ecophenotypic adaptations of a *Hedbergella* (*H.*) ex gr. *delrioensis* stock to warm, epipelagic environments (<100m water depth), such as marginal epicontinental seas or carbonate platforms (cf. Leckie, 1987; Koutsoukos *et al.*, 1989; Chapter 6).

Earliest Cenomanian *Hedbergella* (*H.*) ex gr. *delrioensis* morphotypes, recovered from deep neritic-upper bathyal biotopes with dysaerobic bottom conditions (well 1-US-1-SE: 366-381m), show similarity with forms of *Ticinella primula* Luterbacher in chamber arrangement (generally formed by 5 to 6 chambers in the last whorl, gradually increasing in size, with a smooth test surface). The hedbergellid specimens differ from *Ticinella primula* in having a fewer number of chambers in the last whorl (the ticinellids usually have from 7 to 8 chambers), a narrow umbilicus and complete lack of umbilical supplementary apertures (although this is a morphological feature rarely observed in the ticinellids of Sergipe).

Range: late Aptian to Santonian.

Occurrence: localities A-1, A-2, A-3, A-9, A-15, A-16, A-21, A-29, A-35, A-45, Cruzes 15, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-9, 1-SES-24.

Hedbergella (Hedbergella) flandrini Porthault

(Pl. 25, Figs 8-9)

Hedbergella flandrini Porthault, 1970, p. 64-65, pl. 10, figs 1-3.

Hedbergella flandrini Porthault. Robaszynski & Caron, 1979, p. 129, 134, pl. 24, figs 1-2, pl. 25, figs 1-3.

Hedbergella flandrini Porthault. Caron, 1985, p. 57, figs 25.12-14.

Remarks: The species is characterised by having a small, compressed test (c. 220µm in maximum diameter), with a very lobate equatorial periphery; 4 to 5 globular to spatulate chambers in the last whorl, increasing rapidly in size and height; umbilicus wide and shallow. It differs from Hedbergella (H.) ex gr. simplex by having a more compressed test and spatulate chambers in the last whorl, rather than globular to subclavate.

Range: late Coniacian to early Santonian.

Occurrence: well 1-CRL-1-SE (rare occurrence).

Hedbergella (Hedbergella) gorbachikae Longoria

(Pl. 25, Figs 10-13)

Hedbergella gorbachikae Longoria, 1974, p. 56, 58, pl.15, figs 1-16.

Hedbergella gorbachikae Longoria. Leckie, 1984, p. 598, pl. 4, figs 9-11.

Blefuscuiana gorbachikae (Longoria). Banner & Desai, 1988, p. 160, 162, pl. 5, figs 8-12.

Remarks: Hedbergella (H.) gorbachikae is characterised by its small plano-convex test (c. 260-340µm in maximum diameter), with the umbilical side convex; generally with 5 inflated chambers in the last whorl; last chamber extending over the umbilicus, completely or partially covering it.

Range: late Aptian to Albian.

Occurrence: localities A-15, A-16, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-9, 1-SES-24.

Hedbergella (Hedbergella) holmdelensis Olsson

(Pl. 25, Figs 14-15)

Hedbergella holmdelensis Olsson, 1964, p. 160, pl. 1, fig. 2a-c.

Hedbergella holmdelensis Olsson. Robaszynski *et al.*, 1984, p. 261, pl. 43, fig. 1a-c.

Remarks: *Hedbergella (H.) holmdelensis* is distinguished by having a small test (c. 310μm in maximum diameter) with a very low trochospire; 5 globular to trapezoidal chambers in the last whorl, rapidly increasing in size; lobate equatorial periphery; umbilicus small and shallow; smooth surface.

Range: late Campanian to early Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Hedbergella (Hedbergella) infracretacea (Glaessner)

(Pl. 25, Figs 16-19)

Globigerina infracretacea Glaessner, 1937, p. 28, text-fig. 1.

Hedbergella infracretacea (Glaessner). Renz, Luterbacher & Schneider, 1963, p. 1083.

Hedbergella infracretacea (Glaessner). Glaessner (emend.), 1966, p. 179, pl. 1, figs 1-3.

Hedbergella infracretacea (Glaessner). Longoria, 1974, p. 59-60, pl. 13, fig. 9.

Hedbergella infracretacea (Glaessner). Magniez-Jannin, 1975, p. 250-256, pl. 17, figs 23-26, 34-35 (?), 36, 37 (?), 39, 41-44.

Remarks: Specimens of *Hedbergella (H.) infracretacea* are characterised by having a minute test (varying from around 160-180μm in maximum diameter, in the upper Aptian, to c. 230μm in the Albian), with a moderately low trochospire; lobate and subcircular equatorial periphery; 5 to 6 ovoid chambers in the last whorl, increasing slowly in size; last chamber generally smaller than the penultimate one, in umbilical view; umbilicus narrow and deep. The species is somewhat similar in chamber arrangement to *Hedbergella (H.)* ex gr. *delrioensis* (Carsey), from which it differs by having a generally smaller ovoid last chamber, arranged along the coiling plane, chambers increasing slightly slower in size, and a nearly circular equatorial periphery. It differs from Hedbergella (H.) ex gr. planispira (Tappan) by having a less flatter trochospire and fewer chambers in the last whorl. The morphological variability of Hedbergella (H.) infracretacea seems to fall actually within the range of interspecific variations between populations of Hedbergella (H.) ex gr. delrioensis and Hedbergella (H.) ex gr. planispira (e.g., Harris, 1982, vol. 1, p. 130-142).

Range: late Aptian to Albian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R, 1-US-1-SE, 1-SES-3.

Hedbergella (Hedbergella) labocaensis Longoria

(Pl. 25, Figs 20-21)

Hedbergella labocaensis Longoria, 1974, p. 60-61, pl. 16, figs 7-9, 22-24.
Lilliputianella longorii Banner & Damini Desai, 1988, p. 166, 188, pl. 4, figs 11-12.

Remarks: Specimens of Hedbergella (H.) labocaensis are distinguished by having a minute test (c. 200µm in maximum diameter), with a moderately low trochospire; lobate equatorial periphery; 5 to 6 petalloid chambers in the last whorl, increasing rapidly in height; last and penultimatimate chambers often extending over the umbilicus, which is narrow and deep. It differs from Hedbergella (H.) semielongata Longoria in having less elongate chambers in the last whorl and a smaller umbilicus.

Range: late Aptian.

Occurrence: well 1-CA-1-SE.

Hedbergella (Hedbergella) maslakovae Longoria

(Pl. 25, Figs 22-23)

Hedbergella maslakovae Longoria, 1974, p. 61, 63, pl. 20, figs 1-3, 14-16, pl. 24, figs 11-14.
Hedbergella maslakovae Longoria. Caron,1978, p.658, pl.2, figs 1-2.
Lilliputianella maslakovae (Longoria). Banner & Damini Desai, 1988, p. 169, pl. 8, figs 6-7.

Remarks: The species is characterised by its small test (c. 220µm in maximum diameter), with circular equatorial periphery, strongly lobate; very low trochospire, with a flat dorsal side; 5 to 6 inflated, ovate to semi-elongate chambers in the last whorl, increasing slowly in height; wide umbilicus. It differs from *Hedbergella* (*H.*) ex gr. *planispira* (Tappan) by having oval-shaped to semi-elongate chambers in the last whorl; and from *Hedbergella* (*H.*) *semielongata* Longoria and *Hedbergella* (*H.*) *similis* Longoria by the inflated, less elongate and less clavate chambers in the last whorl.

Range: late Aptian.

Occurrence: well 1-CN-1-SE.

Hedbergella* (*Hedbergella*) ex gr. *planispira (Tappan)

(Pl. 25, Figs 24-30)

Globigerina planispira Tappan, 1940, p. 122, pl. 19, fig. 12.

Hedbergella planispira (Tappan). Loeblich & Tappan, 1961, p. 276-277, p. 276, pl. 5, figs 4-11.

Praeglobotruncana planispira (Tappan). Petri, 1962, p. 121-122, pl. 16, figs 7-8.

Hedbergella planispira (Tappan). Pessagno, 1967, p.283-284, pl. 51, fig. 1; pl. 53, figs 1-4.

Hedbergella planispira (Tappan). Magniez-Jannin, 1975, p. 254-256, pl. 18, figs 1-12.

Hedbergella planispira (Tappan). Sliter, 1977a, pl. 3, figs 4-7.

Hedbergella planispira (Tappan). Robaszynski & Caron, 1979, v.1, p. 139, 144, pl. 27, figs 1-3, pl. 28, figs 1-4.

Remarks: *Hedbergella* (*H.*) ex gr. *planispira* is characterised by its small size (c. 240-320µm in maximum diameter), very low trochospire, nearly flat test; 6 to 8 chambers in the last whorl increasing gradually in size. The morphotypes are somewhat similar to late Aptian specimens of *Hedbergella* (*H.*) *infracretacea* (Glaessner), from which they differ by being more laterally compressed, with a flattened spiral side, having more chambers in the last whorl and a larger umbilicus.

Range: latest Aptian to Turonian.

Occurrence: localities A-1, A-3, A-9, A-15, A-27, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-24.

Hedbergella* (*Hedbergella*) *semielongata Longoria

(Pl. 26, Figs 1-3)

Hedbergella semielongata Longoria, 1974, p. 66, 68, pl. 20, figs. 12-13, pl. 21, figs 1-3, 4-5.

Remarks: Hedbergella (H.) semielongata is characterised by its minute test (c. 190μm in maximum diameter), with a substellate equatorial periphery; 5 to 6 inflated, ovate to semi-elongate chambers in the last whorl, increasing gradually in size; umbilicus narrow. The species is somewhat similar to Hedbergella (H.) similis Longoria, from which it differs by having a narrower umbilicus and inflated, ovate to semi-elongate chambers, in the last whorl.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE.

Hedbergella (Hedbergella) sigali Moullade

(Pl. 26, Figs 4-5)

Hedbergella (Hedbergella) sigali Moullade, 1966, p. 87, pl. 7, figs 20-25.
Hedbergella sigali Moullade. Sliter, 1977a, p. 542, pl. 4, figs 6-8.
Hedbergella sigali Moullade. Caron, 1985, p. 59, figs 25.21-22.

Remarks: This species is recognised by its minute size (c. 180um in maximum diameter), low trochospire, with 4 oval-shaped chambers in the last whorl, increasing rapidly in size; subquadrate test in plan view, with a pronounced lobate equatorial periphery.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-SES-3, 1-SES-9.

Hedbergella (Hedbergella) similis Longoria

(Pl. 26, Figs 6-8)

Hedbergella similis Longoria, 1974, p. 68-69, pl. 16, figs 10-21; pl. 18, figs 12-13; pl. 23, figs 14-16.
Hedbergella labocaensis Longoria. Caron, 1978, p. 658, pl. 2, figs 3-4.
Lilliputianella similis (Longoria). Banner & Damini Desai, 1988, p. 169, pl. 8, figs 8, 9.

Remarks: Specimens of Hedbergella (H.) similis are characterised by their strongly lobate minute test (c. 170-220μm in maximum diameter); elongate equatorial periphery; 5 to 6 ovate to elongate chambers in the last whorl, increasing gradually in size; low trochospire; and a shallow wide umbilicus. This species is similar to Hedbergella. (H.) labocaensis and Hedbergella (H.) maslakovae, all erected simultaneously by Longoria (1974), but differ in being more loosely coiled, with a shallow wide umbilicus, and a nearly flattened trochospire. It differs from other low-trochospire Hedbergella by having ovate to elongate chambers and a peripheral margin elongate and strongly lobate.

Range: late Aptian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE. The sporadic record of Hedbergella (H.) similis morphotypes in lower and middle Albian turbiditic sediments (Angico Member) of the well 1-US-1-SE represent reworking from upper Aptian strata (e.g., in DSDP Site 545, Leckie, op. cit., p. 600).

Hedbergella (Hedbergella) ex gr. simplex (Morrow), emended, Robaszynski & Caron, 1979.

(Pl. 26, Figs 9-11)

Hastigerinella simplex Morrow, 1934, p. 198-199, pl. 30, fig. 6.

Clavihedbergella simplex (Morrow). Loeblich & Tappan, 1961, p. 279-280, pl. 3, figs 12a-14b.

Hedbergella amabilis Loeblich & Tappan, 1961, p. 274, pl. 3, figs. 1-10.

Clavihedbergella simplex (Morrow). Pessagno, 1967, p. 285-286, pl. 52, figs 1-2.

Hedbergella amabilis Loeblich & Tappan. Pessagno, 1967, p. 281-282, pl. 52, figs 6-8.

Hedbergella amabilis Loeblich & Tappan. Carter & Hart, 1977, p. 29, 31, pl. 3, figs 22-23.

Clavihedbergella simplex (Morrow). Masters, 1977, p. 443-445, pl.19, figs 1-3.

Hedbergella simplex (Morrow). Robaszynski & Caron, 1979, v. 1, p. 145, 150, pl. 29, figs 1-3, pl. 30, figs 1-2.

Remarks: Hedbergella (Hedb.) ex gr. simplex is characterised by having a moderately small test (varying from c. 190-260µm in maximum diameter, for the middle Albian-lower Cenomanian, to c. 290-330um, for the middle

Cenomanian-lower Coniacian), with a low trochospire and strongly lobate equatorial periphery; 4 to 5 chambers in the last whorl with the last 2 to 3 ones radially elongated in the plane of coiling; umbilicus wide and shallow. It is distinguished from other species of Hedbergella by the more clavate character of its chambers and the lower spiral height, as seen in peripheral view.

Range: middle Albian to early Coniacian.

Occurrence: localities A-2, A-9, A-11, A-29, A-35, wells 1-CA-1-SE, 1-CRL-1-SE, 1-US-1-SE.

Hedbergella (Hedbergella) subcretacea (Tappan)
(Pl. 26, Figs 12-18)

Hastigerinella subcretacea Tappan, 1943, p. 513-514, pl. 83, figs 4a-c.
Hedbergella amabilis Loeblich & Tappan, 1961, p.274, pl. 3, figs 8a-c,10a-b.
Clavihedbergella subcretacea (Tappan). Masters, 1977, p. 445-446, pl. 19, figs 4-6.
Clavihedbergella subcretacea (Tappan). Leckie, 1984, p.600, pl. 8, figs 9-10.

Remarks: Hedbergella (H.) subcretacea is characterised by its small test (c. 230-300µm in maximum diameter), with strongly lobate equatorial periphery; 6 to 7.5 globose to elongate chambers, gradually increasing in size; umbilicus wide and shallow. It differs from Hedbergella (H.) similis Longoria and Hedbergella (H.) ex gr. simplex (Morrow) by the larger number of chambers in the last whorl.

Range: Albian.

Occurrence: wells 1-CA-1-SE, 1-US-1-SE.

Hedbergella (Hedbergella) trocoidea (Gandolfi)
(Pl. 26, Figs 19-24)

Anomalina lorneiana (d'Orbigny) var. trocoidea Gandolfi, 1942, p. 99, pl. 2, figs 1a-c; pl. 4, figs 2-3; pl. 13, figs 2a-b, 5a-b.
Hedbergella trocoidea (Gandolfi). Longoria, 1974, p. 69, pl. 17, figs 1-16; pl. 18, figs 3-5.
Hedbergella trocoidea (Gandolfi). Masters, 1977, p. 475-477, pl. 25, figs 1-3.

Remarks: Hedbergella (H.) trocoidea is characterised by a moderately small test (c. 350–360μm in maximum diameter), with a low to slightly high trochospire; equatorial periphery moderately lobate, axial periphery rounded; 6 to 7 inflated and embracing chambers in the final whorl, gradually increasing in size; last chamber distinctly large and inflated, extending over the umbilicus; low extraumbilical-umbilical apertural arch bordered by a narrow lip; umbilicus narrow and deep. Hedbergellsa (H.) trocoidea differs from Hedbergella (H.) ex gr. delrioensis (Carsey) in having more chambers in the last whorl and a distinct large, inflated last chamber, extending over the umbilicus; and from Hedbergella (H.) ex gr. planispira (Tappan) in possessing a slightly higher trochospire and fewer chambers in the last whorl. It is also distinguished from the early forms of Ticinella ex gr. roberti (Gandolfi) in having embracing inflated chambers, with a distinctly large last chamber, a generally larger test with a lower trochospire, and in lacking the supplementary apertures that exist in some individuals of the latter.

Range: late Aptian to middle Albian.

Occurrence: localities A-15, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 1-US-1-SE, 1-SES-3.

Subgenus **FAVUSELLA** (Michael), 1972;
emended, Koutsoukos, Leary & Hart (1989)

Type species: Globigerina washitensis Carsey, 1926

Remarks: The definition of the subgenus follows herein the original description of Favusella given by Michael, 1972, p. 212-213.

Hedbergella (Favusella) washitensis (Carsey), 1926, emended

(Pl. 26, Figs 25-32, and Chapter 6 :
Pl. 6.1, Figs 1-15, Pl. 6.2, Figs 1-14)

Globigerina washitensis Carsey, 1926, p. 44, pl. 7, fig. 10; pl. 8, fig. 2

Hedbergella hiltermanni Loeblich & Tappan, 1961, p. 275-276, pl.4, figs 12-13

Hedbergella washitensis (Carsey). Loeblich & Tappan, 1961, p. 278, pl. 4, figs 9-11.

Globigerina washitensis Carsey. Petri, 1962, pp. 119-120, pl. 16, figs 5-6.

Hedbergella *washitensis* (Carsey). Pessagno, 1967, p. 284-285, pl. 49, fig. 1.

Hedbergella aff. *almadenensis* (Cushman & Todd). Prestat, 1970, p. 315-317, pl. 1, figs 17-19.

Favusella *nitida* Michael, 1972, p. 214, p. 3, figs 10-12.

Favusella *orbiculata* Michael, 1972, p. 214, pl. 4, figs 1-3.

Favusella *pessagnoi* Michael, 1972, p. 214-215, pl. 4, figs 4-6.

Favusella *quadrata* Michael, 1972, p. 215, pl. 4, figs 7-9.

Favusella *scitula* Michael, 1972, p. 215, pl. 4, figs 10-12.

Favusella *washitensis* (Carsey). Michael, 1972, p. 215-216, pl. 5, figs 1-3.

Favusella *wenoensis* Michael, 1972, p. 216, pl. 5, figs 4-9; pl. 7, figs.4-5.

Hedbergella *excelsa* Longoria, 1974, p. 55-56, pl. 18, figs 6-8, 9-11, 14-16.

Favusella *confusa* Longoria & Gamper, 1977, p. 204, 207, pl.3, figs 4-6, 10-12; pl. 4, figs 25-27.

Favusella *hedbergellaeformis* Longoria & Gamper, 1977, p. 207, pl. 4, figs 13, 7-9.

Favusella *papagayosensis* Longoria & Gamper, 1977, p. 207, pl. 4, figs 16-21; pl. 5, figs 16-21.

Favusella *planata* Longoria & Gamper, 1977, p. 207-208.

Favusella *voloshinae* Longoria & Gamper, 1977, p. 208, pl. 3, figs 1-3, 16-18.

Favusella *washitensis* (Carsey). Longoria & Gamper, 1977, p. 208, pl. 3, figs 13-15; pl. 4, figs 4-6, 10-12; pl. 5, figs 22-24.

Globigerina *washitensis* Carsey, Masters, 1977, p. 477-479, pl. 25, fig. 4; pl. 26, figs 1-3.

Hedbergella *hoterivica* (Subbotina), Butt, 1978, p. 258-259, pl. 3, figs 1-6; pl. 4, figs 1-6.

Favusella sp. Roesler, Lutze & Pflaumann, 1978, pl. 2, figs. 1-2.

Favusella *stiftia* Roesler, Lutze & Pflaumann, 1978, p. 276, pl. 1, figs 1-5.

Favusella sp. (Antonova). Grigelis & Gorbatchik, 1980, p. 188.

Favusella *tardita* (Antonova). Grigelis & Gorbatchik, 1980, p. 188, pl. 2, fig. 4.

Ascoliella *scotiensis* Banner & Damini Desai, 1988, p. 150-151, pl. 2, figs 3-4.

Hedbergella (*Favusella*) ex gr. *washitensis* (Carsey). Koutsoukos, Leary & Hart, 1989, p. 335, pl. 1, figs 1-15, pl. 2, figs 1-14.

Description :

Test a low to relatively high trochospiral coil, equatorial periphery lobate, peripheral edge rounded. Chambers spherical to subspherical; 1.5 to 3.5 whorls each with 3 to 6 chambers, usually 4 to 5 in last whorl. Last chamber in mature individuals is usually smaller (embryonic), bare or with smooth ornamentation, extending over the umbilicus and partially covering it (Pl. 6.1, Figs 10-15). Primary aperture usually arcuate, low to moderate, interiomarginal, umbilical to umbilical-extraumbilical in position, bordered by wide or narrow lip. Umbilicus shallow, of variable width. Sutures radial to slightly curved, depressed. Test surface covered by variable sculptural ornamentation, progressively developing from fine rounded tubercles (Pl. 6.2, Figs 7-8) and well-defined rounded or elongated tubercles (some forming elongated quadrangles = ridges; Pl. 6.2, Figs 9-10), to reticulate system of fine to coarse ridges forming irregular polygonal cells (honeycomb pattern) in ephebic (adult) stage (Pl. 6.2, Figs 11-14; Pl. 26, Figs 25-32). Numerous minute pores located nearly exclusively within polygonal cells and between tubercles; pores scattered on edges of cell-ridges and tubercles. Size (maximum diameter) 100-250μm in the neanic stage (1 to 2 whorls), 250-350um in ephebic forms (2.5 to 3 whorls) and 350-500um in gerontic specimens (3 to 3.5 whorls).

Remarks : Striking morphological differences can be observed between specimens attributed to Favusella and Hedbergella (e.g., distinctly trochoid shape, chamber characteristics, thicker and distinctly ornamented wall, pore distribution pattern, and umbilical position of the aperture of the favusellids - cf. W.V. Sliter, U.S.G.S., written communication, June 1988), which have been used to support the generic designation of Favusella (e.g., Grigelis & Gorbatchic, 1980; Loeblich & Tappan, 1988). However, all the evidence considered herein (see Chapter 6) demonstrates that the various published "favusellid" taxa are ecophenotypic expressions of a common Hedbergella stock adapted to shallow, warm, hypersaline, carbonate-saturated environments. Until further evidence is produced, it is recommended to keep the Favusella designation at subgeneric level.

Therefore, Hedbergella (Favusella) washitensis is regarded as a species comprising several morphotypes of common origin. The different morphotypes represent different polymorphic stages in the life cycle and ecophenotypes of a single hedbergellid taxon.

Range : late Aptian to early Cenomanian.

Occurrence : localities A-1, A-15, A-27, A-32, A-37, A-38, wells 1-CA-1-SE, 1-CN-1-SE, 1-CPB-1R-SE, 7-CP-252-SE, 1-US-1-SE, 1-SES-9

Subgenus **WHITEINELLA** Pessagno, 1967, emmended

Type species: *Whiteinella archaeocretacea* Pessagno, 1967

Remarks: The definition of the subgenus follows herein the original description of *Whiteinella* given by Pessagno, 1967, p. 298. *Hedbergella (Whiteinella)* is morphologically close to *Hedbergella (Hedbergella)*, from which it differs by possessing a slightly extended umbilical-extraumbilical primary aperture, a larger umbilicus, and generally much larger portici (apertural flaps). Several transitional forms do exist.

The "whiteinellid" morphotypes are included in the group of "grosses globigérines" or "grandes globigérines" (*sensu* Sigal, 1955), i.e., hedbergellids of generally large test size (> 300μm in maximum diameter), that are abundant in uppermost Cenomanian and lowermost Turonian strata.

Hedbergella (Whiteinella) aprica (Loeblich & Tappan)

(Pl. 27, Figs 1-6)

Ticinella aprica Loeblich & Tappan, 1961, p. 292, pl. 4, figs 14-16.

Whiteinella aprica (Loeblich & Tappan). Eicher & Worstell, 1970, p. 314, pl. 11, fig. 7a-c; pl. 12, fig. 1a-c.

Whiteinella aprica (Loeblich & Tappan). Robaszynski & Caron, 1979, v. 1, p. 157, 160, pl. 32, figs 1-2.

Whiteinella aprica (Loeblich & Tappan). Bellier, 1985, p. 17, pl. 5, figs 1-3.

Remarks: *Hedbergella (Whit.) aprica* is characterised by its low trochospiral test (c. 300-310μm in maximum diameter), with the spiral height varying from nearly flat to moderately convex; only very slightly asymmetrical in peripheral view; 6 globose chambers, slowly increasing in size; test surface covered with regularly distributed pustules; umbilicus shallow and rather wide.

Range: latest Cenomanian to early-late Turonian.

Occurrence: localities A-2, A-9, A-29, A-35, A-45, well 1-CA-1-SE.

Hedbergella (Whiteinella) archaeocretacea (Pessagno)

(Pl. 27, Figs 7-12)

Whiteinella archaeocretacea Pessagno, 1967, p. 298-299, pl. 51, figs 2-4; pl. 54, figs 19-25; pl. 100, fig. 8.

Whiteinella archaeocretacea Pessagno. Robaszynski & Caron, 1979, v. 1, p. 161, 167-168, pl. 33, figs 1-3, pl. 34, figs 1-2.

Whiteinella archaeocretacea Pessagno. Wonders, 1980, p.129, pl.3, figs 1a-c.

Remarks: Hedbergella (W.) archaeocretacea is distinguished by its lobate test (c. 470-580µm in maximum diameter)of low trochospire; 5 to 5.5 globular to oval-shaped chambers in the last whorl, increasing rapidly in size, and somewhat elongated in the direction of coiling; primary aperture extraumbilical-umbilical to nearly umbilical in position; umbilicus shallow and wide; test surface coarsely rugose; chambers rather laterally compressed and oval in peripheral outline view. It differs from Hedbergella (W.) aprica (Loeblich & Tappan) in having its later chambers elongated and somewhat compressed, a wider umbilicus, and generally less chambers per whorl, increasing more rapidly in size.

Range: earliest Turonian.

Occurrence: localities A-2, A-35, wells 1-CA-1-SE, 1-US-1-SE.

Hedbergella (Whiteinella) baltica (Douglas & Rankin)

(Pl. 27, Figs 13-19)

Whiteinella baltica Douglas & Rankin, 1969, p. 198, text-figs 9a-c.

Rugoglobigerina? alpina Porthault, 1969, pl. 2, figs 2a-c.

Whiteinella baltica Douglas & Rankin. Caron, 1978, pl. 4, figs. 4-5.

Whiteinella baltica Douglas & Rankin. Robaszynski & Caron, 1979, v. 1, p. 169, 174, pl. 35, figs 1-5, pl. 36, figs 1-2.

Whiteinella baltica Douglas & Rankin. Caron, 1985, p. 79, figs 37.1-3.

Remarks: Hedbergella (W.) baltica specimens are characterised by a test of low trochospire, almost bilaterally symmetrical (c. 340-380µm in maximum diameter); 3.5 to 5 globose chambers, increasing rapidly in size; spinose test surface; umbilicus narrow; chambers circular in peripheral outline view.

Range: middle-late Cenomanian to early-late Turonian.

It is important to note that the range of Hedbergella (W.) baltica in Sergipe is well outside that recorded by Douglas & Rankin (1969 - Bornholm, Denmark) for the species in the Boreal Realm (late Turonian to early Santonian), and actually matches that of Porthault (1969 - SE France) and Robaszynski & Caron (1979) recorded in the Tethyan Realm (middle-late Cenomanian to middle Turonian).

Occurrence: localities A-2, A-9, A-21, A-22, A-35, A-45, well 1-CA-1-SE.

Hedbergella (Whiteinella) brittonensis Loeblich & Tappan

(Pl. 27, Figs 20-22)

Hedbergella brittonensis Loeblich & Tappan, 1961, p. 274-275, pl. 4, figs 1a-c.

Hedbergella brittonensis Loeblich & Tappan. Pessagno, 1967, p. 282, pl. 52, figs 9-12.

Whiteinella brittonensis (Loeblich & Tappan). Robaszynski & Caron, 1979, v. 1, p. 175, 180, pl. 37, figs 1-2, pl. 38, figs 1-2.

Remarks: Hedbergella (W.) brittonensis shows a moderately high asymmetrical trochospire (c. 300/200µm to 330/190µm in maximum diameter/height ratio); 5.5 to 6 globular chambers, increasing slowly in size; last chamber commonly extending over the umbilicus, which often gives an impression of high-trochospire to the test lateral profile; umbilicus narrow. It differs from Hedbergella (W.) aprica (Loeblich & Tappan) in having a higher dorsal side and a narrow umbilicus.

The taxonomic validity of Hedbergella (W.) brittonensis is uncertain, seeing that it may actually turn to be an ecophenotypic variation of Hedbergella (W.) paradubia Sigal (see below) and, consequently, a junior synonym. However, the paucity of specimens recovered from Sergipe made difficult a better assessment of the problem. In the meantine, both morphotypes are treated in this study as separate species.

Range: middle-late Cenomanian to middle-late Turonian.

Occurrence: localities A-2, A-9, A-35, wells 1-CA-1-SE, 1-US-1-SE.

Hedbergella (Whiteinella) paradubia Sigal

(Pl. 27, Figs 23-26)

Hedbergella paradubia Sigal, 1952, p. 28, text-fig. 28.

Hedbergella brittonensis Loeblich & Tappan, 1961, pl. 4 figs 3-4.

Whiteinella paradubia (Sigal). Robaszynski & Caron, 1979, v. 1, p. 181, 184, pl. 39, figs 1-2.

Remarks: This species is characterised by its high trochospire (c. 250/170μm to 310/210μm in maximum diameter/height ratio); lobate, almost circular, equatorial periphery; 5 to 6 inflated chambers, gradually increasing in size, with a rugose surface; and narrow umbilicus. It differs from Hedbergella (W.) brittonensis (Loeblich & Tappan) by having a strongly asymmetrical, spiro-convex test, with a higher trochospire.

Range: Turonian to early Coniacian.

Occurrence: localities A-2, A-10, A-35.

Subfamily **ROTUNDININAE**

Bellier & Salaj, 1977

Genus **PRAEGLOBOTRUNCANA** Bermúdez, 1952

Type species: Globorotalia delrioensis Plummer, 1931

Praeglobotruncana delrioensis (Plummer)

(Pl. 27, Figs 27-34)

Globorotalia delrioensis Plummer, 1931, p. 199, pl. 13, figs 2a-c.

Praeglobotruncana delrioensis (Plummer). Bermudez, 1952, p. 52, pl. 7, fig. 1.

Praeglobotruncana delrioensis (Plummer). Klaus, 1960, p. 300-301, text-fig. 1a.

Praeglobotruncana delrioensis (Plummer). Loeblich & Tappan, 1961, p. 280-284, pl. 6, figs 9-12.

Praeglobotruncana delrioensis (Plummer). Pessagno, 1967, p. 286-287, pl. 52, figs 3-5; pl. 100, fig. 7.

Praeglobotruncana delrioensis (Plummer). Carter & Hart, 1977, p. 38-39, pl. 4, figs 22-24.

Praeglobotruncana delrioensis (Plummer). Sliter, 1977a, p. 542, pl. 8, figs 1-3, 6.

Praeglobotruncana delrioensis (Plummer). Leckie, 1984, p. 600, pl. 12, figs 1-8.

Praeglobotruncana delrioensis (Plummer). Robaszynski & Caron, 1979, v. 2, p. 29, 32, pl. 43, figs 1-2.

Praeglobotruncana delrioensis (Plummer). Caron, 1985, p. 65, figs 30.1-2.

Remarks: Specimens of Praeglobotruncana delrioensis are identified by the coarsely spinose early periphery and compressed test (c. 280-350μm in maximum diameter); 4 to 6 subglobular chambers in the last whorl [the ultimate one has a globular aspect similar do Hedbergella (H.) ex gr. delrioensis (Carsey)]; and prominent interiomarginal, extraumbilical-umbilical arch with a narrow bordering lip. The species differs from Praeglobotruncana sp. cf. P. stephani (Gandolfi) by having a more compressed test and an acute pustulose equatorial periphery. A phylogenetic lineage from Praeglobotruncana delrioensis to Praeglobotruncana stephani was proposed by Klaus (1960, p. 285-308), based on biometric and statistical analysis of Praeglobotruncana populations.

Range: latest Albian to early-middle Cenomanian.

Occurrence: wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE.

Praeglobotruncana sp. cf. P. stephani (Gandolfi)

(Pl. 28, Figs 1-4)

cf. Globotruncana stephani Gandolfi, 1942, p. 130, pl. 3, fig. 4a-c.

cf. Praeglobotruncana stephani (Gandolfi). Robaszynski & Caron, 1979, p. 47, pl. 48, figs 1-3.

cf. Praeglobotruncana stephani (Gandolfi). Bellier, 1985, p.15-16, pl. 2, figs 14-16.

cf. Praeglobotruncana stephani (Gandolfi). Caron, 1985, p. 65, figs 30.3-4.

Remarks: Specimens referred to Praeglobotruncana sp. cf. P. stephani are characterised by having a moderately large, low trochospiral, nearly symmetrical biconvex test (c. 330-340μm in maximum diameter); rounded to subacute equatorial periphery; 6 globular to trapezoidal chambers in the last whorl, in ventral view, increasing rather rapidly in size; petaloid chamber outline in dorsal view; umbilical sutures radial and depressed; sutures raised, oblique, curved forwards on the dorsal side; lobate equatorial periphery. The scarcity and bad preservation of the specimens (commonly very recrystalised) hinders their precise taxonomic attribution.

Range: earliest Turonian.

Occurrence: locality A-2 (rare occurrence).

Family **ROTALIPORIDAE** Sigal, 1958

Subfamily **TICINELLINAE** Longoria, 1974

Genus **BITICINELLA** Sigal, 1956,

Type Species: *Anomalina* *breggiensis* Gandolfi, 1942.

Remarks: *Biticinella* is here regarded, *sensu* Masters (1977, p. 517-518) and Loeblich & Tappan (1988, p. 466), as a genus comprising flat trochospiral-planispiral biumbilicate forms with the presence of both "ventral" accessory apertures and relict "dorsal" apertures, differentiated from *Ticinella* specimens which possess only accessory apertures on the ventral side.

Biticinella ***breggiensis*** (Gandolfi)

(Pl. 28, Figs 5-15)

Anomalina *breggiensis* Gandolfi, 1942, p. 102-103, pl.3, fig.6; pl. 5, fig. 3; pl. 9, fig. 1; pl. 13, figs 7-8; text-figs 34 (1-4).

Biticinella *breggiensis* (Gandolfi). Sigal, 1956, p. 35-36, text-figs 1a-c.

Biticinella *breggiensis* (Gandolfi). Caron & Luterbacher, 1969, p. 25, pl. 7, fig.4.

Ticinella *breggiensis* (Gandolfi). Longoria, 1974, p. 95-96, pl. 25, figs 7, 14-16.

Ticinella *breggiensis* (Gandolfi). Longoria & Gamper, 1977, p. 211-212, pl. 5, figs 10-12, pl. 6, figs 7-12, 16-21.

Biticinella *breggiensis* (Gandolfi). Masters, 1977, p.519, 521, pl. 35, figs 1-3.

Biticinella cf. breggiensis (Gandolfi). Caron, 1978, p. 660, pl. 3, figs 5-7.
Biticinella breggiensis (Gandolfi). Wonders, 1980, p. 106, pl. 1, fig. 4a-c.
Biticinella breggiensis (Gandolfi). Leckie, 1984, p. 600, pl. 8, figs 1-2.
Biticinella breggiensis (Gandolfi). Caron, 1985, p. 43, figs 36.16-17.

Remarks: Biticinella breggiensis is characterised by its moderately large size (c. 300-340µm in maximum diameter), arranged in a low trochospiral coil becoming planispiral in the last whorl; biumbilicate; 6 to 7 inflated chambers in the last whorl (1-3 less than the topotypes, which have 8 to 9), increasing gradually, but irregularly, in size; subcircular equatorial periphery, slightly lobate; rounded axial periphery; primary aperture a low arch, interiomarginal, asymmetric, and bordered by long apertural lip (portici) which extends into each umbilicus; infralaminal accessory apertures often observed along the margin, between the portici, in one side; relict apertures frequently visible on the spiral side.

Range: middle to late Albian.

Occurrence: locality A-15, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-24.

Genus **TICINELLA** Reichel, 1950, emended, Longoria, 1974

Type species: Anomalina roberti Gandolfi, 1942

Remarks: Few Ticinella specimens found in the Albian of Sergipe display the characteristic intraumbilical supplementary apertures, a morhological feature which has been regarded as an ecophenotypic character (cf. Price, 1976). Well-preserved late Albian specimens assigned to this genus have long apertural flaps, which extend into the umbilicus to form a depressed umbilical cover plate (e.g., Pl. 28, Figs 22-23; Pl. 29, figs 8-10). The emended definition given by Longoria (1974, p. 93-94, and p. 52-53, remarks on Hedbergella) allows more variation of the morphological features at the generic level and is, therefore, followed herein.

Ticinella bejaouaensis Sigal

(Pl. 28, Figs 16-25)

Ticinella roberti (Gandolfi) var. *bejaouaensis* Sigal, 1966a, p. 207, pl. 5, figs 5-9.

Ticinella bejaouaensis Sigal. Moullade, 1966, p.103, pl.9, figs 4-5.

Ticinella bejaouaensis Sigal. Longoria, 1974, p. 94-95, not pl. 18, figs 1-2; pl. 19, figs 9-13 (not 14-16); pl. 21, figs 12-13 (not 9-11, 14-16).

Ticinella bejaouaensis Sigal. Longoria & Gamper, 1977, p. 211, pl. 2, figs 16-18.

Ticinella bejaouaensis Sigal. Caron, 1978, p. 659, pl. 2, figs 9-10.

Ticinella bejaouaensis Sigal. Caron, 1985, p.76, figs 36.1-3.

Remarks: Sigal (1966) differentiated the variety *Ticinella roberti bejaouaensis* from *Ticinella roberti* s.s. (Gandolfi) on the basis of more chambers in the last whorl (averaging 9) and a more open umbilicus. On the other hand, Longoria (1974, p. 95) noted that *Ticinella bejaouaensis* differs from *Ticinella roberti* in 'having smaller umbilicus', which is in apparent contradiction with Sigal's original diagnosis. However, the specimens of *Ticinella bejaouaensis* from La Drôme, southeast France, illustrated in Longoria (op. cit., see above), show a moderately wide and shallow umbilicus, flattened spiral side, 8 to 9 subtrapezoidal to globular chambers in the last whorl, tightly arranged to somewhat lobate, and circular equatorial periphery. The figured specimens of *Ticinella roberti* (Longoria, op. cit., pl. 12, figs 1-11) have generally a larger size, variable umbilical width, higher trochospire, around 7 to 8 globular chambers, more loosely arranged, and moderatly lobate circular equqtorial periphery. *Ticinella bejaouaensis* specimens (c. 210-320μm in maximum diameter) recovered from the Sergipe sections are morphologically close to the ones from La Drôme and, therefore, show the same characteristics. Although the taxonomic status of this species has been challenged (e.g., Masters, 1977, p. 530; Leckie, 1984, p. 600-601), its distinguishing features seem to be reliable enough to retain it as valid. Furthermore, *Tic. bejaouaensis* is a biostratigraphically useful species in Sergipe and elsewhere (Chapter 4).

Range: late Aptian to middle Albian.

Occurrence: localities A-15, A-27, wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-9

Ticinella madecassiana Sigal

(Pl. 28, Figs 26-32)

Ticinella madecassiana Sigal, 1966a, p. 197-198, pl. 3, figs 7a-10b.
Ticinella madecassiana Sigal. Caron, 1978, p. 660, pl. 3, figs 4-5.
Ticinella madecassiana Sigal. Leckie, 1984, p. 600, pl. 6, figs 7-12.
Ticinella madecassiana Sigal. Caron, 1985, p. 76, figs. 36.4-5.

Remarks: This species is characterised by its moderately large size (c. 310-340μm in maximum diameter) and very low trochospire; generally 6 to 7 globular chambers in the last whorl, increasing rapidly in size; and a narrower umbilicus. It shows a trend towards pseudoplanispiral coiling (i.e., somewhat concave spiral side), which makes the ventral view resembles *Globigerinelloides bentonensis* (Morrow), in peripheral outline and chamber arrangement (cf. Leckie, 1981).

Range: middle to late Albian

Occurrence: locality A-15, wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-24.

Ticinella praeticinensis Sigal

(Pl. 28, Figs 33-34)

Ticinella praeticinensis Sigal, 1966a, p. 195-196, pl. 2, figs 3-8; pl. 3, figs. 1-6.
Ticinella praeticinensis Sigal. Masters, 1977, p. 523-525, pl. 35, fig. 4, pl. 36, figs 1-2.
Ticinella praeticinensis Sigal. Caron, 1978, p. 660, pl. 7, figs 1-2.
Ticinella praeticinensis Sigal. Leckie, 1984, p. 600, pl. 13, figs. 9-10.
Ticinella praeticinensis Sigal. Caron, 1985, p. 78, figs. 36.8-9.

Remarks: *Ticinella praeticinensis* is characterised by a low trochospiral test (c. 240-320μm in maximum diameter) with a flattened, nearly symmetrical, peripheral profile; 8 to 9 globular chambers in the last whorl, slowly increasing in size; lobate, circular equatorial periphery; wide and deep umbilicus. Caron (1978, p. 660) describes specimens of *Ticinella* praeticinensis Sigal recovered from the Angola Basin, southeastern Atlantic Ocean, that "have 1 or 2 chambers less than the holotype" and that "the primary aperture is clearly visible, umbilical to extraumbilical in position. Umbilical sutural supplementary apertures are infrequent and not easily visible." It differs from Ticinella bejaouaensis Sigal in the flattened, subrounded peripheral outline.

Range: middle to late Albian.

Occurrence: wells 1-CN-1-SE, 1-US-1-SE, 1-SES-24.

Ticinella ex gr. primula Luterbacher

[Pl. 29, Figs 1-5, 6-7 (cf.)]

Ticinella primula Luterbacher, in Renz et al.,1963, p.1083-1086, text-fig. 4.

Ticinella raynaudi var. aperta Sigal, 1966a, p. 206, pl.6, figs 11-13.

Ticinella primula Luterbacher. Sigal, 1966a, p. 198-199, pl. 3, figs 11-14; pl. 4, figs 1-9.

Ticinella raynaudi var. aperta Sigal. Caron, 1971, p. 155, text- fig. 20.

Ticinella primula Luterbacher. Longoria, 1974, pl. 25, figs 1-6; pl. 26, figs 12-14.

Ticinella aperta Sigal. Longoria & Gamper, 1977, p. 211, pl. 1, figs 10-12, pl. 5, figs 7-9.

Ticinella caronae Longoria & Gamper, 1977, p. 212, pl. 1, figs 1-3, 13-15.

Ticinella primula Luterbacher. Longoria & Gamper, 1977, p. 215, pl. 1, figs 7-9, 16-18.

Ticinella primula Luterbacher. Masters, 1977, p. 525-526, pl. 36, figs 3, 4, pl. 37, figs 1, 3.

Ticinella primula Luterbacher. Caron, 1978, p. 659, pl.3, figs 1-3; pl. 9, figs 3-4.

Ticinella primula Luterbacher. Bellier, 1985, p. 10, pl. 1, figs 4-6.

Ticinella primula Luterbacher. Caron, 1985, p. 79, figs 36.6-7.

Remarks: The specimens of Ticinella ex gr. primula from Sergipe generally have a moderately large test (c. 290-370µm in maximum diameter), coiled in a very low trochospiral, almost flat to somewhat concave (pseudoplanispiral coil); usually 7 to 8 globular to subtrapezoidal chambers in the last whorl, increasing gradually in size; smooth surface; and an umbilical to extraumbilical aperture which is highest towards the periphery. *Ticinella* ex gr. *primula* differs from *Ticinella* *madecassiana* Sigal by its more numerous chambers, looser coiling and wider umbilicus. It is distinguished from *Ticinella* *bejaouaensis* Sigal in having fewer chambers, an elliptical and lobate, rather than circular, equatorial periphery and a pseudoplanispiral coil. They apparently lack the supplementary (sutural) apertures of Luterbacher's species, and in this respect resemble forms described by Hermes (1969, p. 40, pl. 1, figs 13–18) as "(?) *Ticinella* sp. cf. *T.* *primula*", by Caron (1971, p. 146, figs. 2a–c) as "(?)*Ticinella* *primula*", and by Playford *et* *al.* (1975, p. 343, fig. 2, nos 10–12) as "*Hedbergella* sp. A". Also, Price (1976, p. 640, pl. 2, fig. 6) records that all specimens of *Ticinella* *primula* from northwest Germany have either obscured or very small accessory apertures and relates the latter as being probably the result of lower temperatures. Specimens described as *Ticinella* *raynaudi* var. *aperta* by Sigal (1966a, see above) appear to represent either an intraspecific (ecophenotypic) variation or the late ephebic/gerontic stage of *Ticinella* ex gr. *primula* (see Pl. 29, Figs 3–5). They differ by having an often larger test (c. 350–370μm in maximum diameter) with a more elongate circular peripheral margin, 7 to 8 ovate to subtrapezoidal chambers in the last whorl, and narrower umbilicus. A few specimens referable to *Ticinella* sp. cf. *T.* *primula* (see Pl. 29, Figs 6–7) were observed in the upper Aptian–lower Albian sections of the basin. They generally display only 6 chambers in the last whorl and a more closed umbilicus than the typical middle–late Albian specimens. These early forms morphologically resemble specimens described as *Blefuscuiana* *speetonensis* by Banner & Damini Desai (1988, p. 164, pl. 7, figs 3–4) from the upper Aptian of Speeton Cliff, North Yorkshire, England. These species may prove, with further research, to be regarded as synonymous, but this subject is here left open for further review.

Range: middle to late Albian.

Occurrence: locality A-15, A-27, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-9, 1-SES-24.

Ticinella raynaudi Sigal

(Pl. 29, Figs 8-14)

Ticinella raynaudi var. raynaudi Sigal, 1966a, p. 201-202, pl. 5, fig. 10; pl. 6, figs 1-5.

Ticinella raynaudi var. digitalis Sigal, 1966a, p.202, pl.6, figs 6-8.

Ticinella raynaudi var. digitalis Sigal. Caron, 1971, p. 155, text-fig. 21 a-c.

Ticinella raynaudi Sigal. Longoria & Gamper, 1977, p. 215, pl. 5, figs 4-6.

Ticinella raynaudi Sigal. Caron, 1978, p. 660, pl. 9, figs 8-9.

Ticinella raynaudi Sigal. Leckie, 1984, p. 600, pl. 7, figs 1-4; pl.8, figs 3-4.

Ticinella raynaudi Sigal. Caron, 1985, p. 79, figs 36.10-12.

Remarks: Ticinella raynaudi is characterised by its moderately large test (c. 270-380μm in maximum diameter) with a lobate equatorial periphery; low trochospire; 6 to 7 chambers in the last whorl, gradually increasing in size, with a tendency for the last 2-4 chambers to become radially elongate; last chamber often with long portici extending into the umbilicus; wide and shallow umbilicus. It is similar to Ticinella ex gr. primula Luterbacher from which it differs in the slightly higher trochospire, more lobate equatorial periphery and in possessing more elongate last chambers. Latest Albian morphotypes of Ticinella raynaudi have very rugose and/or pustulose test surface ornamentation (Hedbergella "à costellae" assemblage of Caron, 1978).

Range: middle to latest Albian.

Occurrence: locality A-15, wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE.

Ticinella roberti (Gandolfi)

(Pl. 29, Figs 15-27)

Anomalina roberti Gandolfi, 1942, p. 100-101, text-fig. 22; pl. 2, fig. 2; pl. 4, figs 5-7; pl. 13, figs 3, 6.

Ticinella roberti (Gandolfi). Sigal, 1952, fig. 19.

Ticinella roberti (Gandolfi). Sigal, 1966a, p. 203, pl. 5, figs 1a-4b; pl. 6, figs 10 a-b, 12 a-b.

Ticinella roberti (Gandolfi). Longoria, 1974, p. 98, 100, pl. 12, figs 1-11).

Ticinella roberti Sigal. Longoria & Gamper, 1977, p. 215, pl. 1, figs 22-24 (not 19-21), pl. 2, figs 19-21 (not 1-3).

Ticinella roberti (Gandolfi) Masters, 1977, p. 527-530, pl. 36, figs 5-6, pl. 37, fig. 2.

Ticinella roberti (Gandolfi). Caron, 1978, p. 660, pl. 6, figs 1-4.
Ticinella roberti (Gandolfi). Bellier, 1985, p. 10, pl. 1, figs 1-3.
Ticinella roberti (Gandolfi). Caron, 1985, p. 79, figs 36.13-15.

Remarks: Ticinella roberti is characterised by its small to moderately large test (c. 230-330μm in maximum diameter), with the last whorl coiled in a lower plane than the penultime whorl; around 6 to 7 globular chambers (1-3 less than the topotypes, which usually have 8 to 9), loosely arranged, in the last whorl, increasing gradually in size; low to moderately high trochospire; variable umbilical width, and a slightly lobate circular equatorial periphery (see discussion under remarks of Ticinella bejaouaensis Sigal). Middle-late Albian specimens have generally a larger test (c. 280-330μm in maximum diameter) and an irregularly roughened surface ornamentation of the first 2 or 3 chambers of the last whorl. It differs from Ticinella ex gr. primula Luterbacher by its more embrancing chambers, a peripheral outline that is circular rather than elliptical, and higher trochospire; and from late Aptian-middle Albian specimens of Hedbergella trocoidea (Gandolfi) in having a slightly higher trochospire, a generally smaller test and a roughened surface on the first chambers of the last whorl. As already noted by Caron (1978, p. 660), specimens of Ticinella roberti from the South Atlantic are atypical, always having one less chamber per whorl than the topotypes, and possessing a lower trochospiral coil (probably representing younger ontogenetic stages and/or ecophenotypic adaptations to a water-mass with warm temperature, hypersalinity and oxygen depleted bottom conditions - see Chapters 6 and 8, section 8.2.4).

Range: late Aptian to Albian.

Occurrence: localities A-15, A-27, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-US-1-SE, 1-SES-3, 1-SES-24.

Subfamily **ROTALIPORINAE** Sigal, 1958

Genus **ROTALIPORA** Brotzen, 1942

Type Species: Rotalipora turonica Brotzen, 1942.

Remarks: Rotalipora are single keeled planktonic foraminifera with a primary extraumbilical-umbilical aperture, almost reaching the periphery, and umbilical or sutural supplementary apertures.

Rotalipora appenninica (Renz)

(Pl. 29, Figs 28-30)

Globotruncana appenninica Renz, 1936, p. 14, fig. 2.

Rotalipora appenninica appenninica (Renz). Luterbacher & Premoli Silva, 1962, p. 266-268, pl. 19, figs 1, 2; pl. 20, figs 1-4; pl. 21, figs 1-4.

Rotalipora appenninica (Renz). Masters, 1977, p. 497, pl. 30, figs 1-3.

Rotalipora appenninica (Renz). Robaszynski & Caron, 1979, v. 1, p. 59, 64; pl. 4, figs 1-3; pl. 5, figs 1-3.

Rotalipora appenninica (Renz). Leckie, 1984, p. 601, pl. 14, figs 4-12 (not 1-3).

Thalmanninella appenninica (Renz). Bellier, 1985, p. 12, pl. 1, figs 14-17.

Rotalipora appenninica (Renz). Caron, 1985, p. 67, figs 31.1-4.

Remarks: Rotalipora appenninica is characterised by a symmetrically biconvex test (c. 550µm in maximum diameter) with 5 to 6 chambers in the last whorl, triangular to trapezoidal in shape on the ventral side; sutures raised on the dorsal side, those of the last whorl joining the preceding whorl at right angles, chambers petaloid in shape; no true periumbilical flange; narrow umbilicus. It differs from Rotalipora gandolfii Luterbacher & Premoli Silva in being generally flatter, in lacking a true periumbilical flange and in having spiral sutures joining the preceding whorl at right angles.

Range: early Cenomanian.

Occurrence: localities A-1, A-3, well 1-CN-1-SE.

Rotalipora brotzeni (Sigal)

(Pl. 29, Figs 31-34)

Thalmanninella brotzeni Sigal, 1948, p. 102, pl. 1, fig. 5, pl. 2, figs 6-7.

Rotalipora brotzeni (Sigal). Robaszynski & Caron, 1979, v. 1, p. 65, 68, pl.6, figs 1-2.

Thalmanninella brotzeni Sigal. Bellier, 1985, p. 13, pl. 11, figs 1-4.

Rotalipora brotzeni (Sigal). Caron, 1985, p. 67, figs 31.5-7.

Remarks: Rotalipora brotzeni is characterised by a biconvex, slightly asymmetrical test (c. 340µm in maximum diameter); 6 trapezoidal chambers in ventral view, increasing gradually in size; raised umbilical sutures and periumbilical flanges on most of the chambers; chambers petaloid in shape in dorsal view. It differs from Rotalipora appenninica (Renz) in having a less lobate outline and periumbilical flanges.

Range: earliest Cenomanian.

Occurrence: well 1-CN-1-SE (rare occurrence).

Rotalipora greenhornensis (Morrow)

(Pl. 30, Figs 1-3)

Globorotalia greenhornensis Morrow, 1934, p. 199, pl. 31, fig. 1.

Rotalipora greenhornensis (Morrow). Loeblich & Tappan, 1961, p. 299-301, pl. 7, figs 5-10.

Rotalipora greenhornensis (Morrow). Masters, 1977, p. 508-511, pl. 31, figs 5-6.

Rotalipora greenhornensis (Morrow). Robaszynski & Caron, 1979, v. 1, p. 85, 90, pl. 12, figs 1-2; pl. 13, figs 1a-2c.

Rotalipora greenhornensis (Morrow). Leckie, 1984, p. 601, pl. 15, figs 1-4; pl. 16, figs 7-12.

Rotalipora greenhornensis (Morrow). Caron, 1985, p. 69, figs 32.1-2.

Remarks: A single specimen of Rotalipora greenhornensis, very recrystalised, was recovered from the uppermost Cenomanian. It is characterised by having a small, unequally biconvex test (c. 295µm in maximum diameter), the umbilical side being more convex; 6 trapezoidal chambers in dorsal view, with strongly oblique sutures.

Range: latest Cenomanian.

Occurrence: locality A-9.

Superfamily **GLOBOTRUNCANACEA**
Brotzen, 1942

Family **GLOBOTRUNCANIDAE**
Brotzen, 1942

Subfamily **GLOBOTRUNCANINAE**
Brotzen, 1942

Remarks: Although distinctive generic features are on many occasions difficult to distinguish on recrystalised or partially dissolved tests (common features in the foraminiferal assemblages recovered from the Turonian-lower Coniacian carbonate sections of Sergipe; Cotinguiba Formation), most of the mid-Cretaceous keeled planktonic specimens have been given a specific taxonomic identification.

Genus **CONTUSOTRUNCANA**
Korchagin, 1982
(*sensu* Loeblich & Tappan, 1988, p. 468)

Type species: *Pulvinulina arca* Cushman
var. *contusa* Cushman, 1926

Remarks: Species assigned to this genus have an interiomarginal and umbilical primary aperture, portici extending into the umbilicus and covering the successive apertures, spiral side virtually always high or very high, and periphery with two very closely spaced keels. The generic name *Contusotruncana* has priority over *Rosita*, proposed by Robaszynski *et al.* (1984, p. 244; type species: *Globotruncana fornicata* Plummer, 1931), which is, therefore, considered invalid (err. emend.).

Contusotruncana contusa (Cushman)
(Pl. 30, Figs 4-9)

Pulvinulina arca Cushman var. *contusa* Cushman, 1926a, p. 23, *nomen nudum* (no type figure given).

Globotruncana arca (Cushman) var. *contusa* Cushman. Cushman, 1946, p. 150, pl. 62, fig. 6a-c (holotype).
Globotruncana contusa Pessagno, 1967, p. 330-333, pl. 77, figs 7-9 (not figs 1-6), pl. 96, figs 15-16 (not figs 11, 13-14).
Globotruncana contusa (Cushman). Smith & Pessagno, 1973, p. 45-46, pl. 21, figs 1-5.
Globotruncana contusa (Cushman). Masters, 1977, p. 545-549, pl.40, figs 1-4.
Globotruncana contusa (Cushman). Wonders, 1980, p. 107, pl. 8, fig. 2a-c.
Rosita contusa (Cushman). Robaszynski *et al.*, 1984, p. 246, 248, pl. 35, figs 5-6, 9, pl. 36, figs 1-2, pl. 37, figs 1-3.
Globotruncana contusa (Cushman). Bellier, 1985, p. 29-30, pl. 6, figs 12-14.
Rosita contusa (Cushman). Caron, 1985, p. 67, figs 28.1-2.

Remarks: *Contusotruncana contusa* is characterised by its large-sized and highly trochospiral test (c. 450/280µm to 530/310µm in maximum diameter/height ratio), with concave umbilical side; two closely spaced keels; 5 to 7 subtrapezoidal chambers in ventral view, with flat, smooth to pustulose surfaces; chambers globular to strongly elongated in dorsal view, with undulating surfaces; umbilicus wide and deep.

Range: late Maastrichtian.

Occurrence: wells 1-SES-3, 1-SES-24.

Contusotruncana ex gr. fornicata (Plummer)

(Pl. 30, Figs 10-17)

Globotruncana fornicata Plummer, 1931, p. 130, pl. 13, fig. 4a-c.
Globotruncana fornicata Plummer. Pessano, 1967, p. 338-341, pl. 63, figs 1-9, pl. 80, figs 7-9, pl. 96, figs 3-4.
Globotruncana fornicata Plummer. Masters, 1977, p.564-566, pl. 44, figs 4-6.
Rosita fornicata (Plummer). Robaszynski *et al.*, 1984, p. 250, 301, pl. 38, figs 1-5.
Globotruncana fornicata Plummer. Bellier, 1985, p. 27-28, pl. 6, figs 1-3.

Remarks: Specimens of *Contusotruncana* ex gr. *fornicata* specimens have a large test with a low to moderately high trochospire (c. 410/210µm to 470/250µm in maximum diameter/height ratio); two keels on all chambers; keel band widening towards the anterior part of each chamber, forming a pattern of embracing V-shapes; 4 to 5 kidney-shaped chambers in ventral view, increasing rapidly in size, with smooth and undulating surfaces; crescentic-shaped in dorsal view, strongly elongated in the direction of coiling, with smooth and undulating surfaces; circular to subpolygonal equatorial periphery, slightly lobate; moderately wide umbilicus.

Range: Santonian to early Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-CA-1-SE, 1-CRL-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Contusotruncana patelliformis (Gandolfi)

(Pl. 30, Figs 18-20)

Globotruncana (*Globotruncana*) *contusa* (Cushman) subsp. *patelliformis*, Gandolfi, 1955, p. 54-55, pl. 4, fig. 2a-c.

Globotruncana contusa (Cushman). Pessagno, 1967, p. 330-333, pl. 75, figs 18-20, pl. 77, figs 4-6, pl. 78, figs 6-11, pl. 92, figs 10-12, pl. 96, figs 11, 13-14.

Globotruncana patelliformis Gandolfi. Smith & Pessagno, 1973, p. 50-51, pl. 21, figs 6-8.

Rosita patelliformis (Gandolfi). Robaszynski *et al.*, 1984, p. 252, pl. 35, fig. 8, pl. 39, figs 1-3.

Remarks: Specimens of *Contusotruncana patelliformis* are characterised by having a large test with moderately to fairly high trochospire (c. 360/220µm to 460/250µm in maximum diameter/ height ratio), with umbilical side flat to concave; two closely spaced keels; 4 to 5 elongated trapezoidal chambers in ventral view; globular to elongated, crescentic chambers in dorsal view, with smooth and undulating surfaces; wide and deep umbilicus. *Contusotruncana patteliformis* is morphologically transitional between *Contusotruncana contusa* (Cushman) and *Contusotruncana* ex gr. *fornicata* (Plummer), probably representing a phylogenetic lineage sequence of *fornicata-patteliformis-contusa*, of progressive increase in test size and trochospire height. The species differs from *C. contusa* in having a lower trochospire, fewer number of whorls, and in a generally smaller size; and from *C.* ex gr. *fornicata* in having a higher spiral side, with a flat to concave umbilical side.

Range: Maastrichtian.

Occurrence: wells 1-SES-3, 1-SES-24.

Genus **DICARINELLA** Porthault, 1970,

(sensu Robaszynski & Caron, 1979, v. 2, p. 51-55)

Type species: Globotruncana indica Jacob & Sastry, 1950

Remarks: Dicarinella specimens are characterised by the presence of an imperforate peripheral band separating two distinct keels; radial and depressed sutures on the umbilical side; and a primary aperture extraumbilical-umbilical. It differs from Praeglobotruncana Bermùdez in having portici and two well developed keels separated by an imperforate peripheral band, and from Marginotruncana Hofker in possessing depressed and radial sutures on the umbilical side.

Dicarinella asymetrica (Sigal)

(Pl. 30, Figs 27-31)

Globotruncana asymetrica Sigal, 1952, p. 35, fig. 35.

Globotruncana (Globotruncana) ventricosa White subsp. carinata Dalbiez, 1955, p. 168-169, fig 8a-c.

Marginotruncana concavata (Brotzen). Pessagno, 1967, p. 304-305, pl. 58, figs 3-6, pl. 95, figs 6-7.

Dicarinella asymetrica (Sigal). Robaszynski & Caron, 1979, v. 2, p. 61, 66, pl. 51, figs 1-2, pl. 52, figs 52, pl. 55, fig. 2.

Marginotruncana carinata (Dalbiez). Wonders, 1980, p. 122-123, pl.6, fig. 1a-c.

Dicarinella asymetrica (Sigal). Bellier, 1985, p. 22-23, pl. 3, figs 16-18.

Dicarinella asymetrica (Sigal). Caron, 1985, p. 43, figs 17.3-4.

Remarks: Dicarinella asymetrica is characterised by having a large (c. 300-580μm in maximum diameter), asymmetrical, low trochospiral, plano-convex to concavo-convex test; two closely spaced keels; 5 to 6 inflated chambers in ventral view, gradually increasing in size, with a rugose surface; petaloid chamber outline at the spiral side; pustules forming a well developed periumbilical ridge; lobate equatorial periphery; radial, depressed umbilical sutures; umbilicus wide and moderately deep. It is distinguished from Dicarinella concavata (Brotzen) in the presence of the periumbilical ridge.

Range: late Santonian.

Occurrence: wells 1-SES-3, 1-SES-24.

Dicarinella concavata (Brotzen)

(Pl. 30, Figs 21-26)

Rotalia concavata Brotzen, 1934, p. 66, pl. 3, fig. b.

Marginotruncana concavata (Brotzen). Pessagno, 1967, p. 304-305, pl. 58, figs 1-2, 7-9 (not figs 3-6 and pl. 95, figs 6-7), pl. 99, figs 1, 3.

Dicarinella concavata (Brotzen). Robaszynski & Caron, 1979, v. 2, p. 71, 77-78, pl. 54, figs 1(?)-2, pl. 55, fig. 1.

Marginotruncana concavata (Brotzen). Wonders, 1980, p. 123, pl. 5, figs 2a-c.

Dicarinella concavata (Brotzen). Bellier, 1985, p. 21-22, pl. 3, figs 13-15.

Dicarinella concavata (Brotzen). Caron, 1985, p. 45, figs 17.7-8.

Remarks: Specimens of *Dicarinella concavata* are distinguished by having a large (c. 380-440μm in maximum diameter), asymmetrical, low trochospiral, plano-convex to concavo-convex test; two close keels; 5 to 6 inflated chambers in ventral view, covered by pustules; petaloid chamber outline in dorsal view; lobate equatorial periphery; umbilical sutures radial and depressed; umbilicus wide and moderately deep. It differs from *Dicarinella asymetrica* (Sigal) in lacking the periumbilical ridge.

Range: late Coniacian to early-late Santonian.

Occurrence: wells 1-CRL-1-SE, 1-SES-9, 1-SES-24.

Dicarinella primitiva (Dalbiez)

(Pl. 31, Figs 1-3)

Globotruncana (*Globotruncana*) *ventricosa* White subsp. *primitiva* Dalbiez, 1955, p. 168, text-fig. 6.

Dicarinella primitiva (Dalbiez). Robaszynski & Caron, 1979, v. 2, p. 96, pl. 60.

Dicarinella primitiva (Dalbiez). Bellier, 1985, p. 21, pl. 3, figs 10-12.

Dicarinella primitiva (Dalbiez). Caron, 1985, p. 45, figs 18.6-8.

Remarks: *Dicarinella primitiva* shows a large (c. 650μm in maximum diameter), low trochospiral, asymmetrically biconvex, slightly umbilico-convex test; two close keels; 4 slightly inflated chambers; surface covered by pustules concentrated around the umbilicus; umbilical sutures radial and depressed; lobate equatorial periphery. It differs from *Dicarinella asymetrica* (Sigal) and *Dicarinella concavata* (Brotzen) in possessing a compressed test with a slightly elevated dorsal side and less inflated chambers on the ventral side.

Range: latest Turonian to early Coniacian.

Occurrence: localities A-8, A-10.

Genus **GANSSERINA** Caron,
Gonzáles Donoso, Robaszynski & Wonders, 1984

Gansserina gansseri (Bolli)
(Pl. 31, Figs 4-6)

Globotruncana gansseri Bolli, 1951, p. 196-197, pl. 35, figs 1-3.

Globotruncana gansseri Bolli. Pessagno, 1967, p. 341-343, pl. 75, fig. 1, pl. 92, figs 13-15 (not 16-18), pl. 95, figs 1-4.

Globotruncana aeggyptiaca Bolli. Smith & Pessagno, 1973, p. 48-49, pl. 20, figs 5-12 (not 1-4).

Globotruncana gansseri Bolli. Masters, 1977, p. 566-569, pl. 45, figs 1-3.

Globotruncana gansseri Bolli. Wonders, 1980, p. 114, pl. 7, fig. 1a-c.

Gansserina gansseri (Bolli). Robaszynski et al., 1984, p. 294, 296, pl. 51, figs 1-7, 10-11, pl. 52, figs 1-5, pl. 53, figs 1-5.

Globotruncana gansseri (Bolli). Bellier, 1985, p. 33-34, pl. 5, figs 17-19.

Gansserina gansseri (Bolli). Caron, 1985, p. 45, 47, figs 30.11-13.

Remarks: Specimens of Gansserina gansseri are characterised by their large, strongly asymmetrical, plano-convex test (c. 490-500μm in maximum diameter), with a flat to slightly concave dorsal side and a highly convex ventral side; single peripheral keel; 5 to 6 inflated trapezoidal chambers, on ventral view, increasing gradually in size; pustulose test surface tending to be smooth on the last 1 to 2 chambers; petaloid to crescentic chamber shape on the dorsal side; equatorial periphery circular to subcircular and slightly lobate; umbilicus of variable width.

Range: early to late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9, 1-SES-24.

Genus **GLOBOTRUNCANA** Cushman, 1927

Type Species: Pulvinulina arca Cushman, 1926.

Remarks: Taxa belonging to this genus have an umbilical primary aperture, and an umbilical system composed of tegilla bordering the successive apertures, covering a large part of the umbilicus and having both proximal and distal apertures.

Globotruncana aegyptiaca Nakkady

(Pl. 31, Figs 7-11)

Globotruncana aegyptiaca Nakkady, 1950, p. 690, pl. 80, fig. 20.

Globotruncana aegyptiaca Nakkady var. duwi Nakkady, 1950, p. 690, pl. 90, figs 17-19.

Globotruncana gagnebini Tilev, 1951, p. 50-56, text-figs 14-17, pl. 3, figs 2-5.

Globotruncana aegyptiaca Nakkady. Pessagno, 1967, p. 319-321, pl.79, figs 2-4, pl. 83, figs 8-10, pl. 94, fig. 6, pl. 95, figs 8, 9.

Globotruncana duwi Nakkady. Pessagno, 1967, p. 333-334, pl. 83, figs 5-6, 7, pl. 95, figs 12-14.

Globotruncana aegyptiaca Nakkady. Smith & Pessagno, 1973, p. 42-43, pl. 17, figs 1-7.

Globotruncana duwi Nakkady. Smith & Pessagno, 1973, p. 46-47, pl.17, figs 8-10, 11-13.

Globotruncana aegyptiaca Nakkady. Masters, 1977, p. 535-536, pl. 37, fig. 4.

Globotruncana duwi Nakkady. Masters, 1977, p. 555-559, pl. 43, figs 1-5.

Globotruncana aegyptiaca Nakkady. Robaszynski et al., 1984, p. 178, 180, pl. 2, figs 1-6, pl. 3, figs 1-4.

Globotruncana gagnebini Tilev. Bellier, 1985, p. 33, pl.5, figs 14-16.

Globotruncana aegyptiaca Nakkady. Caron, 1985, p. 50, figs 19.1-3.

Remarks: Specimens of Globotruncana aegyptiaca show a large (c. 340-430µm in maximum diameter) lobate test in outline, with a flat to slightly convex spiral side and a convex umbilical side; 3 to 5 subtrapezoidal chambers, increasing rapidly in size, with pustulose surfaces becoming smooth towards the last or penultimate chambers; umbilical sutures radial, straight to slightly curved; spiral side with globular chambers, then petaloid and finally elongated, crescentic in shape, with inflated and postulose surfaces; two keels on all chambers, equally developed, parallel, of variable width; wide umbilicus.

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Globotruncana arca (Cushman)

(Pl. 31, Figs 12-14)

Pulvinulina arca Cushman, 1926a, p. 23, pl. 3, fig. 1a-c.

Globotruncana arca (Cushman). Plummer, 1931, p. 195-198, pl. 13, fig. 8.

Globotruncana arca (Cushman). Pessagno, 1967, p. 321-323, pl. 79, figs 5-8, pl. 90, figs 5-8, pl. 96, figs 7, 8, 17.

Globotruncana arca (Cushman). Smith & Pessagno, 1973, p. 43-44, pl. 18, figs 1-3, 5-6.

Globotruncana arca (Cushman). Masters, 1977, p.536-540, pl. 38, figs 1-2, 4.

Globotruncana arca (Cushman). Robaszynski et al, 1984, p. 182, 184, pl. 1, figs 2-3, pl. 4, figs 1-3.

Globotruncana arca (Cushman). Bellier, 1985, p. 30-31, pl. 8, figs 1-3.

Globotruncana arca (Cushman). Caron, 1985, p. 50, figs 19.4-8.

Remarks: The species is distinguished by having a large test (c. 460μm in maximum diameter) nearly symmetrical test in profile, with a moderately high trochospire; outline lobate to subcircular; 5 to 6 chambers in the last whorl, increasing slowly to moderately in size; chambers elongate, somewhat rectangular, in umbilical view, generally with a flat to concave, smooth to finely postulose surface; spiral side with curved sutures, joining the spiral sutures at acute angles, but at almost right angles in the end of the last whorl; two keels on all chambers, equally developed and parallel.

Range: Campanian to early Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-SES-9.

Globotruncana bulloides Vogler

(Pl. 31, Figs 15-17)

Globotruncana linnei (d'Orbigny) subsp. bulloides Vogler, 1941, p. 287, pl. 23, figs 32-39.

Globotruncana bulloides bulloides Vogler. Gandolfi, 1955, p. 32, pl. 1, fig. 9a-c.

Globotruncana bulloides Vogler. Pessagno, 1967, p. 324-326, pl. 64, figs 15-17, pl. 67, figs 1-3, pl. 73, figs 9-10, pl. 75, figs 4-8, pl. 97, figs 14-15.

Globotruncana bulloides Vogler. Robaszynski *et al.*, 1984, p. 186, 300, pl.6, figs 1-4.

Globotruncana bulloides Vogler. Caron, 1985, p. 50, figs 20.1-2.

Remarks: Specimens of *Globotruncana bulloides* show a large test (c. 330-540µm in maximum diameter), with a low trochospire and typical symmetrical biconvex profile (sometimes slightly asymmetrical with spiral side more convex); 6 to 7 chambers in the last whorl, incresing slowly in size; trapezoidal chamber shape, with an inflated and slightly pustulose surface, in ventral view; umbilical sutures curved to straight, depressed; chambers petaloid, semi-circular to crescent-shaped in the spiral side, with an inflated surface bearing pustules typically concentrated in the middle, sutures curved, raised; lobate outline; two keels on all chambers, equally developed and parallel, tending to be narrower on the last chambers.

Range: late Campanian to early Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Globotruncana linneiana (d'Orbigny)

(Pl. 31, Figs 18-26)

Rosalina linneiana d'Orbigny, 1839, p. 101, pl. 5, figs 10-12.

Pulvulina tricarinata Quereau, 1893, p. 89, pl. 5, fig. 3a-c.

Globotruncana lapparenti Brotzen, 1936, p. 175-176, pl. 2, fig. n.

Globotruncana lapparenti Broten. Pessagno, 1967, p. 344-346, pl. 71, figs 6-13, pl. 97, fig. 8 (not fig. 9).

Globotruncana linneiana (d'Orbigny). Pessagno, 1967, p. 346-349, pl. 72, figs 1-4, 7-9, pl. 97, figs 11-13.

Globotruncana linneiana (d'Orbigny). Robaszynski *et al.*, 1984, p. 200, 202, pl. 13, figs 1-4, pl. 14, figs 1-5.

Globotruncana linneiana (d'Orbigny). Caron, 1985, p.50, figs 20.5-6.

Remarks: Globotruncana linneiana is characterised by a large test (c. 360–490µm in maximum diameter) with a very low trochospire; profile slightly asymmetrical; two wide peripheral keels, equally developed and parallel; 5 to 6 subtrapezoidal chambers in ventral view, increasing variably in size (generally slowly); slightly convex, in the umbilical side; chambers petaloid to crescent-shaped in dorsal view, with a flat and sometimes convex surface; spiral sutures generally curved, sometimes straight, raised and beaded; wide umbilicus. The species is homeomorphic with Marginotruncana pseudolinneiana Pessagno, from which it differs in having an umbilical primary aperture rather than one that is extraumbilical-umbilical in position (cf. Robaszynski & Caron, 1979, v. 2, p. 128); Globotruncana bulloides Vogleri has distinctly inflated chambers on both umbilical and spiral sides; Globotruncana arca (Cushman) has an asymmetrical biconvex profile.

Range: late Campanian to early Maastrichtian.

Occurrence: wells 1-CN-1-SE, 1-SES-9.

Globotruncana orientalis El Naggar

(Pl. 31, Figs 27–29)

Globotruncana orientalis El Naggar, 1966, p. 125, pl. 12, fig. 4a–d.

Globotruncana stephensoni Pessagno, 1967, p. 354–357, pl. 69, figs 1–7, pl. 96, figs 5–6.

Globotruncana stephensoni Pessagno. Smith & Pessagno, 1973, p. 51–52, pl. 18, figs 7–10.

Globotruncana orientalis El Naggar. Robaszynski et al., 1984, p. 206, 208, pl. 16, figs figs 1–3, pl. 17, figs 1–4..

Remarks: Specimens of Globotruncana orientalis are characterised by having a large test (c. 440µm in maximum diameter) with moderately high trochospire, a nearly symmetrical biconvex profile, more convex on the spiral side; two closely-spaced parallel keels, but umbilical keel absent on last 1-2 chambers; 5 trapezoidal to kidney-shaped chambers in ventral view, increasing gradually in size; chambers crescent-shaped in dorsal view; subcircular equatorial periphery. It differs from Globotruncana arca Cushman in its narrow keel and presence of only one keel on the last chambers. There are less chambers in the last whorl and more rapid increase in chamber size. The specimens have a more rapid increase in chamber size and less chambers in the last whorl than the hypotypes (Robaszynski et al., 1984, see above). They appear to be intermediate morphotypes between Globotruncana orientalis and Globotruncanita esnehensis (Nakkady).

Range: late Campanian.

Occurrence: wells 1-SES-1A, 1-SES-3 (rare occurrence).

Globotruncana rosetta (Carsey)

(Pl. 31, Figs 30-34)

Globigerina rosetta Carsey, 1926, p. 44, pl. 5, figs 3a-b.

Globotruncana rosetta (Carsey). Pessagno, 1967, p. 352-354, pl. 70, figs 9-12, pl. 73, figs 5-8, pl. 98, fig. 14, pl. 97, figs 19-23.

Globotruncana rosetta (Carsey). Robaszynski et al., 1984, p. 210, 301, pl. 18, figs 1-5.

Remarks: Globotruncana rosetta shows a moderately large test (c. 340-450µm in maximum diameter) with an asymmetrical to nearly symmetrical profile, with the spiral side moderately convex; two narrow parallel keels, umbilical keel absent on one or more last chambers; 4 to 5.5 trapezoidal to kidney-shaped chambers in ventral view, increasing rapidly in size, with a flat to convex surface; crescent-shaped to petaloid chambers, with a flat surface, on the spiral side; equatorial periphery moderately lobate. It differs from Globotruncana aegyptiaca Nakkady in being more convex umbilically and non-rugose, in both sides; and, by possessing a somewhat smaller umbilicus. Intermediate forms between Globotruncana rosetta and Globotruncana mariei Banner & Blow, with a more convex dorsal side, were also recorded (Pl. 31, Figs 32-34).

Range: late Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-9.

Globotruncana subcircumnodifer Gandolfi

(Pl. 32, Figs 1-3)

Globotruncana (Rugoglobigerina) circumnodifer subcircumnodifer Gandolfi, 1955, p. 44, pl. 2, fig. 8a-c.

Globotruncana subcircumnodifer Gandolfi. Pessagno, 1967, p. 369-370, pl. 62, figs 14-16.

Archaeoglobigerina blowi Pessagno. Robaszynski et al., 1984, p. 276, pl. 47, fig.2a-c, pl.48, fig.3.
Rugotruncana subcircumnodifer (Gandolfi). Caron, 1985, p. 76, figs 34.11-12.

Remarks: Globotruncana subcircumnodifer specimens are distinguished by having a moderately large (c. 310-410μm in maximum diameyter) low trochospiral test, with a nearly flat spiral side; two narrow peripheral keels on all chambers; 4 to 5 subsphaerical to slightly elongate chambers in ventral view, rapidly increasing in size; umbilical sutures radial and depressed; test surface perforate, pustulose or with fine costellae; lobate equatorial periphery; umbilicus wide and shallow. It differs from Globotruncana aegyptiaca Nakkady in having a more rugose test surface and globular chambers in the umbilical side, with a rounded periphery.

Range: Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-9, 1-SES-24.

Globotruncana ventricosa White

(Pl. 32, Figs 4-9)

Globotruncana canaliculata (Reuss) var. ventricosa White, 1928b, p. 284, pl. 38, fig. 5 a-c.
Globotruncana ventricosa White. Pessagno, 1967, p. 362-364, pl.75, figs 21-26, pl. 79, figs 9-14, pl. 95, figs 10-11, pl. 99, fig. 2.
Globotruncana ventricosa White. Masters, 1977, p. 614-615, pl. 55, figs 1-3.
Globotruncana ventricosa White. Robaszynski et al., 1984, p. 214, 216, pl. 20, figs 1-3, pl. 21, figs 1-4.
Globotruncana ventricosa White. Caron, 1985, p. 50, figs 20.7-9.

Remarks: Specimens of Globotruncana ventricosa have a large, typically asymmetrical, biconvex test (c. 440-550μm in maximum diameter), with a very low trochospire; spiral side flat, umbilical side convex; two wide, parallel, keels, well developed on all chambers; 5 to 6 trapezoidal chambers in ventral view, with a flat to convex surface; crescent-shaped chambers in dorsal view, with a generally flat surface. The species differs from Globotruncana linneiana (d'Orbigny) in having an asymmetrical biconvex profile. It differs from Dicarinella asymetrica (Sigal) in having an umbilical primary aperture, generally more widely spaced keels and more numerous chambers; from Globotruncana linneiana (d'Orbigny) in the more inflated umbilical side; and from Globotruncana rosetta (Carsey) in the more widely spaced keels an slower increase in chamber size.

Range: late Campanian to Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-CA-1-SE, 1-SES-24.

Genus **GLOBOTRUNCANITA** Reiss, 1957,
emended, Robaszynski et al., 1984,
p. 218, pl. 22, figs 1-7.

Remarks: The genus is represented by single-keeled specimens, including also forms with two close rows of pustules on the first chambers of the last whorl (as on some early specimens of the Globotruncanita elevata-Globotruncanita stuartiformis plexus - e.g., Pl. 32, Figs 13-18), an umbilical primary aperture and the presence of a well developed portici (this last feature being generally only observed in well preserved specimens).

Globotruncanita sp. cf. G. calcarata (Cushman)
(Pl. 32, Figs 10-12)

Globotruncana calcarata Cushman, 1927a, p. 115-116, pl. 23, fig. 10a-b.

Globotruncana calcarata Cushman. Pessagno, 1967, p. 326-328, pl. 64, figs 18-20, pl. 72, figs 5-6, pl. 93, fig. 14, pl. 94, fig. 8.

Globotruncana calcarata Cushman. Masters, 1977, p. 540-541, pl.38, fig. 3, pl. 39, fig. 1.

Globotruncana calcarata Cushman. Wonders, 1980, p.114, pl. 7, fig.2.

Globotruncanita calcarata (Cushman). Robaszynski et al., 1984, p. 224, pl. 22, fig. 4, pl. 25, figs 1-3, pl. 34, fig. 3a-c.

Globotruncanita calcarata (Cushman). Bellier, 1985, p. 35-36, pl. 7, figs 11-13.

Globotruncanita calcarata (Cushman). Caron, 1985, p.51,figs 23.6-7.

Remarks: Rare specimens referable to *Globotruncanita* sp. cf. *G. calcarata* were recovered from the uppermost Campanian. They are characterised by having a large (c. 560μm in maximum diameter) asymmetrical test with very low trochospire; spiral side flat to slightly concave, umbilical side strongly convex; one peripheral keel with the development of tubulospines produced by the posterior part of each chamber; 5 trapezoidal chambers in ventral view, increasing gradually in size, with pustulose surface; triangular chambers in dorsal view; wide umbilicus. The paucity and bad preservation of the specimens, with broken tubulospines, do not allow an unequivocal determination of the species. It seems, however, that they represent intermediate forms between *Globotruncanita subspinosa* (Pessagno) and *Globotruncanita calcarata*.

Range: latest Campanian.

Occurrence: well 1-AU-1-SE (rare occurrence).

Globotruncanita elevata (Brotzen)- ***Globotruncanita stuartiformis*** (Dalbiez) **plexus**

(Pl. 32, Figs 13-18)

Rotalia elevata Brotzen, 1934, p. 66, pl. 3, fig. C.

Globotruncana (*Globotruncana*) *elevata* Brotzen subsp. *stuartiformis* Dalbiez, 1955, p. 169, text-figs 10a-c.

Globotruncana elevata (Brotzen). Pessagno, 1967, p. 336, 337-338, pl. 80, figs 3-6 (*G. elevata* transitional to *G. stuartiformis*).

Remarks: Specimens of the *Globotruncanita elevata*-*Globotruncanita stuartiformis* plexus are characterised by having a large, strongly asymmetrical, plano-convex test (c. 350-550μm in maximum diameter); flat to concave spiral side in the last whorl, with the previous whorls slightly more elevated; umbilical side strongly convex; one peripheral keel; 5 trapezoidal chambers in ventral view, increasing gradually in size, with smooth surfaces; distinctly convex last chamber, oblique-angled to the equatorial plane (rather than near to right-angled as in typical *Globotruncanita elevata*); chambers triangular to crescentic in dorsal view; moderately wide umbilicus. The specimens from Sergipe are closely similar to transitional morphotypes between *G. elevata* and *G. stuartiformis*, illustrated by Pessagno (1967, see above) from the western Gulf Coastal Plain. They differ from *G. stuartiformis* (Dalbiez) s.s. in having a strongly asymmetrical plano-convex profile and triangular to crescentic chambers on the dorsal side. The morphotypes seem to represent, most likely, inter-specific (ecophenotypic ?) variations within the range of morphological variability of the plexus.

Range: early Campanian.

Occurrence: wells 1-AU-1-SE, 1-SES-3.

Globotruncanita esnehensis (Nakkady)

(Pl. 32, Figs 19-20)

Globotruncana arca (Cushman) var. *esnehensis* Nakkady, 1950, p. 690, pl. 90, figs 23-26.

Globotruncana esnehensis Nakkady. Robaszynski *et al.*, 1984, p. 192, 301, pl. 9, figs 1-4.

Remarks: *Globotruncanita esnehensis* is characterised by having an asymmetrical test (c. 320µm in maximum diameter) with a trochospire of moderate height; spiral side more convex than the umbilical side; 5 smooth trapezoidal chambers in ventral view, increasing rapidly in size; radial umbilical sutures radial, but curved in the last chamber; petaloid chamber shape in dorsal view, with sutures curved and raised, but straight between final chambers; slightly lobate outline; one peripheral keel; umbilical keel missing on all chambers of the last whorl. It differs from *Globotruncanita stuarti* (de Lapparent) in possessing a more rapid increase in chamber size and more petaloid chambers in dorsal view.

Range: late Maastrichtian.

Occurrence: well 1-SES-1A.

Globotruncanita pettersi (Gandolfi)

(Pl. 32, Figs 21-23)

Globotruncana (*Globotruncana*) *rosetta* (Carsey) subsp. *pettersi* Gandolfi, 1955, p. 68, pl. 6, fig. 3a-c.

Globotruncanita pettersi (Gandolfi). Robaszynski *et al.*, 1984, p. 232, pl. 29, figs 1-5.

Remarks: Specimens of *Globotruncanita pettersi* are characterised by having a large, asymmetrical test (c. 470-520µm), with a very low trochospire; one peripheral keel; spiral side flat to slightly convex and umbilical side strongly convex; 4 to 5 trapezoidal chambers in the last whorl, increasing rapidly in size, with the surfaces covered with scattered rugosities; early chambers of the last whorl with a slightly raised sutural ridge on the ventral side; chambers crescent-shaped in dorsal view, with a flat and smooth surfaces; umbilicus wide and deep. The species differs from *Gansserina gansseri* (Bolli) in having adumbilical ridges, less rugose/pustulose chambers, and in the raised sutural ridges on the umbilical side; from *Globotruncanita elevata* (Broten) in the fewer chambers in the last whorl and in lacking a central cone on the dorsal side; and from *Globotruncanita angulata* Tilev in the lobate equatorial periphery, more elongated chambers on the dorsal side and a more convex ventral side.

Range: late Maastrichtian.

Occurrence: well 1-MO-1-SE (rare occurrence).

Globotruncanita stuarti (de Lapparent)

(Pl. 32, Figs 24-29)

Rosalina stuarti de Lapparent, 1918, p. 11, pl. 1, figs 5-7; text-fig. 4 (p. 12), lower 3 figs, text-figs 5a-c (p. 13).

Globotruncana stuarti (de Lapparent). Bolli, 1945, p. 236, pl. 19, fig. 18.

Globotruncana stuarti (de Lapparent). Pessagno, 1967, p. 356-357, pl. 81, figs 1-6; pl. 93, figs 9-11; pl. 94, fig. 7.

Globotruncanita stuarti (de Lapparent). Robaszynski *et al.*, 1984, p. 234, pl. 30, figs 1-3, pl. 31, figs 1-3.

Globotruncanita stuarti (de Lapparent). Bellier, 1985, p. 36-37, pl. 7, figs 17-19.

Globotruncanita stuarti (de Lapparent). Caron, 1985, p. 51, figs 23.1-3.

Remarks: The species is characterised by having a large, symmetrical, biconvex test (c. 560-690µm in maximum diameter); a moderatly high trochospire; one peripheral keel; circular equatorial periphery; 5 to 6 trapezoidal chambers in ventral view, increasing slowly in size, with a flat and smooth surface; chambers trapezoidal to subrectangular in dorsal view; wide umbilicus. It differs from *Globotruncanita conica* (White) in its more symmetrical, biconvex test and trapezoidal shape of the chambers on the spiral side.

Range: latest Campanian.

Occurrence: wells 1-CA-1-SE, 1-AU-1-SE.

Globotruncanita stuartiformis s.s. (Dalbiez)

(Pl. 32, Figs 30-34)

Globotruncana (Globotruncana) elevata Brotzen subsp. stuartiformis Dalbiez, 1955, p. 169, text-figs 10a-c.

Globotruncana stuartiformis Dalbiez. Pessagno, 1967, p. 357-359, pl. 92, figs 1-3, pl. 93, figs 6-7, text-figs 44, fig. 17.

Globotruncana stuartiformis Dalbiez. Smith & Pessagno, 1973, p. 52-54, pl. 19, figs 10-12.

Globotruncanita stuartiformis (Dalbiez). Robaszynski et al., 1984, p. 238, pl. 32, figs 1-4.

Remarks: Specimens of Globotruncanita stuartiformis s.s. show a large (c. 380-600μm in maximum diameter) trochospiral test of moderate height; symmetrical to slightly asymmetrical profile; one peripheral keel; 5 subtrapezoidal chambers in ventral view, increasing slowly in size, with a flat and smooth surfaces; chambers typically triangular in dorsal view; moderately wide umbilicus; subcircular equatorial periphery. It differs from Globotruncannita stuarti (de Lapparent) in the triangular rather than trapezoidal shape of the chambers on the dorsal side and the very acute angles formed by the sutures and the spiral suture, and from the Globotruncanita elevata (Brotzen)-Globotruncanita stuartiformis plexus by having a more symmetrical profile and triangular chambers on the dorsal side.

Range: Campanian to Maastrichtian.

Occurrence: wells 1-AU-1-SE, 1-SES-3, 1-SES-24.

Globotruncanita subspinosa (Pessagno)

(Pl. 33, Figs 1-3)

Globotruncana (Globotruncana) subspinosa Pessagno, 1960, p. 101-102, pl. 1, figs 1-9, pl. 5, fig. 5.

Globotruncanita subspinosa (Pessagno). Robaszynski et al., 1984, p. 240, pl. 22, fig. 5, pl. 33, figs 1-3, pl. 34, figs 1-2.

Globotruncanita subspinosa (Pessagno). Bellier, 1985, p. 35, pl. 7, figs 8-10.

Globotruncanita subspinosa (Pessagno). Caron, 1985, p. 51, figs 22.5-8.

Remarks: The species is distinguished by having a large, asymmetrical test (c. 510μm in maximum diameter); spiral side flat or slightly convex; umbilical side convex; one peripheral keel; 5 to 6 trapezoidal chambers in ventral view; chambers crescent-shaped in dorsal view, radially elongated with an undulating surface; equatorial periphery strongly lobate; moderately wide umbilicus. It differs from Globotruncanita calcarata (Cushman) - with which it has interspecific variations (e.g., Robaszynski et al., 1984, pl. 34, fig. 3a-c) - in the absence of tubulospines (not always visible in badly preserved specimens). It differs from Globotruncanita stuartiformis (Dalbiez) in having crescent-shaped chambers in the spiral side with undulating surfaces.

Range: late Campanian to early Maastrichtian.

Occurrence: well 1-SES-24 (rare occurrence).

Genus **MARGINOTRUNCANA** Hofker, 1956

(sensu Robaszynski & Caron, 1979, v. 2, p. 97-101)

Type species: Rosalina marginata Reuss, 1846

Remarks: Marginotruncana specimens are characterised by possessing a biconvex to plano-convex test; extraumbilical-umbilical primary aperture; two keels; and more or less sigmoidal, elevated sutures on the umbilical side. The last feature differs it from Dicarinella. It is also similar to Globotruncana, from which it differs by possessing a clearly extraumbilical primary aperture.

Marginotruncana renzi (Gandolfi)

(Pl. 33, Figs 4-6)

Globotruncana renzi Gandolfi, 1942, p. 124-125, pl. 3, fig. 1, pl. 4, fig. 16, 28-29, pl. 10, fig. 2.

Globotruncana linnei (d'Orbigny) var. angusticarenata Gandolfi, 1942, p. 125-130, fig. 46.3, pl. 4, figs 17, 30.

Marginotruncana angusticarenata (Gandolfi). Pessagno, 1967, p. 300-301, pl. 65, figs 14-19, pl. 98, figs 5, 9-11.

Marginotruncana renzi (Gandolfi). Robaszynski & Caron, 1979, v. 2, p. 129, 133, pl. 69, figs 1-2.

Marginotruncana angusticarinata (Gandolfi). Wonders, 1980, p. 120, pl. 4, fig. 3a-c.

Marginotruncana renzi (Gandolfi). Bellier, 1985, p. 24, pl. 4, figs 1-3.

Marginotruncana renzi (Gandolfi). Caron, 1985, p. 61, figs 27.1-2.

Remarks: *Marginotruncana renzi* is distinguished by having a moderately large, low trochospiral, biconvex test (c. 390µm in maximum diameter); two closely spaced keels becoming a single one on the last two chambers; 5 elongated trapezoidal chambers in ventral view, slowly increasing in size; crescent-shaped to petaloid chambers in dorsal view. It differs from *Marginotruncana paraconcavata* Porthault in its biconvex test and two closely spaced keels.

Range: late Coniacian.

Occurrence: well 1-SES-3 (rare occurrence).

Marginotruncana sinuosa Porthault

[Pl. 33, Figs 7-9, 10 (detail of neanic *Hedbergella*)]

Marginotruncana sinuosa Porthault, 1970, p. 81, pl. 11, figs 11-13.

Marginotruncana sinuosa Porthault. Robaszynski & Caron, eds, 1979, v. 2, p. 147, 152-154, pl. 74, figs 1-2, pl. 75, figs 1-2.

Marginotruncana sinuosa Porthault. Caron, 1985, p. 61, figs 27.9-11.

Remarks: This species is characterised by having a large, somewhat asymmetrically, biconvex test (c. 460-530µm in maximum diameter), with a moderately high trochospire; two closely spaced peripheral keels; 6 reniform chambers, strongly elongated, in ventral view, increasing slowly in size; strongly elongated chambers in dorsal view, with a flat or slightly undulated surface; subcircular equatorial periphery. It differs from *Marginotruncana renzi* (Gandolfi) in having strongly elongated chambers on the dorsal side.

Range: late Coniacian to Santonian.

Occurrence: wells 1-CRL-1-SE, 1-SES-3.

Marginotruncana undulata (Lehmann)

(Pl. 33, Figs 11-13)

Globotruncana undulata Lehmann, 1963, p. 148, pl. 9, fig. 3a-c.

Marginotruncana undulata (Lehmann). Robaszynski & Caron, 1979, v. 2, p. 159, 162, pl. 77, figs 1-2.

Remarks: Marginotruncana undulata is characterised by having a large, slightly asymmetrical, biconvex test (c. 680µm in maximum diameter), with a moderately high trochospire; single peripheral keel, formed by a double row of pustules, which tend to become very closely spaced on the last two chambers; 6 subrectangular to reniform chambers in ventral view, slowly increasing in size; trapezoidal chambers with undulating surfaces in dorsal view; slightly lobate, subcircular equatorial periphery. It differs from Marginotruncana sinuosa Porthault in possessing a single keel and in having less elongated chambers in the spiral side.

Range: early-late Turonian to early Santonian.

Occurrence: wells 1-CA-1-SE, 1-SES-3.

Subfamily **GLOBOTRUNCANELLINAE**

Maslakova, 1964

Genus **GLOBOTRUNCANELLA**

Reiss, 1957, emended Robaszynski, Caron,
Gonzales Donoso & Wonders, 1984, p. 264

Type species: Globotruncana citae Bolli, 1951
(= Globoruncana havanensis Voorwijk, 1937)

Globotruncanella havanensis (Voorwijk)

(Pl. 33, Figs 14-16)

Globotruncana havanensis Voorwijk, 1937, p. 195, pl. 1, figs 25-26, 29.

Globotruncana havanensis Voorwijk. Masters, 1977, p. 569-572, pl. 45, figs 4-6

Globotruncanella havanensis (Voorwijk). Robaszynski et al., 1984, p. 265, pl. 44, figs 4-6.
Globotruncanella minuta Caron & Gonzales Donoso, in Robaszynski et al., 1984, p. 266, pl. 43, figs 5-8.

Remarks: This species is characterised by having a moderately small, asymmetrical, biconvex test (c. 240-340µm in maximum diameter); spiral side convex, low to moderately high, and convex umbilical side; 4.5 to 5 subglobular chambers in ventral view, with pustulose surface; chambers petaloid in dorsal view. The specimens described as Globotruncanella minuta by Caron & Gonzales Donoso (see above) would appear to be neanic stages of Globotruncanella havanensis and are, therefore, not considered as a separate species.

Range: Campanian to Maastrichtian.

Occurrence: wells 1-CA-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9.

Globotruncanella petaloidea (Gandolfi)

(Pl. 33, Figs 17-21)

Globotruncana (Rugoglobigerina) petaloidea Gandolfi subsp. petaloidea Gandolfi, 1955, p. 52, pl. 3, fig. 13a-c.
Globotruncanella petaloidea (Gandolfi). Robaszynski et al., 1984, p. 268, pl. 44, figs 1-3.
Globotruncanella havanensis (Voorwijk). Bellier, 1985, p. 38-39, pl. 8, figs 18-20.

Remarks: Globotruncanella petaloidea is characterised by having a biconvex to concavo-convex test (c. 230-320µm in maximum diameter) with an asymmetrical profile; 4 trapezoidal, subglobular chambers in ventral view, with a pustulose surface, except on the last chamber; chambers petaloid in dorsal view. It differs from Globotruncanella havanensis (Voorwijk) in having 4 petaloid chambers in the last whorl.

Range: Maastrichtian.

Occurrence: wells 1-SES-1A, 1-SES-24.

Family **RUGOGLOBIGERINIDAE**

Subbotina, 1959

Genus **ARCHAEOGLOBIGERINA** Pessagno, 1967

Type species: Archaeoglobigerina blowi Pessagno, 1967

Remarks: Archaeoglobigerina specimens have a low to moderately high trochospire (e.g., A. bosquensis Pessagno), with globular chambers; primary aperture umbilical; wide umbilicus, covered by tegilla; chamber profile rounded, with or without a large imperforate peripheral band, mainly on the first chambers of the last whorl; two faint rows of pustules may be present; chamber surface rugose.

Archaeoglobigerina blowi Pessagno

(Pl. 34, Figs 1-11)

Archaeoglobigerina blowi Pessagno, 1967, p. 316, pl. 59, figs 5-7.

Archaeoglobigerina blowi Pessagno. Robaszynski & Caron, 1979, v. 2, p. 172, pl. 79, figs 1-2.

Archaeoglobigerina blowi Pessagno. Robaszynski et al., 1984, p. 276, pl. 47, fig 1a-c (not 2); pl. 48, fig 1 (not 3).

Remarks: Specimens of Archaeoglobigerina blowi show a moderately large, very low trochospiral test (varying in maximum diameter from c. 240μm, neanic stage, to c. 360-400μm, ephebic and gerontic stages), with a lobate equatorial periphery; 4 globular chambers in the last whorl, increasing very rapidly in size, with pustulose/rugose surfaces. It differs from Archaeoglobigerina cretacea (d'Orbigny) in having fewer chambers in the last whorl, a more lobate equatorial periphery and a very low trochospire.

Range: Coniacian to Maastrichtian.

Occurrence: localities A-11, A-18, Tabocas 2, wells 1-CA-1-SE, 1-CN-1-SE, 1-CRL-1-SE, 1-SES-3, 1-SES-1A, 1-SES-9, 1-SES-24 .

Archaeoglobigerina cretacea (d'Orbigny)

(Pl. 34, Figs 12-14, 18-20)

Globigerina cretacea d'Orbigny, 1840, p. 34, pl. 3, figs 12-14.

Globotruncana cretacea (d'Orbigny). Banner & Blow, 1960, p. 8-10, pl. 7, fig. 1a-c.

Archaeoglobigerina cretacea (d'Orbigny). Pessagno, 1967, p. 317-318, pl. 70, figs 3-8, pl. 94, figs 4-5.

Globotruncana cretacea (d'Orbigny). Masters, 1977, p. 551-555, pl. 41, figs 3-4, pl. 41, fig. 1.

Archaeoglobigerina cretacea (d'Orbigny). Robaszynski & Caron, 1979, v. 2, p. 176, pl. 80, figs 1a-e.

Archaeoglobigerina cretacea (d'Orbigny). Robaszynski et al., 1984, p. 278, pl. 47, figs 3-6; pl. 48, fig. 2.

Remarks: Specimens of Archaeoglobigerina cretacea have a moderately large, almost symmetrical, low trochospiral test (ephebic and gerontic specimens are c. 300-530μm in maximum diameter) with 5 to 6 globular chambers in the last whorl, increasing slowly in size, with pustulose/rugose surfaces. Neanic specimens are c. 240-250μm in maximum diameter, have about 5 chambers in the last whorl, with pustulose surfaces and a broad imperforate peripheral band (Pl. 34, Figs 12-14). It differs from Archaeoglobigerina blowi in having more chambers in the last whorl, a less lobate outline and a slightly higher trochospire.

Range: Coniacian to early Maastrichtian

Occurrence: locality A-11, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-3, 1-SES-24.

Genus **RUGOGLOBIGERINA** Bronnimann, 1952

Type species: Globigerina rugosa Plummer, 1927

Rugoglobigerina ex gr. rugosa (Plummer), emended

(Pl. 34, Figs 21-27)

Globigerina rugosa Plummer, 1926, p. 38-39, pl. 2, figs 10a-d.

Rugoglobigerina (Rugoglobigerina macrocephala macrocephala Bronnimann, 1952, p. 25, pl. 2, figs 1-3.

Rugoglobigerina *(Rugoglobigerina* *rugosa* *pennyi* Bronnimann, 1952, p. 34, pl. 4, figs 1-3.

Rugoglobigerina *(Rugoglobigerina)* *rugosa* *rotundata* Bronnimann, 1952, p. 34, pl. 4, figs 7-9.

Rugoglobigerina *(Rugoglobigerina)* *pilula* Belford, 1960, p. 92, pl. 25, figs 7-13, text-fig. 6 (1-6).

Rugoglobigerina *macrocephala* Bronnimann. Petri, 1962, p. 122-123, pl. 17, fig. 3.

Rugoglobigerina *rotundata* Bronnimann. Pessagno, 1967, p. 365-366, pl. 65, figs 1-3, pl. 68, figs 1-3.

Rugoglobigerina *rugosa* (Plummer). Pessagno, 1967, p. 366-367, pl. 75, figs 2-3, pl. 101, figs 8-9.

Rugoglobigerina *tradinghousensis* Pessagno, 1967, p.367-368, pl. 64, figs 1-8.

Rugoglobigerina *macrocephala* Smith & Pessagno, 1973, p. 55-56, pl. 23, figs 1-3, 7-10.

Rugoglobigerina *milamensis* Smith & Pessagno, 1973, p. 56, pl. 24, figs 4-7.

Rugoglobigerina *pennyi* Bronnimann. Smith & Pessagno, 1973, p. 57, pl. 24, figs 1-3.

Rugoglobigerina *rotundata* Bronnimann. Smith & Pessagno, 1973, p. 58, pl. 24, figs 8-11.

Rugoglobigerina *rugosa* (Plummer). Smith & Pessagno, 1973, p. 58-60, pl. 25, figs 1-4.

Rugoglobigerina *rugosa* (Plummer). Masters, 1977, p. 622-626, pl. 56, figs 1, 4, 5, pl. 57, figs 1, 2.

Rugoglobigerina *tradinghousensis* Pessagno. Masters, 1977, p. 626-628, pl. 58, figs 1, 3.

Rugoglobigerina *hexacamerata* Bronnimann. Robaszynski *et* *al.*, 1984, p. 282, pl. 49, fig 8a-c.

Rugoglobigerina *macrocephala* Bronnimann. Robaszynski *et* *al.*, 1984, p. 284, pl. 49, fig. 7.

Rugoglobigerina *milamensis* Smith & Pessagno. Robaszynski *et* *al.*, 1984, p. 284, pl. 50, fig. 3.

Rugoglobigerina *pennyi* Bronnimann. Robaszynski *et* *al.*, 1984, p. 285, pl. 50, fig. 1.

Rugoglobigerina *pilula* Belford. Robaszynski *et* *al.*, 1984, p. 285, 302, pl. 49, figs 1-3.

Rugoglobigerina rotundata Bronnimann. Robaszynski et al., 1984, p. 288, pl. 50, fig. 2.

Rugoglobigerina rugosa (Plummer). Robaszynski et al., 1984, p. 288-289, pl. 49, figs 4, 6.

Description: This species-group has a broad morphological variabilit and is characterised by having a low to high trochospiral test; generally 3 to 5 globular chambers in the last whorl, increasing rapidly to slowly in size; test surface covered by variable sculptural ornamentation, progressively developing with ontogeny from fine pustules and rugosities to thick, closely-spaced rugosities and costellae, arranged in a meridional pattern; surface ornamentation generally less developed on the last chamber; equatorial periphery lobate; wide umbilicus. Young ephebic specimens are around 300-345µm in maximum diameter, have 4 chambers in the last whorl and less coarse pustulose/rugose surfaces. Late ephebic and gerontic specimens are around 350-480µm in maximum diameter, have less variable chamber shape and coarser surface ornamentation.

Remarks: It was observed a close relationship between the test size, chamber arrangement, coarseness of surface ornamentation, abundance and variability of Rugoglobigerina morphotypes and their environments, in many aspects similar to the distribution patterns of the mid-Cretaceous favusellid foraminifera (see Chapter 6). Therefore, Rugoglobigerina ex gr. rugosa is regarded as a species-group comprising several morphotypes representing different polymorphic stages in the life cycle. The synonymy list exemplifies the morphological variability of this species-group.

Range: late Campanian to Maastrichtian.

Occurrence: localities A-18, wells 1-CA-1-SE, 1-CN-1-SE, 1-SES-1A, 1-SES-3, 1-SES-9, 1-SES-24.

Rugoglobigerina hexacamerata Bronnimann

(Pl. 34, Figs 15–17, 28–30)

Rugoglobigerina (Rugoglobigerina) reicheli hexacamerata Bronnimann, 1952, p. 23–25, pl. 2, figs 10–12.
Rugoglobigerina hexacamerata Bronnimann. Pessagno, 1967, p. 364–365, pl. 74, fig. 4, pl. 91, figs 5–7.
Rugoglobigerina hexacamerata Bronnimann. Smith & Pessagno, 1973, p. 54–55, pl. 23, figs 4–6.
Rugoglobigerina hexacamerata Bronnimann. Robaszynski et al., 1984, p. 282, pl. 49, fig 5a–c (not 8).

Remarks: This species is characterised by having a large, very low to flat trochospiral test (varying from in maximum diameter from c. 260µm, neanic/early ephebic stage, specimen intermediate between R. hexacamerata and Archaeoglobigerina cretacea (d'Orbigny), to c. 470µm, late ephebic/gerontic stage); generally 6 globular to rounded chambers in the last whorl, increasing slowly in size; wide and deep umbilicus.

Range: late Maastrichtian.

Occurrence: well 1-SES-3 (rare occurrence).

3.2 - RADIOLARIANS

Subphylum **SARCODINA**

Class **ACTINOPODEA**

Subclass **RADIOLARIA**

Remarks: Entries and taxonomic remarks for each radiolarian species are brief. References are restricted to the original description of the species and to relevant references used in this study. Furthermore, because of the fragmentation of tests and common recrystalisation, no decision could be made on specific attribution of several morphotypes. Such forms were either placed in single species-groups, each regarded with broad morphological variability, or placed in open nomenclature.

Order **POLYCYSTIDA**

Suborder **NASSELLARIINA**

Gongylothorax sp. A

(Pl. 35, Figs 1-3)

Remarks: This species is characterised by its small (around 190-300µm in maximum diameter), subspherical shape, covered by sharply defined pentagonal or hexagonal depressions.

Range: late Albian to earliest Turonian.

Occurrence: wells 1-CA-1-SE, 1-CRL-1-SE, 1-US-1-SE.

Dictyomitra ex gr. multicostata Zittel

(Pl. 35, Figs 4-7)

Dictyomitra multicostata Zittel, 1876, p. 81, pl. 2, fig. 2.
Dictyomitra multicostata Zittel. Pessagno, 1976, p. 52, pl. 14, figs 4-9.
Dictyomitra multicostata Zittel. Bergstresser, 1983, p. 880-881, figs. 6 a-d.

Remarks: Dictyomitra ex gr. multicostata morphotypes are characterised by having a small (c. 200-210µm in maximum length), elongate, subconical test consisting of 8 to 10 segments, gradually increasing in diameter; in some cases the last 3 to 4 segments have the same diameter, or the last two have progressively smaller widths; each segment has one transverse row of very small pores near the segment suture; the surface contains numerous longitudinal costae.

Range: late Albian to early-late Turonian.

Occurrence: localities A-9, A-21, A-22, wells 1-CRL-1-SE, 1-US-1-SE.

Dictyomitra(?) sp. A

(Pl. 35, Fig. 8)

Remarks: Test moderately large (c. 400µm in maximum length), elongate, subconical, consisting of approximately nine segments, with the last two segments having a slightly smaller diameter than the previous segment; test surface probably with small pores (not well distinguished due to bad preservation). The lack of vertical costae, if at all present, may be due to recrystalisation. The morphotypes somewhat ressemble specimens of Dictyomitra rotundata (Aliev) illustrated by Foreman (1978-a, p. 841, pl. 1, figs 1-3) from the late Albian-Cenomanian of Angola Basin. However, because of uncertainty as to the exact diagnosis of the present species it is tentatively assigned to the Dictyomitra genus.

Range: latest Cenomanian.

Occurrence: locality A-9 (rare occurrence).

Lithostrobus sp. A

(Pl. 35, Figs 9-11)

Remarks: Specimens of Lithostrobus sp. A have a small (about 290μm in maximum length), elongate, subconical test with 6 segments, gradually increasing in diameter, with the last segment having a slightly smaller diameter than the previous one; last 4 segments inflated, with well-defined segmental strictures; reticulate test surface covered with numerous small polygonal depressions.

Range: late Albian.

Occurrence: well 1-CRL-1-SE.

Lithostrobus sp. B

(Pl. 35, Fig. 12)

Remarks: Lithostrobus sp. B morphotypes are distinguished by having a minute (c. 160μm in maximum length), elongate, subconical test with 6 segments, gradually increasing in diameter; test surface covered with numerous small pores.

Range: late Albian.

Occurrence: well 1-CRL-1-SE.

Suborder SPUMELLARIINA

Arachnosphaera(?) sp. A

(Pl. 36, Figs 1-3)

Remarks: This is by far the most abundant species-group amongst the spumellarians. They are characterised by spherical shaped specimens of variable sizes (about 110-360μm in maximum diameter), with a spongy wall texture and very thin pores.

Range: late Albian to Turonian.

Occurrence: localities A-1, A-3, A-9, A-12, A-21, A-22, A-35, wells 1-CA-1-SE, 1-US-1-SE.

Crucella irwini Pessagno
(Pl. 36, Figs 4-6)

Crucella irwini Pessagno, 1971, p. 55, pl. 9, figs 4-6.

Remarks: Specimens of Crucella irwini are characterised by having large (c. 400-450µm in maximum diameter) tests with four long and slender rays, tapering distally and nearly equal in length; central area with shallow lacuna.

Range: latest Cenomanian to early-late Turonian.

Occurrence: localities A-9, A-21.

Crucella messinae Pessagno
(Pl. 36, Figs 7-8)

Crucella messinae Pessagno, 1971, p. 56, pl. 6, figs 1-3.

Remarks: The species is distinguished by its moderately large (c. 330-380µm in maximum diameter) cruciform test with cylindrical longitudinal rays and by lacking a lacuna in its central area.

Range: early Cenomanian.

Occurrence: locality A-3.

Crucella(?) sp. A
(Pl. 36, Figs 9-11)

Remarks: This species is characterised by having a large (c. 400-550µm in maximum diameter) test with shorter rays, subclindrical longitudinally; rays and central area planiform horizontally.

Range: early Cenomanian to early-late Turonian.

Occurrence: localities A-1, A-21, well 1-US-1-SE.

<u>Histiastrum</u> <u>anisum</u> Foreman

(Pl. 37, Fig. 1)

<u>Histiastrum</u> <u>anisum</u> Foreman, 1978-a, p. 841, pl. 1, figs 5-7.

Remarks: The species is distinguished by its large (about 480µm in maximum length) test with the presence of three to four irregularly developed arms.

Range: latest Cenomanian.

Occurrence: locality A-9 (rare occurrence).

<u>Orbiculiforma</u> ex gr. <u>monticelloensis</u> Pessagno

(Pl. 37, Figs 2-5)

<u>Orbiculiforma</u> <u>monticelloensis</u> Pessagno, 1973, p. 72-73, pl. 16, figs 5-6, pl. 18, figs 1-2.

Remarks: Test small (c. 240-360µm in maximum diameter), disc-shaped, nearly circular in outline, with a vertical to rounded periphery; central cavity relatively wide and shallow; centre slightly raised; fine meshwork.

Range: early Cenomanian to early-middle Turonian.

Occurrence: localities A-3, A-21, A-22, well 1-US-1-SE.

<u>Phaseliforma</u> ex gr. <u>laxa</u> Pessagno

(Pl. 37, Figs 6-7)

<u>Phaseliforma</u> <u>laxa</u> Pessagno, 1972-a, p. 276-277, pl. 23, figs 7-9.

Remnarks: Specimens of <u>Phaseliforma</u> ex gr. <u>laxa</u> are characterised by having small (c. 140-230µm in maximum length), elongate, subellipsoidal tests, varying in width (c. 70-130µm in maximum width); smooth surface with fine meshwork.

Range: Cenomanian.

Occurrence: localities A-3, A-9.

Pseudoaulophacus parqueraensis Pessagno

(Pl. 37, Figs 8–9)

Pseudoaulophacus parqueraensis Pessagno, 1963, p. 204, pl. 2, figs 4, 7, pl. 6, figs 4–5.

Pseudoaulophacus parqueraensis Pessagno. Pessagno, 1972, p. 309, pl. 30, fig. 4.

Remarks: This species is distinguished by its moderately small (c. 300μm in maximum diameter), circular test, lenticular in peripheral view; lobate periphery with 9 lobes, each lobe bearing a short spine, which is commonly not preserved.

Range: latest Cenomanian to earliest Turonian.

Occurrence: localities A-9, A-22.

Spongotripus(?) sp. A

(Pl. 37, Figs 10–12)

Remarks: Moderately large (c. 300–400μm in maximum diameter), irregular shaped specimens, with apparently three to four rays and thickened central area.

Range: early Cenomanian.

Occurrence: locality A-3.

Genus and species indet.

Spumellariinid sp. A

(Pl. 37, Figs 13–14)

Remarks: This species is distinguished by having a small (c. 200–320μm in maximum diameter) test with three irregularly developed rays (which give the test a triangular shape) and thickened central area.

Range: early Cenomanian.

Occurrence: locality A-3.

6.3 - DIATOMS

Class **DIATOMACEA**

Remarks: Because of the great uncertainty regarding the systematic positions of diatom frustules recovered during this study, a taxonomic listing of species is not attempted. Rather, the microflora is briefly discussed in general informal terms (and arranged in morphotypes). Specimens of morphotypes D, E and F, with an angular or rounded periphery, are tentatively thought to be diatom frustules, mostly based on their non-spongy, smooth and even outer surface and general similarity to the group.

Morphotype A

(Pl. 38, Figs 1-2)

Remarks: Small (c. 220-230µm in maximum diameter), broad, thin, flattened discs (biscuit-shaped).

Range: earliest Turonian.

Occurrence: locality Pati 1.

Morphotype B

(Pl. 38, Figs 3-4)

Remarks: Small (c. 190µm in maximum diameter), broad, moderately thick, flattened discs, with a vertical periphery (pill-shaped).

Range: earliest Turonian.

Occurrence: locality Pati 1.

Morphotype C

(Pl. 38, Figs 5-8)

Remarks: Minute (c. 120-190µm in maximum diameter), thick, flattened discs (drum-like forms).

Range: latest Cenomanian to earliest Turonian.

Occurrence: localities A-9, Pati 1, well 1-US-1-SE.

Morphotype D

(Pl. 38, Figs 9-10)

Remarks: Moderately small (c. 280µm in maximum diameter), lenticular, moderately thin, biconvex discs (lentil-shaped); surface smooth and even.

Range: latest Cenomanian.

Occurrence: locality A-9.

Morphotype E

(Pl. 38, Figs 11-12)

Remarks: Moderately small (c. 300µm in maximum diameter), broad, moderately thick, flattened discs, with a rounded periphery (biscuit-shaped); surface smooth and even.

Range: latest Cenomanian to earliest Cenomanian.

Occurrence: localities A-9, Pati 1.

Morphotype F

(Pl. 38, Figs 13-14)

Remarks: Small (c. 240µm in maximum diameter), shorth, thick, flattened disc, with a rounded periphery (pill-shaped); surface smooth and even.

Range: latest Cenomanian.

Occurrence: locality A-9.

CHAPTER 4

MICROBIOSTRATIGRAPHY

4.1 - INTRODUCTION

4.1.1 - Methods

Because of the caving and sample mixing that commonly occurs in oil-well cuttings samples, only the top down-hole occurrences (the evolutionary extinction datum level or the last appearance in the stratigraphical section due to environmental changes) of foraminifera and their peaks of abundances have biostratigraphic significance. In other words, the upper boundary of the zones described were defined mainly by means of the last appearance (highest occurrence) of its nominative and associated diagnostic species in the well-sections studied. However, with the careful examination of all the assemblages and differentiation of caved and/or reworked specimens (decrease in abundance and stray occurrences, differentiation in colour and preservation) it was also possible to assess the approximate total range of the recorded taxa (see Tables 4.1-7), therefore allowing a more refined microbiostratigraphical framework to be established.

The microfossil zonations proposed here are primarily defined for regional application. However, there are close analogies between the proposed planktonic foraminiferal zonal scheme and others established for coeval strata in other basins in the equatorial (Ceará: Viviers, 1982; Potiguar: Viviers & Regali, 1987; Maranhão and Pará: Beurlen & Regali, 1987) and southeastern Brazilian continental margin (Santos Basin: Viviers, 1986, 1987; Campos Basin: Azevedo et al., 1987, Koutsoukos, 1987) and elsewhere (e.g., Bolli, 1966; Pessagno, 1967; Premoli-Silva & Bolli, 1973; Longoria, 1974; van Hinte, 1976; Premoli-Silva & Boersma, 1977; Sigal, 1977; Robaszynski et al., 1979, 1984; Wonders, 1980; Leckie, 1981; Caron, 1985; and Sliter, 1989) -Tables 4.9, 4.11-12. This makes it possible to assess their significance on a larger scale as well to allow correlation with, and identification of, worldwide palaeoceanographical events. It has also been possible to integrate the microbiostratigraphy with the mid-Cretaceous ammonite zonal schemes for the basin (Beurlen, 1967-a,b, 1970; Schaller, 1970; Bengtson, 1983) - see Tables 4.8 and 4.10.

4.1.2 - Types of Biostratigraphic Units

The biostratigraphic units defined in the proposed schemes are for the most part what are termed **Oppel-zones** by the ISSC International

Stratigraphic Guide (Hedberg, 1976). According to Hedberg (op. cit., p. 58): "The Oppel-zone may be defined as a zone characterized by an association or aggregation of selected taxons of restricted and largely concurrent range, chosen as indicative of approximate contemporaneity. Not all of the taxons considered diagnostic need be present at any one place for the zone to be legitimately identified. The lower part of the zone is commonly marked largely by first appearance and its upper part by last appearance of certain taxons. The body of the zone is marked largely by concurrences of the diagnostic taxons." According to Carter (1974, p. 197), the critical arguments in favour of recognising Oppel-zones (which have also been recognised by Hedberg, op. cit.) are: "(1) they 'stack' (contrast with strict range zones); (2) they are logically distinct from concurrent-range zones (which in the final analysis are objective, rigorously defined units, of doubtful practical use if more than two taxa are involved in their recognition), (3) that they are ultimately non-objective, and - being defined by common consensus or usage - therefore flexible, and (4) that in this respect they correspond exactly to the working units termed 'stages' in many classifications". Moreover, in addition to being defined by the concurrence of certain diagnostic taxa, an Oppel-zone may be based on a combination of other criteria having time-significance such as lineage (evolutionary) zones, abundance zones (Acme-zones), and so forth (Pessagno, 1977). For all these reasons, such usage has been adopted in the microbiostratigraphic study.

The onshore area of the basin mostly consists of neritic and upper bathyal deposits, where the sediments and associated microfossil biota are strongly sensitive to environmental changes. This study indicates that the complex interplay of abiotic and biotic components (the nature of the total microfossil biota) does not conform to a generalised microbiostratigraphical and palaeo-environmental model based on the distribution of individual foraminifera species or genera (see Chapter 5). Therefore, some environmentally-related assemblage-zones (sensu Hedberg, 1976, p. 50-52; chiefly "ecozones"), of primary local application, had to be defined in order to achieve fine-scale biostratigraphic interpretation and the maximum detail in stratigraphical correlation. The proposed schemes are composite ones based on all sections studied. For boundary decisions the total microfauna has been evaluated.

4.2 - PROPOSED FORAMINIFERAL ZONAL SCHEMES

Each foraminiferal group has great biostratigraphic potential but they are limited in some lithologic units due to unfavorable depositional environments. For example, small-sized (c. 100-300μm in maximum diameter, width or length) benthonic foraminiferal assemblages are the basis for biostratigraphic studies of shelf pelagic carbonates of the mid-Cretaceous (upper Aptian through Coniacian), whereas planktonic foraminifera permit a detailed zonation of outer shelf-slope marls and shales throughout the mid- and Upper Cretaceous succession. The benthonic foraminiferal Oppel-zones from upper Aptian-lower Coniacian neritic environments have only a local character and their age was mostly assigned by means of both microfaunal/lithofacies correlation with nearby planktonic foraminifera-dated localities and after the ammonite zonal schemes of Beurlen (1967-a,b, 1970, and Schaller, 1969, for the Albian) and Bengtson (1983, for the Cenomanian-Coniacian succession) for the outcrop-localities.

The biostratigraphic zones discussed below, from the oldest to the youngest, are defined after characteristic constituent microfossils. They have been named after one or two of the prominent species, for the Oppel-zones, and after two or more diagnostic species for the assemblages-zones (Hedberg, 1976, p. 52, 58), which, individually, may or may not be everywhere present in the zonal assemblage. A prefix consisting of the first one or two letters of the correspondent assigned stage is used as an informal notation for the zones, numbered stratigraphically upwards within each assigned age/stage (e.g., Al-1 to Al-6, for the Albian). The zone-notations are also followed by a letter between brackets indicating either a planktonic (P) or benthonic (B) foraminiferal zone. The zones, together with the ranges and abundances of the diagnostic species are shown in Tables 4.1-4.7. The biochronostratigraphic summary of the studied well sections is presented in Table 4.13.

4.2.1 - Planktonic Foraminifera

The sequence of planktonic foraminifera is based in part on the works of Masters (1977), Robaszynski & Caron (1979), Robaszynski et al. (1984) and Caron (1985). Not all of the zones defined for the central North

Atlantic-western Tethyan/Transitional bioprovinces are represented in the area, mostly because the waters were too shallow (mainly neritic) during the deposition of the Cotinguiba Formation, in the Cenomanian to Coniacian. The presence of a considerable, well-developed, oxygen minimum zone, of variable intensity and thickness, conspicuous in the northern South Atlantic during the mid-Cretaceous (see Chapters 5 and 8), is likely to have been of further restraint to the widespread colonisation of deeper-water, zonally significant, planktonic taxa. Since a major part of this scheme is based on drilled material (as well as primarily intended to be applied to, and enhance, subsurface stratigraphic correlation), the upper boundaries of several biozones were defined mainly by means of last datum appearances in the well sections, i.e., at the highest down-hole occurrence (extinction datum) of diagnostic species.

4.2.1.(i) - Definition of the zones

Globigerinelloides barri-
Hedbergella (H.) gorbachikae Zone
[Ap-1.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of Globigerinelloides barri and Hedbergella (H.) trocoidea with common specimens of Hedb. (H.) gorbachikae.

Assigned age: late Aptian.

Reference section: well 1-CN-1-SE (1002-1047m).

Associated microfauna: Hedbergella (Favusella) washitensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) trocoidea.

Distribution: Sedimentary rocks within this zone have also been recovered from the well 1-CA-1-SE [1275-1320/1350m(?)].

Palaeo-environments: shallow to middle neritic.

Remarks: A cored section of the uppermost Oiterinhos Member, Muribeca Formation, in the Aracaju High (well 1-CPB-1R-SE, core 7:370.90m), yielded a single specimen referred to Globuligerina sp. cf. G. hoterivica (see Chapter 3), associated with an abundant assemblage of microgastropods and microbivalves, representing deposition in a tidal flat environment with the influence of nearby open marine conditions (see Chapter 6, section 6.3, and Chapter 8, section 8.2.1). Minute, high trochospiral, globuligerinid specimens, tentatively referred to Conoglobigerina(?) sp. A (see Chapter 3), are also recovered from the upper Aptian [well 1-CA-1-SE: 1095-1110m, 1125-1140m, 1245-1260m; Zone Ap-2.(P)]. Globuligerinids have been reported elsewhere from Jurassic to lower-upper Aptian strata (cf. Masters, 1977; Grigelis & Gorbatchik, 1980; Caron, 1985; Sliter, 1989). The evidence suggests, therefore, either a higher (younger) last appearance datum (in the late Aptian) at low-latitudes for the group or, quite likely, new taxa placed within the phylogenetic lineage of Conoglogigerina-Globuligerina-Hedbergella (Favusella). Moreover, the record of globuligerinid specimens, in the lowermost marine sediments of Sergipe, may further suggest an earlier dating (early-late Aptian) for the first true marine episode in the northern proto-South Atlantic Ocean.

The zone has been recorded in the lowermost marine section of wells 1-CA-1-SE and 1-CN-1-SE, underlying a section of paralic (lagoonal) sediments. The biostratigraphic position of the zone seems to correspond to that of the Globigerinelloides algerianus, Hedb. gorbachikae and Hedb. trocoidea zones of Longoria (1974), and G'des algerianus and Hedb. gorbachikae Zone of Caron (1985) and Sliter (1989) - see Tables 4.8-4.9. However, the general applicability of this zone is uncertain and it needs to be tested with further coeval sections where sediments in similar facies have been found.

Globigerinelloides ex gr. maridalensis-Hedbergella (H.) similis Zone

[Ap-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last appearances (highest occurrences) of a number of species. Foremost amongst these are the last occurrences of Globigerinelloides barri, G'des ferreolensis, G'des ex gr. maridalensis, and Hedbergella (H.) similis. It is important to note the first appearance of Ticinella species in the zonal assemblage. In all other aspects, this zone closely resembles the underlying one.

Assigned age: late Aptian.

Reference sections: wells 1-CA-1-SE (1095-1260m), 1-US-1-SE (981-1260/1276m) and 1-SES-3 (2325-2460m).

Associated microfauna:

(1) Middle to deep neritic biofacies: *Globigerinelloides aptiense*, *Conoglobigerina*(?) sp. A, *Hedbergella* (*F.*) *washitensis*, *Hedb.* (*H.*) ex gr. *delrioensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) *infracretacea*, *Hedb.* (*H.*) *labocaensis*, *Hedb.* (*H.*) ex gr. *planispira*, *Hedb.* (*H.*) *semielongata*, *Hedb.* (*H.*) *sigali*, *Hedb.* (*H.*) *trocoidea*, *Ticinella bejaouaensis*, *T.* *roberti* and *T.* sp. cf. *T.* *primula*.

(2) Deep neritic to upper bathyal biofacies: *Globigerinelloides aptiense*, *G'des* *macrocamerata*, *Hedb.* (*F.*) *washitensis*, *Hedb.* (*H.*) ex gr. *delrioensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) *infracretacea*, *Hedb.* (*H.*) *maslakovae*, *Hedb.* (*H.*) ex gr. *planispira*, *Hedb.* (*H.*) *sigali*, *Hedb.* (*H.*) *trocoidea*, *T.* *bejaouaensis*, *T.* and *T.* sp. cf. *T.* *primula*.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-CN-1-SE (811-1002m), 1-SES-9 [2628(?)-2862m] and 1-SES-24 [2670(?)-2805m].

Palaeo-environments: middle to deep neritic (wells 1-CA-1-SE, 1-CN-1-SE), deep neritic to upper bathyal (wells 1-US-1-SE, 1-SES-3, 1-SES-9, 1-SES-24).

Remarks: The zonal assemblage contains abundant, minute and small-sized (c. 150-250μm in maximum diameter) specimens of *Globigerinelloides*, *Hedbergella* and *Ticinella*. Particularly significant at this horizon is the sudden increase in abundance of *Hedb.* (*F.*) *washitensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) *infracretacea*, *Hedb.* (*H.*) ex gr. *planispira*, *Hedb.* (*H.*) *trocoidea*, *T.* *bejaouaensis* and *T.* *roberti* ("1st abundance peak" of species of *Ticinella*). There is the first appearance of specimens referred to *Ticinella* sp. cf. *T.* *primula*. They generally display only 6 chambers in the last whorl, rather than 7 to 8, and a more closed umbilicus than the typical middle-late Albian *T.* ex gr. *primula* morphotypes (see Chapter 3).

Populations of *Hedb.* (*F.*) *washitensis* are here considered facies indicators but not good time markers. Occasional "blooms" of large favusellid specimens (later ephebic and gerontic specimens) are probably linked to periods of sea-level lowering and/or to displacement of unconsolidated shallow-water deposits by turbidity currents (see Chapter 6).

The "flood" abundances of favusellids may be used, therefore, with considerable caution, for short distance biostratigraphic correlation (locally defined acme-zones; cf. Hedberg, 1976, p. 59-60), such as amongst and between well sections of the Aracaju High and the Divina Pastora Low areas.

Specimens of Globigerinelloides ex gr. maridalensis were recovered from wells 1-CA-1-SE (1095-1110m) and 1-SES-3. The joint occurrence of T. bejaouaensis and T. roberti specimens indicate an age not older than the late Aptian for the zonal assemblage and a last appearance datum for G'des ex gr. maridalensis most likely at or near the Aptian-Albian boundary. The evidence from Sergipe suggests, therefore, a higher (younger) extinction datum for this species-group at low-latitudes than kwown elsewhere in the northern hemisphere (e.g., Sigal, 1977; Longoria, 1974; Sliter, 1989).

The biostratigraphic position of the zone is equivalent to the G'des ferreolensis-T. bejaouaensis Zone of van Hinte (1976) and to the lower part of the T. bejaouaensis Zone of Longoria (1974), Caron (1985) and Sliter (1989)- Tables 4.8-4.9.

Globigerinelloides cushmani-Ticinella bejaouaensis Zone

[Al-1.(P)]

Category: Oppel-zone.

Definition: The zone is characterised by a marked increase in the abundance of specimens of Ticinella bejaouaensis and T. roberti ("2nd abundance peak"), and by the first appearance of Globigerinelloides cushmani in the zonal assemblage. In addition, its lower limit is set by the last occurrences of G'des barri, G'des ferreolensis, G'des ex gr. maridalensis and Hedbergella (H.) similis, here placed at the Aptian-Albian boundary.

Assigned age: earliest Albian.

Reference section: well 1-CA-1-SE (1035-1095m).

Associated microfauna: Hedbergella (F.) washitensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) gorbachikae, Hedb. (H.) infracretacea, Hedb. (H.) ex gr. planispira, Hedb. (H.) trocoidea and T. sp. cf. T. primula.

Distribution: Sedimentary rocks of this zone have also been recorded from well 1-US-1-SE (891-981m).

Palaeo-environment: middle to deep neritic.

Remarks: The biostratigraphic position of the zone is equivalent to the lower part of the *T. bejaouaensis* Zone of van Hinte (1976) - Tables 4.8-4.9.

Ticinella bejaouaensis Zone
[Al-2.(P)]

Category: Acme-zone (cf. Hedberg, 1976, p. 59-60).

Definition: This zone is characterised by a marked increase in the abundance of specimens of *Ticinella bejaouaensis* and *T. roberti* ("3rd abundance peak"). There is the first occurrence of *Hedbergella* (*H.*) *infracretacea* in the zonal assemblage.

Assigned age: early Albian.

Reference section: well 1-CA-1-SE (945-1035m).

Associated microfauna: *Globigerinelloides cushmani*, *Hedb.* (*F.*) *washitensis*, *Hedb.* (*H.*) ex gr. *delrioensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) ex gr. *planispira*, *Hedb.* (*H.*) *trocoidea* and *T.* sp. cf. *T. primula*.

Distribution: Sedimentary rocks within this zone have also been recovered from locality A-27, wells 1-CN-1-SE (732-811m), 1-SES-9 [2160(?)-2628m] and 1-US-1-SE (711-891m).

Palaeo-environments: middle to deep neritic (locality A-27, wells 1-CA-1-SE, 1-CN-1-SE), deep neritic to upper bathyal (wells 1-US-1-SE, 1-SES-9).

Remarks: The biostratigraphic position of the zone is equivalent to the upper part of the *T. bejaouaensis* Zone of van Hinte (1976) - Tables 4.8-4.9.

Ticinella bejaouaensis-
T. ex gr. *primula* Zone
[Al-3.(P)]

Category: Oppel-zone.

Definition: The upper limit of this zone is characterised by the last occurrences of *Globigerinelloides cushmani* and *Ticinella bejaouaensis*, both occurring rarely. It is important to note the first occurrences in the zonal assemblage of *Hedbergella* (*H.*) ex gr. *simplex* and *G'des bentonensis*, near the upper boundary, and of the *Ticinella primula* species-group.

Assigned age: middle Albian.

Reference section: well 1-CA-1-SE (915-945m).

Associated microfauna: *Hedb.* (*F.*) *washitensis*, *Hedb.* (*H.*) ex gr. *delrioensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) *infracretacea*, *Hedb.* (*H.*) ex gr. *planispira* and *T. roberti*.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-CN-1-SE(672-732m) and 1-US-1-SE (621-711m).

Palaeo-environments: middle to deep neritic (wells 1-CA-1-SE, 1-CN-1-SE), deep neritic to upper bathyal (well 1-US-1-SE).

Remarks: Particularly significant at this horizon is the marked abundance of specimens of *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) ex gr. *planispira* and *T.* ex gr. *primula*.

The biostratigraphic position of the zone corresponds to the *T. bejaouaensis*-*T. primula* Zone of van Hinte (1976) and *T. primula* Zone of Caron (1985) and Sliter (1989) - Tables 4.8-4.9.

***Biticinella breggiensis*-*Ticinella* ex gr. *primula* Zone**

[A1-4.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances of *Biticinella breggiensis*, *Ticinella madecassiana* (probable total range zone in the basin) and *T. raynaudi* in the zonal assemblage. Furthermore, the upper limit of the zone is marked by a sudden increase in the abundance of "large ticinellids", i.e., specimens of *B. breggiensis*, *T.* ex gr. *primula* and *T. madecassiana* (c. 300-380μm in maximum diameter) - ("4th abundance peak" of ticinellids).

Assigned age: middle to late Albian.

Reference section: well 1-US-1-SE (426-621m).

Associated microfauna: *Globigerinelloides bentonensis*, *Hedbergella* (*F.*) *washitensis*, *Hedb.* (*H.*) ex gr. *delrioensis*, *Hedb.* (*H.*) *gorbachikae*, *Hedb.* (*H.*) *infracretacea*, *Hedb.* (*H.*) ex gr. *planispira*, *T. praeticinensis* and *T. roberti*.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-15, wells 1-CA-1-SE (855-915m), 1-CN-1-SE (612-672m), 1-SES-3 [2250/2265(?)-2325m] and 1-SES-24 [2490/2505(?)-2670m].

Palaeo-environments: middle neritic to upper bathyal.

Remarks: The biostratigraphic position of the zone is equivalent to the T. praeticinensis Zone of van Hinte (1976), and to the B. breggiensis Zone/ T. praeticinensis Subzone of Sliter (1989) - Tables 4.8-4.9.

Biticinella breggiensis-
Globigerinelloides texomaensis Zone
[Al-5.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit of the zone is distinguished by the last appearances of Biticinella breggiensis and Ticinella ex gr. primula. It is important to note the first occurrences in the zonal assemblage of Globigerinelloides texomaensis and, near the upper boundary, of Praeglobotruncana delrioensis and species of Heterohelix.

Assigned age: late Albian.

Reference section: well 1-US-1-SE (396-426m).

Associated microfauna: G'des bentonensis, Hedbergella (F.) washitensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) gorbachikae, Hedb. (H.) infracretacea, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Hedb. (H.) subcretacea, Heterohelix ex gr. globulosa, Het. ex gr. moremani, T. raynaudi and T. roberti.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE (765-855m), 1-CN-1-SE (582-612m) and 1-CRL-1-SE (core 2: 1200.80m-core 3: 1214.50m).

Palaeo-environments: deep neritic.

Remarks:

Particularly significant at this horizon is the marked increase in abundance of hedbergellids [such as Hedb. (H.) ex gr. delrioensis, Hedb. (H.) gorbachikae and Hedb. (H.) ex gr. planispira] and specimens of T. ex gr. primula.

The biostratigraphic position of the zone is equivalent to the T. (B.) breggiensis and Planomalina buxtorfi-Rotalipora appenninica zones of van Hinte (1976) - Tables 4.8-4.9.

Hedbergella (Hedb.) gorbachikae-Ticinella raynaudi Zone

[Al-6.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit of the zone is characterised by the last appearances of Globigerinelloides texomaensis and Hedbergella (H.) gorbachikae. The zone also contains the last appearance of species of Ticinella (T. raynaudi and T. roberti), occurring rarely in transitional morphotypes within a Ticinella-Hedbergella plexus assemblage. It is particularly significant the first occurrence of Guembelitria cenomana in the zonal assemblage.

Assigned age: latest Albian.

Reference section: well 1-US-1-SE (381-396m).

Associated microfauna: G'des bentonensis, Hedb. (F.) washitensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Heterohelix ex gr. globulosa, Praeglobotruncana delrioensis.

Distribution: Sedimentary rocks within this zone have also been recorded from 1-CA-1-SE (core 2: 761.80m-765m), 1-CN-1-SE (552-582m), 1-CRL-1-SE (core 1: 1182.50m-core 2: 1200.80m), 1-SES-24 [2460(?)-2490m].

Palaeo-environments: middle to deep neritic.

Remarks: Particularly significant at this horizon is the marked increase in abundance of specimens with a rugose/pustulose (with pustules and/or costellae) chamber surface, such as Hedb. (H.) ex gr. delrioensis, T. raynaudi and Pr. delrioensis (wells 1-CA-1-SE and 1-CN-1-SE). These "rugose and/or pustulose" planktonic morphotypes are equivalent to the Hedbergella "à costellae" assemblage of Caron (1978) described from the middle to upper Albian of Site 364, DSDP Leg 40, in the Angola Basin.

The biostratigraphic position of the zone corresponds to the Planomalina buxtorfi-Rotalipora appenninica Zone of van Hinte (1976) - Tables 4.8-4.9.

Rotalipora brotzeni Zone

[Ce-1.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first appearances of Rotalipora appenninica and Rot. brotzeni, and an abundance of "rugose and/or pustulose" morphotypes of Hedbergella (H.) ex gr. delrioensis. In addition, the lower limit of the zone is marked by the last occurrences of Globigerinelloides texomaensis, Hedb. (H.) gorbachikae, Ticinella raynaudi and T. roberti, placed at the Albian-Cenomanian boundary.

Assigned age: earliest Cenomanian.

Reference section: well 1-CN-1-SE (core 5:537.00m-552m).

Associated microfauna: G'des bentonensis, Guembelitria cenomana, Hedb. (F.) washitensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Heterohelix ex gr. globulosa, Het. ex gr. moremani, Planomalina sp. cf. P. praebuxtorfi and Praeglobotruncana delrioensis.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE (732-core 2:761.80m), 1-US-1-SE (366-381m).

Palaeo-environments: deep neritic.

Remarks: Several specimens referred to Planomalina sp. cf. P. praebuxtorfi were recovered from well 1-CN-1-SE (core 5: 537.00m), and seem to be transitional morphotypes between G'des bentonensis and Pl. praebuxtorfi (Chapter 3).

The biostratigraphic position of the zone corresponds to the Rot. brotzeni Zone of Caron (1985) and Sliter (1989) - Tables 4.10-4.11.

Praeglobotruncana delrioensis-Rotalipora appenninica Zone

[Ce-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the last appearances of Hedbergella (F.) washitensis, Praeglobotruncana delrioensis and Rotalipora appenninica (rare specimens of c. 300µm in maximum diameter) in the zonal assemblage.

Assigned age: early to middle Cenomanian.

Reference section: locality A-1.

Associated microfauna: Globigerinelloides bentonensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Heterohelix ex gr. globulosa and Het. ex gr. moremani.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE (705-core 2: 761.80m), 1-CN-1-SE (162-core 5: 537.00m) and 1-SES-24 [2370(?)-2460m].

Palaeo-environments: middle to deep neritic (locality A-1, well 1-CN-1-SE), deep neritic to upper bathyal (wells 1-CA-1-SE, 1-SES-24).

Remarks: Particularly significant at this horizon is the marked increase in the abundance of small-sized (c. 200-300μm in maximum diameter) specimens of Hedb. (H.) ex gr. delrioensis and Het. ex gr. moremani. Specimens of Hedb. (F.) washitensis and "rugose and/or pustulose" morphotypes of Hedb. (H.) ex gr. delrioensis are occasionally abundant at layers of shallower environments.

The biostratigraphic position of the zone is equivalent to the Rot. reicheli Zone and lower part of the Rot. cushmani Zone/ Rot. greenhornensis Subzone of Caron (1985) and Sliter (1989) - Tables 4.10-4.11.

Hedbergella (Whiteinella) baltica-Hedb. (W.) brittonensis Zone

[Ce-3.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances of Hedbergella (Whiteinella) baltica and Hedb. (W.) brittonensis in the zonal assemblage. Furthermore, the lower limit of the zone is marked by the last occurrences of Hedb. (F.) washitensis, Praeglobotruncana delrioensis and Rotalipora appenninica.

Assigned age: middle to late Cenomanian.

Reference section: well 1-CA-1-SE (645-705m).

Associated microfauna: Globigerinelloides bentonensis, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Heterohelix ex gr. globulosa and Het. ex gr. moremani.

Palaeo-environments: deep neritic.

Remarks: Particularly significant at this horizon is the marked abundance of normal-sized (c. 300-350μm in maximum diameter) specimens of Hedb. (H.) ex gr. delrioensis.

The biostratigraphic position of the zone corresponds to the Rot. cushmani Zone, upper part of the Rot. greenhornensis Subzone and lower part of the Dicarinella algeriana Subzone, of Caron (1985) and Sliter (1989) - Tables 4.10-4.11.

Globigerinelloides bentonensis- Hedbergella (W.) aprica Zone
[Ce-4.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit of the zone is marked by the last appearance of Globigerinelloides bentonensis. Furthermore, it is important to note the first occurrence of Hedbergella (Whiteinella) aprica in the zonal assemblage.

Assigned age: latest Cenomanian.

Reference section: locality A-9.

Associated microfauna: Guembelitria cenomana, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Hedb. (W.) baltica, Hedb. (W.) brittonensis, Heterohelix ex gr. globulosa and Het. ex gr. moremani.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-45 and well 1-CA-1-SE (615-645m).

Palaeo-environments: shallow to middle neritic (locality A-45), upper bathyal (locality A-9, well 1-CA-1-SE).

Remarks: Particularly significant at this horizon are the marked increase in abundance of G'des bentonensis (locality A-9), and large-sized (> 300µm in maximum diameter or length) hedbergellids (mostly "whiteinellid" morphotypes) and heterohelicids. A single small-sized (c. 295µm in maximum diameter) specimen of Rot. greenhornensis was recovered from locality A-9, thus suggesting either reworking or a higher (younger) last appearance datum (at or near the Cenomanian-Turonian boundary) for the taxon at low-latitudes than recorded elsewhere (e.g., Robaszynski et al., 1984; Caron, 1985).

The biostratigraphic position of the zone is equivalent to the lower part of the "zone à grosses globigérines" or "zone à grandes globigérines" of Sigal (1955) and van Hinte (1976), and to the upper part of the Dic.

algeriana Subzone/Rot. cushmani Zone and lower part of the Whit. archaeocretacea Zone of Caron (op. cit.) and Sliter (1989) - Tables 4.10-4.11.

Hedbergella (Whiteinella) archaeocretacea-Heterohelix reussi Zone

[T-1.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note the first appearances of Hedbergella (W.) archaeocretacea and Heterohélix reussi in the zonal assemblage.

Assigned age: earliest Turonian.

Reference section: locality A-2.

Associated microfauna: Guembelitria cenomana, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, Hedb. (W.) aprica, Hedb. (W.) baltica, Hedb. (W.) paradubia, Heterohelix ex gr. globulosa, Het. ex gr. moremani and Praeglobotruncana sp. cf. P. stephani.

Distribution: Sedimentary rocks within this zone have also been recovered from localities A-22, A-35, well 1-CA-1-SE (core 1: 604.20m-615m) and 1-US-1-SE (core 1: 98.50m-366m).

Palaeo-environments: middle to deep neritic (localities A-2, A-35), deep neritic to upper bathyal (locality A-22, wells 1-CA-1-SE, 1-US-1-SE).

Remarks: Particularly significant at this horizon is the marked increase in the abundance of large-sized (c. 300-580μm in maximum diameter or length) hedbergellids (mostly "whiteinellid" morphotypes) and heterohelicids. The record of Heterohelix reussi (Cushman) in the lowermost Turonian of Sergipe is coeval with first occurrences of the species reported from the western Gulf Coastal Plain area (Pessagno, 1967) and Trinidad (Koutsoukos & Merrick, 1986).

The biostratigraphic position of the zone is equivalent to the lower part of the "zone à grosses globigérines" or "zone à grandes globigérines" of Sigal (1955) and van hinte (1976), and to the upper part of the W. archaeocretacea Zone of Caron (op. cit.) and Sliter (1989) - Tables 4.10-4.11.

Hedbergella (Whiteinella) aprica-
Hedb. (W.) baltica Zone
[T-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the last occurrences of Hedbergella (W.) aprica, Hedb. (W.) baltica and Heterohelix ex gr. moremani in the zonal assemblage. It is important to note the first appearance of Marginotruncana undulata (well 1-CA-1-SE), near the upper boundary.
Assigned age: early to late Turonian.
Reference section: well 1-CA-1-SE [555/585m(?)-core 1: 604.20m].
Associated microfauna: Guembelitria cenomana, Hedb. (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Hedb. (H.) ex gr. simplex, H. (Whit.) paradubia, Heterohelix ex gr. globulosa, and Het. reussi.
Distribution: Sedimentary rocks of this zone have also been recovered from localities A-21 and A-29.
Palaeo-environments: middle to deep neritic (localities A-21, A-29), deep neritic to upper bathyal (well 1-CA-1-SE).
Remarks: Particularly significant at this horizon is the marked increase in abundance of specimens of Guembelitria cenomana and heterohelicids in strata from shallower environments (localities A-21 and A-29).

The biostratigraphic position of the zone is equivalent to the Helvetoglobotruncana helvetica Zone and M. sigali Zone of Wonders (1980) and Caron (1985) - Tables 4.10-4.11.

Dicarinella primitiva Zone
[T-3.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note the first appearance in the zonal assemblage of Dicarinella primitiva (locality A-8) and the last occurrence of Guembelitria cenomana (locality A-17).

Assigned age: latest Turonian.

Reference sections: localities A-8 and A-17.
Associated microfauna: Hedbergella (H.) ex gr. delrioensis, Hedb. (H.) ex gr. planispira, Heterohelix ex gr. globulosa and Het. reussi.
Palaeo-environments: shallow to middle neritic (locality A-17), middle to deep neritic (locality A-8).

Remarks: Particularly significant at this horizon is the paucity of the planktonic Foraminifera recovered from the studied sections, probably as a result of non-preservation and very indurated calcareous lithofacies. The occurrence of Guembelitria cenomana in uppermost Turonian strata indicates a higher (younger) last appearance datum for the taxon at low-latitude shelf regions than recorded elsewhere (e.g., Caron, 1985; Sliter, 1989).

The biostratigraphic position of the zone is equivalent to the lower part of the Dicarinella primitiva Zone of Caron (op. cit.) - Tables 4.10-4.11.

Archaeoglobigerina cretacea-Dicarinella primitiva Zone

[Co. (P)]

Category: Oppel-zone.
Definition: This zone is characterised by the association of its nominate and associated species. There is the first appearance of Archaeoglobigerina blowi and A. cretacea (locality A-11), and the last occurrences of Dicarinella primitiva (locality A-10) and Hedbergella (Hedb.) ex gr. simplex in the zonal assemblage.
Assigned age: early Coniacian.
Reference sections: localities A-10 and A-11.
Associated microfauna: Hedb (W.) paradubia, Heterohelix ex gr. globulosa and Het. reussi.
Distribution: Sedimentary rocks of this zone have also been recovered from locality Tabocas 2.
Palaeo-environments: middle neritic.
Remarks: The biostratigraphic position of the zone may correspond to the upper part of the D. primitiva Zone of Caron (1985) - Tables 4.10-4.11.

Dicarinella concavata-*Marginotruncana sinuosa* Zone

[S-1.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last appearances of *Dicarinella concavata* (probable total range zone in the basin), *Marginotruncana sinuosa* and *Hedbergella* (*H.*) *flandrini*. It is important to note the last occurrences in the zonal assemblage of *M. renzi* and *M. undulata* (well 1-SES-3: 2235-2250m; upper Coniacian), together with the first appearances of *Contusotruncana* ex gr. *fornicata*, near the upper boundary, and *Ventrilabrella austinana* (well 1-CRL-1-SE).

Assigned age: late Coniacian to early-late Santonian.

Reference sections: wells 1-CRL-1-SE (core 1: 1176.40-1182.50m) and 1-SES-3 (2205-2250/2265m).

Associated microfana: *Archaeoglobigerina blowi*, *A. cretacea*, *Globigerinelloides escheri*, *Hedb.* (*H.*) ex gr. *delrioensis*, , *Heterohelix* ex gr. *globulosa*, *Het. pulchra*, *Het. reussi*, *Pseudoguembelina costata*.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-SES-9 [2124(?)-2160m], 1-SES-24 [2310-2370m(?)].

Palaeo-environments: upper bathyal (well 1-CRL-1-SE), upper to middle bathyal (wells 1-SES-3, 1-SES-9 and 1-SES-4)

Remarks: The biostratigraphic position of the zone is equivalent to the *D. concavata* Zone and lower part of the *D. asymetrica* Zone of Caron (1985) and Sliter (1989) - Table 4.12.

Dicarinella asymetrica Zone

[S-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the last appearances of *Dicarinella asymetrica* (probable total range zone in the basin) and morphotypes of *Hedbergella* (*H.*) ex gr. *delrioensis*. The lower limit of the zone is marked by the last occurrences of *D. concavata*, *Hedb.* (*H.*) *flandrini* and *Marginotruncana sinuosa*.

Assigned age: late Santonian.

Reference section: well 1-SES-3 (2175-2205m).

Associated microfauna: Archaeoglobigerina blowi, A. cretacea, Contusotruncana ex gr. fornicata, Globigerinelloides aberranta, G'des escheri, G'des ultramicra, Heterohelix ex gr. globulosa, Het. pulchra, Het. reussi, Pseudoguembelina costata, Pseud'lina excolata.

Distribution: Sedimentary rocks within this zone have also been probably recovered from wells 1-CA-1-SE [465(?)-555m] and 1-SES-9 [1980(?)-2124m].

Palaeo-environments: deep neritic to upper bathyal (well 1-CA-1-SE), upper to middle bathyal (wells 1-SES-3, 1-SES-9).

Remarks: The biostratigraphic position of the zone is equivalent to the upper part of the D. asymetrica Zone of Caron (1985) and Sliter (1989) - Table 4.12.

Contusotruncana patelliformis-Globotruncanita elevata-G'nita stuartiformis plexus Zone

[Ca-L(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances in the zonal assemblage of Contusotruncana patelliformis, Globotruncanella havanensis, Globotruncanita elevata-G'nita stuartiformis plexus (total range zone) and G'nita stuartiformis s.s., and the last occurrence of Heterohelix reussi. Moreover, the lower limit of the zone is marked by the last occurrences of Hedb. (H.) ex gr. delrioensis and Dicarinella asymetrica, placed at the Santonian-Campanian boundary.

Assigned age: early Campanian.

Reference section: well 1-SES-3 (2085-2175m).

Associated microfauna: Archaeoglobigerina blowi, A. cretacea, C. ex gr. fornicata, Globigerinelloides escheri, G'des ultramicra, Globotruncana arca, Heterohelix ex gr. globulosa, Het. pulchra, Pseudoguembelina costulata.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-AU-1-SE (510-540/555m), 1-CN-1-SE (0-21/42m), and 1-SES-24 [2220(?)-2310m].

Palaeo-environments: upper bathyal (wells 1-AU-1-SE, 1-CN-1-SE), middle to lower bathyal (wells 1-SES-3, 1-SES-24).

Remarks: The biostratigraphic position of the zone is equivalent to the *G'nita elevata* Zone of Sliter (1989) - Table 4.12.

Globotruncana orientalis-*G'cana ventricosa* Zone

[Ca-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances in the zonal assemblage of *Globotruncana linneiana*, *G'cana bulloides*, *G'cana orientalis*, *G'cana ventricosa*, *Globotruncanita subspinosa*, *Pseudotextularia elegans* and *Rugoglobigerina* ex gr. *rugosa*, and of *G'nita stuarti*, near the upper boundary.

Assigned age: early-late Campanian.

Reference section: well 1-SES-9 [1638-1980m(?)].

Associated microfauna: *Archaeoglobigerina blowi*, *A. cretacea*, *Contusotruncana* ex gr. *fornicata*, *Globigerinelloides aberranta*, *G'des escheri*, *Globotruncanita stuartiformis* s.s., *Hedbergella* (*H.*) *holmdelensis*, *Heterohelix americana*, *Het.* ex gr. *globulosa*, *Het. planata*, *Het. pulchra*, *Het. striata*, *Pseudoguembelina costata*.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-AU-1-SE (core 2: 143m-510m), 1-CA-1-SE [0/84(?)-465m], and 1-SES-1A (1980-2070m).

Palaeo-environments: deep neritic to upper bathyal (well 1-AU-1-SE, 1-CA-1-SE), upper to middle bathyal (wells 1-SES-1A, 1-SES-9).

Remarks: Rare specimens referred to *G'nita* sp. cf. *G. calcarata* were recovered from well 1-AU-1-SE (core 2: 143-145m). The paucity and bad preservation of the specimens, with broken tubulospines, do not allow an unequivocal determination of the species. It seems, however, that they represent intermediate forms between *G'nita subspinosa* and *G'nita calcarata* (Chapter 3).

The biostratigraphic position of the zone is equivalent to the *Globotruncana ventricosa* Zone and *Globotruncanita calcarata* Zone of Caron (1985) and Sliter (1989) - Table 4.12.

Contusotruncana ex gr. *fornicata*-*Globotruncana linneiana* Zone

[M-1.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the last appearances of *Contusotruncana* ex gr. *fornicata*, *Globotruncana bulloides*, *G'cana linneiana* and *Globotruncanita subspinosa* (well 1-SES-24) in the zonal assemblage. Furthermore, there are the first occurrences of *Gansserina gansseri*, *Globotruncanella petaloidea* and *G'cana aegyptiaca* (e.g., well 1-SES-9: 1350-1458m), near the upper boundary.

Assigned age: early Maastrichtian.

Reference section: well 1-SES-9 (1350-1638m).

Associated microfauna: *Archaeoglobigerina blowi*, *A. cretacea*, *C. patelliformis*, *Globigerinelloides aberranta*, *G'des escheri*, *G'des ultramicra*, *G'cana arca*, *G'cana linneiana*, *G'cana subcircumnodifer*, *G'nella havanensis*, *G'nita stuartiformis* s.s., *Hedbergella* (*H.*) *holmdelensis*, *Heterohelix* ex gr. *globulosa*, *Het. planata*, *Het. pulchra*, *Het. striata*, *Pseudoguembelina costata*, *Pseud'lina palpebra*, *Pseudotextularia elegans* and *Rugoglobigerina* ex gr. *rugosa*.

Distribution: Sedimentary rocks within this zone have also been recovered from well 1-SES-24 [2190(?)-2220m].

Palaeo-environments: upper to middle bathyal (well 1-SES-9), middle to lower bathyal (well 1-SES-24).

Remarks:

The last appearance datum of specimens of *C.* ex gr. *fornicata* is in the Campanian on the onshore well-sections (e.g., 1-AU-1-SE: 510-540m, lower Campanian; 1-CA-1-SE: 174-189m, upper Campanian), due to progressively shallower pelagic conditions (upper bathyal to deep neritic) upwards in the stratigraphic sequence, and towards the NW area of the basin (i.e., present-day onshore area) - [see Chapter 5, Fig. 5.13(E), and Chapter 8, section 8.4, Figs 8.23-25].

The biostratigraphic position of the zone may be equivalent to the *G'nita calcarata* Zone, *G'nella havanensis* Zone, *G'cana aeyptiaca* Zone and lower part of the *Ganss. gansseri* Zone of Caron (1985) and Sliter (1989) - Table 4.12.

Ganسserina gansseri-
Globotruncanita stuartiformis Zone
[M-2.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last occurrences of Gansserina gansseri, Globotruncana rosetta, G'cana ventricosa (wells 1-SES-1A, 1-SES-9 and 1-SES-24), Globotruncanita stuartiformis s.s. (well 1-SES-3) and Contusotruncana patelliformis . Furthermore, it is important to note the first appearances of G'nita pettersi and Guembelitria cretacea in the zonal assemblage.

Assigned age: late Maastrichtian.

Reference section: well 1-SES-24 (2100-2190m).

Associated microfauna: Archaeoglobigerina blowi, Globigerinelloides escheri, G'des ultramicra, G'cana aegyptiaca, G'cana subcircumnodifer, Globotruncanella havanensis, Heterohelix ex gr. globulosa, Het. planata, Het. pulchra, Het. striata, Pseudoguembelina costata, Pseud'lina excolata, Pseud'lina palpebra, Pseudotextularia browni, Pseudotext. elegans, Rugoglobigerina hexacamerata, R. ex gr. rugosa.

Distribution: Sedimentary rocks within this zone have also been recorded from wells 1-SES-1A (1530-1920m), 1-SES-3 (1995-2085m) and 1-SES-9 (1314-1350m).

Palaeo-environments: upper to middle bathyal (wells 1-SES-1A, 1-SES-9), middle to lower bathyal (well 1-SES-3, 1-SES-24).

Remarks: The biostratigraphic position of the zone is equivalent to the middle and upper parts of the G. gansseri Zone and lower part of the Abathomphalus mayaroensis Zone of Caron (1985) and Sliter (1989) - Table. 4.12.

Contusotruncana contusa-Globotruncana aegyptiaca Zone

[M-3.(P)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last occurrences of Contusotruncana contusa (total range zone), Globotruncana aegyptiaca, Planoglobulina varians (total range zone) and of all associated Late Cretaceous species.

Assigned age: latest Maastrichtian.

Reference section: well 1-SES-3 (1905-1995m).

Associated microfauna: Archaeoglobigerina blowi, Globigerinelloides escheri, G'des ultramicra, Globotruncanita esnehensis, G'nita pettersi, Globotruncanella havanensis, G'nella petaloidea, Guembelitria cretacea, Heterohelix ex gr. globulosa, Het. pulchra, Het. striata, Pseudoguembelina costata, Pseud'lina excolata, Pseudotextularia browni, Pseudotext. elegans, Rugoglobigerina ex gr. rugosa.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-SES-1A (1410-1530m), 1-SES-9 (1170-1314m) and 1-SES-24 (1980-2100m).

Palaeo-environments: upper to middle bathyal (wells 1-SES-1A, 1-SES-9), middle to lower bathyal (wells 1-SES-3, 1-SES-24).

Remarks: Specimens of C. contusa were only recovered from upper Maastrichtian well-sections deposited in middle to lower bathyal environments (e.g., wells 1-SES-3, 1-SES-24), suggesting the taxon to have been the deepest dwelling (meso- to bathypelagic) Cretaceous planktonic Foraminifera.

The biostratigraphic position of the zone is equivalent to the upper part of the Abathomphalus mayaroensis Zone of Caron (1985) and Sliter (1989) - Table. 4.12.

4.2.2 - Benthonic Foraminifera

The proposed benthonic foraminiferal zones were defined taking into account the following considerations:

1. The overall distribution pattern of foraminiferal assemblages was chiefly controlled by environmental variations within the basin of deposition (Chapter 5).

2. The upper Aptian-Maastrichtian assemblages are apparently representative of a single bioprovince (the central North Atlantic-western Tethyan/ Transitional realm; Chapter 9).

3. Within the basin (where no major physical barriers to microfaunal migration existed), species disappeared abruptly and newly evolved or immigrant species spread rapidly, within the limits of their environmental tolerance, occupying the vacant niches. For instance, 28 species of calcareous benthonic Foraminifera and 21 agglutinated taxa (a total of 49 species) have been recorded from the upper Aptian strata. At the Aptian-Albian boundary 7 calcareous benthonic and 5 agglutinated species disappear from the zonal assemblage. These were replaced by 6 calcareous and 6 agglutinated new species in the earliest Albian, keeping unchanged the total number of 49 taxa [see Chapter 5, Fig. 5.13(B)], suggesting, therefore, full exploitation of niches.

4. Consequently, first and last appearances of short-ranging benthonic species potentially provide isochronous zonal boundaries within the basin. However, the selection of zonal markers and the precise recognition of their first appearance and extinction levels have to be established after facies-constant stratigraphic sequences, where no major environmental change has taken place over a long time-interval.

Comparison between the zonal scheme proposed herein and the planktonic Foraminifera (section 4.2.1) and ammonite schemes is made and presented in Tables 4.8-12. Although the limitations of the present scheme for stratigraphical correlation, chiefly restricted to particular biofacies within the basin, many of the species ranges listed in Tables 4.2, 4.4 and 4.6-7 are recognised to be of regional importance. The zone-notations of assemblage-zones are sometimes followed by a letter, which corresponds to zones defined for different biofacies within a probable coeval unit [e.g., Ap-1(B)A and Ap-1(B)B, for the upper Aptian].

4.2.2.(i) - Definition of the zones

Lingulogavelinella *ciryi*-
Lingulonodosaria *nodosaria*-
Marginulina ex gr. *aequivoca* Zone
[Ap-1.(B)A]

Category: Assemblage-zone.

Definition: This zone is characterised by the association of its nominate and associated species.

Assigned age: late Aptian.

Reference section: well 7-CP-252-SE (core 1: 466.00m-core 4: 497.70m).

Associated microfauna: *Astacolus* sp. cf. *A.* *scitula*, *Astacolus* sp. A, *Conorboides* ex gr. *minutissima*, *Dentalina* *communis*, *Dent.* *raristriata*, *Eoguttulina* *anderyi*, *Globulina* *lacrima*, *Glob.* *prisca*, *Lenticulina* ex gr. *gaultina*, *Lent.* ex gr. *rotulata* [morphotypes of *Lent.* *muensteri* (Roemer)], *Lent.* ex gr. *subangulata*, *Lingulogavelinella* *ciryi*, *Lingulonodosaria* *nodosaria*, *Marginulina* ex gr. *aequivoca*, *Patellina* *subcretacea*, *Pyrulina* *cylindroides*, *Ramulina* *fusiformis*, *Spirillina* *minima*, *Turrispirillina* *subconica*, *Pseudonodosaria* ex gr. *humilis*, *Vaginulina* ex gr. *debilis*, *Vaginulina* ex gr. *kochii*; *Quinqueloculina*(?) sp. A; *Ammobaculites* *reophacoides*, *Gaudryinopsis* *filiformis*, *Marssonella* *kummi*, *Marss.* *ozawai*, *Marss.* *trochus* *oxycona*, *Marss.* *trochus* *turris*, *Quasispiroplectammina* ex gr. *alexanderi*, *Quas.* ex gr. *goodlandana*, *Quas.* *linki*.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-38 and well 1-CPB-1R-SE [320/330m(?)-core 3: 357.25m].

Palaeo-environments: shallow to middle neritic.

Remarks: This zone has been only recorded in the lowermost marine sediments of the Taquari Member, Riachuelo Formation, in the area of the Carmópolis Field, Aracajú High.

Ammobaculites sp. cf. *A. coprolithiformis*-*Buccicrenata* sp. cf. *B. libyca*-*Haplophragmium lueckei* Zone

[Ap-1.(B)B]

Category: Assemblage-zone.

Definition: This zone is characterised by the association of its nominate species [*Ammobaculites* sp. cf. *A. coprolithiformis*, *Buccicrenata* sp. cf. *B. libyca*, *Haplophragmium lueckei*].

Assigned age: late Aptian.

Reference section: well 1-CA-1-SE (1245-1260m).

Distribution: Sedimentary rocks of this zone have also been recovered from well 1-CN-1-SE (912-927m).

Palaeo-environments: paralic (lagoonal).

Lenticulina ex gr. *nodosa*-*Lent.* ex gr. *subangulata* Zone

[Ap-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first occurrences of *Lent.* ex gr. *subangulata* and *Budashevaella nonioninoides* in the zonal assemblage. The upper limit is marked by the last appearance of *Lenticulina* ex gr. *nodosa*.

Reference section: well 1-US-1-SE (981-1260/1276m).

Assigned age: late Aptian.

Associated microfauna: *Conorboides* ex gr. *minutissima* (probably drifted specimens by turbiditic currents from shallower environments), *Gavelinella barremiana*-*Gav. flandrini* plexus, *Globorotalites multisepta*, *Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*, *Lenticulina* ex gr. *gaultina*, *Lent.* ex gr. *rotulata* [morphotypes of *Lent. muensteri* (Roemer)]; *Ammodiscus incertus*, *Ammod. tenuissimus*, *Bathysiphon* ex gr. *vitta*, *Eggerellina mariae*, *Gaudryinopsis filiformis*, *Hyperammina* ex gr. *gaultina*, *Marssonella kummi*, *Marss. ozawai*, *Marss. trochus oxycona*, *Marss. trochus trochus*, *Marss. trochus turris*, *Quasispiroplectammina* ex gr. *alexanderi*, *Quas.* sp. cf. *Q. anceps*, *Quas. linki*, *Textularia minuta*, *Trochammina* ex gr. *minuta*.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE [1095-1245m, 1260-1320/1350(?)m], 1-CN-1-SE (811-912m, 942-1050m) and 1-SES-9 [2628(?)-2862m].

Palaeo-environments: middle neritic to upper bathyal.

Epistomina carpenteri-
Gaudryinopsis filiformis Zone
[Al-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first occurrences of Epistomina carpenteri, Ep. chapmani, Gaudryinopsis sp. cf. G. gradata and Pseudogaudryinella/ Spiroplectinata ex gr. dividens in the zonal assemblage. The upper limit is marked by the last appearance of Gaudryinopsis filiformis.

Assigned age: earliest Albian.

Reference section: well 1-CA-1-SE (1035-1095m).

Associated microfauna: Trocholina sp. A (specimens drifted by turbiditic currents from shallower, oolitic/oncolitic shoals), Citharina sp. A, Dentalina ex gr. legumen, Lenticulina ex gr. gaultina, Lent. ex gr. rotulata, Lent. sp. A, Ramulina aculeata; Bathysiphon ex gr. vitta, Marssonella kummi, Quasispiroplectammina sp. cf. Q. anceps, Trochamminoides ex gr. dubia, Valvulammina(?) sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CPB-1R-SE [198-320/330(?)m], 1-US-1-SE (891-981m) and 1-SES-9 [2412(?)-2628m].

Palaeo-environments: shallow to middle neritic (well 1-CPB-1R-SE), middle to deep neritic (wells 1-CA-1-SE, 1-US-1-SE, 1-SES-9).

Remarks: An outcrop-section (locality A-32, 'Douvilleiceras euzebioi Zone'; lowermost Albian), of a paralic (lagoonal) facies, yielded an assemblage composed of Ammobaculites sp. A, Buccicrenata sp. cf. B. libyca, Haplophragmium ex gr. foedissimum, together with few specimens of Ep. chapmani, Lent. ex gr. rotulata, and Quas. ex gr. goodlandana (the last named three probably drifted specimens from shallow/middle neritic environments by storm-generated bottom currents, as suggested by the sedimentological evidence on the outcrop-section, which shows the influence of storm waves - storm-generated hummocky cross-stratification - see Chapter 8, Photo 8.3).

Osangularia schloenbachi-Pseudogaudryinella/Spiroplectinata ex gr. dividens Zone

[A1-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first occurrences of Osangularia schloenbachi and Tristix ex gr. excavata, near the upper limit. The upper limit is marked by the last appearances of Epistomina chapmani, Gavelinella barremiana-Gav. flandrini plexus, Budashevaella nonioninoides, Marssonella ozawai and Pseudogaudryinella/Spiroplectinata ex gr. dividens.

Assigned age: early Albian.

Reference section: well 1-US-1-SE (711-891m).

Associated microfauna: Conorboides ex gr. minutissima, Globorotalites ex gr. micheliniana (see taxonomic remarks, Chapter 3), Glob'tes sp. cf. G. multisepta, Gyroidinoides ex gr. globosa, Gyr'des ex gr. nitida, Patellina subcretacea, Spirillina minima (probably drifted specimens by turbiditic currents from shallower environments), Lent. ex gr. rotulata, Lent. ex gr. subangulata, Lenticulina sp. A, Lingulogavelinella ciryi, Pseudonodosaria ex gr. humilis, Ramulina aculeata, Ram. fusiformis; Pseudosigmoilina(?) sp. A; Paracoskinolina(?) sp. A (specimens drifted by turbiditic currents from shallower environments), Ammodiscus incertus, Bathysiphon ex gr. vitta, Eggerellina mariae, Gaudryinopsis sp. cf. G. gradata, Glomospirella gaultina, Hyperammina ex gr. gaultina, Marssonella kummi, Marss. trochus oxycona, Marss. trochus trochus, Marss. trochus turris, Quasispiroplectammina ex gr. alexanderi, Quas. sp. cf. Q. anceps, Trochamminoides sp. cf. subcoronata.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-27, wells 1-CA-1-SE (945-1035m), 1-CN-1-SE (732-811m), 1-SES-1A [2070(?)-2400m] and 1-SES-9 [2160(?)-2412m].

Palaeo-environments: middle to deep neritic (locality A-27, wells 1-CA-1-SE, 1-CN-1-SE), deep neritic to upper bathyal (wells 1-US-1-SE, 1-SES-1A, 1-SES-9).

Epistomina carpenteri-
Ep. spinulifera Zone
[Al-3.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note the first occurrences in the zonal assemblage of Cassidella ex gr. viscidus and Epistomina spinulifera, and the last appearances of Ep. carpenteri and Globorotalites sp. cf. G. multisepta.

Assigned age: middle Albian.

Reference section: well 1-US-1-SE (621-711m).

Associated microfauna: Conorboides ex gr. minutissima, Turrispirillina subconica (probably drifted specimens by turbiditic currents from shallower environments), Gyroidinoides ex gr. globosa, Gyr'des ex gr. nitida, Lenticulina ex gr. rotulata, Lent. ex gr. subangulata, Tristix ex gr. excavata; Pseudo-sigmoilina(?) sp. A, Quinqueloculina(?) sp. A; Bathysiphon ex gr. vitta, Hyperammina ex gr. gaultina, Marssonella trochus oxycona, Marss. trochus turris, Quasispiroplectammina sp. cf. Q. anceps, Quas. ex gr. goodlandana, Quas. linki, Textularia minuta.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-37, wells 1-CA-1-SE (915-945m) and 1-CN-1-SE (672-732m).

Palaeo-environments: middle to deep neritic (locality A-37, wells 1-CA-1-SE, 1-CN-1-SE), deep neritic to upper bathyal (well 1-US-1-SE).

Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus - Gaudryinopsis sp. cf. G. gradata Zone
[Al-4.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances of Gavelinella berthelini - Gav. plummerae - Gav. reussi plexus and Textularia ex gr. subconica, near the upper boundary. the upper limit is marked by the last occurrences of Osangularia schloenbachi, Gaudryinopsis sp. cf. G. gradata, Quasispiroplectammina ex gr. alexanderi, Quas. ex gr. goodlandana and Quas. linki in the zonal assemblage.

Reference sections: locality A-15 (middle Albian), well 1-SES-3 [2250/2265(?)-2325m].

Assigned age: middle to late Albian.

Associated microfauna:

(1) middle to deep neritic biofacies: Conorboides ex gr. minutissima, Eoguttulina anderyi, Epistomina spinulifera, Gavelinella berthelini - Gav. plummerae - Gav. reussi plexus, Lenticulina ex gr. rotulata, Spirillina minima, Patellina subcretacea; Marssonella trochus trochus, Quasispiroplectammina sp. cf. Q. anceps, Textularia minuta.

(2) deep neritic to upper bathyal biofacies: Gyroidinoides ex gr. globosa, Gyr'des ex gr. nitida, Lenticulina ex gr. rotulata; Ammodiscus incertus, Bathysiphon ex gr. vitta, Glomospirella gaultina, Hyperammina ex gr. gaultina, Marss. trochus turris.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-16, wells 1-CA-1-SE (855-915m), 1-CN-1-SE (612-672m), 1-US-1-SE (426-621m) and 1-SES-24 [2490/2505m(?)-2670m].

Palaeo-environments: middle to deep neritic (localities A-15, A-16), deep neritic to upper bathyal (wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE, 1-SES-24.

Neobulimina subcretacea- Saracenaria sp. cf. S. crassicostata Zone

[Al-5.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances of Neobulimina subcretacea and Saracenaria sp. cf. S. crassicostata in the zonal assemblage.

Assigned age: late Albian.

Reference section: well 1-CRL-1-SE (core 2: 1200.80m - core 3: 1214.50m).

Associated microfauna: Conorboides ex gr. minutissima (probably drifted specimens by turbiditic currents from shallower environments), Cassidella ex gr. viscidus, Dentalina communis, Gavelinella berthelini - Gav. plummerae - Gav. reussi plexus, Globulina prisca, Gyroidinoides ex gr. globosa, Gyr'des ex gr. nitida, Lenticulina ex gr. subangulata, Bathysiphon ex gr. vitta, Marssonella trochus oxycona.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE (765-855m), 1-CN-1-SE (582-612m) and 1-US-1-SE (396-426m).

Palaeo-environments: deep neritic.

Neobulimina subcretacea- *Tristix* ex gr. *excavata* Zone

[AL-6.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit of the zone is marked by the last appearances of *Lenticulina* ex gr. *subangulata*, *Neobulimina subcretacea*, *Ramulina tetrahedralis* (probably total range zone in the basin) and *Tristix* ex gr. *excavata* in the zonal assemblage.

Assigned age: latest Albian.

Reference section: well 1-US-1-SE (381-396m).

Associated microfauna: *Dentalina communis*, *Gavelinella berthelini* - *Gav. plummerae* - *Gav. reussi* plexus, *Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*, *Lenticulina* ex gr. *gaultina*, *Lent.* ex gr. *rotulata*; *Pseudosigmoilina*(?) sp. A; *Marssonella trochus oxycona*, *Marss. trochus turris*, *Trochamminoides* ex gr. *subcoronata*.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-CA-1-SE (core 2: 761.80m-765m), 1-CN-1-SE (552-582m) and 1-CRL-1-SE (core 1: 1182.50m-core 2: 1200.80m).

Palaeo-environments: middle to deep neritic.

Cibicides sp. A- *Planularia complanata* Zone

[Ce-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first appearances in the zonal assemblage of *Cibicides* sp. A, *Praebulimina* ex gr. *nannina*, and *Planularia complanata*, and the last occurrence of *Saracenaria* sp. cf. *S. crassicostata*.

Assigned age: earliest Cenomanian.

Reference section: well 1-CN-1-SE (core 5: 537.00m).

Associated microfauna: Cassidella ex gr. viscidus, Dentalina communis, Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Globorotalites ex gr. micheliniana, Lenticulina ex gr. rotulata, Marssonella trochus turris.

Distribution: Sedimentary rocks of this zone have also been recovered from well 1-US-1-SE (366-381m).

Palaeo-environments: deep neritic.

Lingulogavelinella(?) sp. cf. L. thalmanniformis-Spiroloculina cretacea Zone

[Ce-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the first occurrences of Gavelinella sp. A, Lingulogavelinella(?) sp. cf. L. thalmanniformis, Lingulogav. tormarpensis, Spiroloculina cretacea (probably total range zone in the basin) and Spiroloculina sp. A in the zonal assemblage.

Assigned age: early Cenomanian.

Reference section: locality A-1.

Associated microfauna: Anomalinoides sp. A, Conorboides ex gr. minutissima, Coryphostoma sp. A, Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Gyroidinoides ex gr. nitida, Lenticulina ex gr. rotulata, Patellina subcretacea, Praebulimina ex gr. nannina, Spirillina minima, Vaginulina ex gr. kochii; Textularia ex gr. subconica.

Distribution: Sedimentary rocks of this zone have also been recovered from localities A-3, Itaporanga 2, wells 1-CA-1-SE (705-735m) and 1-CN-1-SE (162-core 5: 537.00m).

Palaeo-environments: middle to deep neritic (localities A-1, A-3, Itaporanga 2, well 1-CN-1-SE), deep neritic to upper bathyal (well 1-CA-1-SE).

Cibicides sp. A-Nodosaria ex gr. obscura Zone

[Ce-3.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first occurrence of Nodosaria ex gr. obscura and the last appearance of Cibicides sp. A.

Assigned age: middle to late Cenomanian.

Reference section: well 1-CA-1-SE (645-705m).

Associated microfauna: Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Lingulogavelinella tormarpensis.

Distribution: Sedimentary rocks of this zone have also been recovered from locality Cruzes 15.

Palaeo-environments: shallow to middle neritic (Cruzes 15), deep neritic (well 1-CA-1-SE).

Gabonita levis-Discammina sp. A Zone

[Ce-4.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first occurrences of Gabonita levis, Ammobaculites impexus, Ammomarginulina paterella and the last appearances of Spiroloculina sp. A and Discammina sp. A (probably total range zone in the basin).

Assigned age: latest Cenomanian.

Reference sections: localities A-9, A-45.

Associated microfauna:

(1) shallow to middle neritic biofacies: Conorboides ex gr. minutissima, Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Praebulimina ex gr. nannina; Tritaxilina(?) sp. A.

(2) upper bathyal biofacies: Cassidella ex gr. viscidus, Gavelinella berthelini - Gav. plummerae - Gav. reussi plexus, Gavelinella sp. A, Gavelinopsis(?) sp. A, Conorboides ex gr. minutissima (probable drifted specimens from shallower environments), Globulina lacrima, Glob. prisca, Lingulogavelinella(?) sp. cf. L. thalmanniformis, Neobulimina minima, Praebulimina ex gr. nannina, Spiroloculina sp. A, Valvulineria sp. B; Marssonella kummi, Marss. trochus turris, Textularia ex gr. subconica, Trochammina sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-46.

Palaeo-environments: shallow to middle neritic (locality A-45), upper bathyal (locality A-9).

Remarks: There is a marked increase in the number of gavelinellid morphotypes of the Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus. Specimens of normal sized tests (around 300-370µm in maximum diameter) are usually present, although variable numbers of minute individuals, with lower dorsal height, also occur in the size fractions below 200um (Chapter 3).

Gabonita levis-
Gab. obesa Zone
[T-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first occurrences of Buliminella sp. A and Gabonita obesa (probably total range zone in the basin), together with abundant specimens of Gabonita levis and the last appearance of Cassidella ex gr. viscidus.

Assigned age: earliest Turonian.

Reference section: well 1-US-1-SE (core 1: 98.50m-366m).

Associated microfauna: Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Gavelinopsis(?) sp. A, Spirillina minima, Turrispirillina subconica (probably drifted specimens from shallower environments), Caucasina sp. A, Coryphostoma sp. B, Dentalina vistulae, Lingulogavelinella(?) sp. cf. L. thalmanniformis, Lingulogav. tormarpensis, Neobulimina minima, Nodosaria ex gr. obscura, Valvulineria sp. B; Trochammina sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from localities A-2, A-22, A-35 and well 1-CA-1-SE (core 1: 604.20m-615m).

Palaeo-environments: middle to deep neritic (localities A-2, A-35), deep neritic to upper bathyal (locality A-22, wells 1-CA-1-SE, 1-US-1-SE).

Gabonita levis-
Nodosaria ex gr. obscura Zone
[T-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. It is important to note in the zonal assemblage the first occurrence of Gabonita sp. cf. G. parva, together with the last appearances of Gabonita levis and Nodosaria ex gr. obscura.

Assigned age: early to late Turonian.

Reference section: well 1-CA-1-SE [555/585m(?)-core 1: 604.20m].

Associated microfauna: Buliminella sp. A, Conorboides ex gr. minutissima, Dentalina ex gr. legumen, Dent. vistulae, Gavelinella berthelini - Gav. plummerae - Gav. reussi plexus, Lagena paucicostata, Lenticulina ex gr. gaultina, Lent. revoluta, Lent. ex gr. rotulata, Nonionella sp. cf. N. austinana, Nodogenerina sp. cf. N. alexanderi, Nodosaria limbata, Spirillina minima, Turrispirillina subconica, Valvulineria sp. B.

Distribution: Sedimentary rocks of this zone have also been recovered from localities A-7 and A-29.

Palaeo-environments: middle to deep neritic (localities A-7, A-29), deep neritic to upper bathyal (well 1-CA-1-SE).

Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus - Valvulineria sp. A Zone

[T-3.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associate species. It is important to note in the zonal assemblage the first occurrences of Bolivina sp. cf. B. incrassata (see taxonomic remarks, Chapter 3) and Valvulineria sp. A, together with the last appearances of the Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus.

Assigned age: latest Turonian.

Reference section: locality A-6.

Associated microfauna: Gavelinella sp. A, Lenticulina ex gr. rotulata, Lingulogavelinella tormarpensis, Spirillina minima, Patellina subcretacea, Planulina sp. A, Praebulimina ex gr. nannina, Turrispirillina subconica.

Distribution: Sedimentary rocks of this zone have also been recovered from localities A-8, A-12 and well 1-CN-1-SE (21/42-162m).

Palaeo-environments: shallow to middle neritic (localities A-6, A-12, well 1-CN-1-SE), middle to deep neritic (locality A-8).

Gavelinella sp. A–
Valvulineria sp. A Zone
[Co.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associate species. There are the last appearances of *Gavelinella* sp. A, *Lingulogavelinella* *tormarpensis*, *Valvulineria* sp. A and *Textularia* ex gr. *subconica* in the zonal assemblage.

Assigned age: early Coniacian.

Reference section: Tabocas 2.

Associated microfauna: *Conorboides* ex gr. *minutissima*, *Lenticulina* ex gr. *rotulata*, *Neobulimina* *minima*; *Spiroloculina* sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from localities A-10 and A-11.

Palaeo-environments: middle neritic.

Globorotalites *spinea*–
Lenticulina *revoluta* Zone
[S-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associate species. It is important to note the first occurrences of *Eponides* *aracajuensis*, *Gavelinella* ex gr. *beccariiformis*, *Gavelinella* *correcta*, *Gav.* *sandidgei*, *Gav.* *spissocostata*, *Gavelinopsis*(?) sp. B, *Reussella* ex gr. *szajnochae* (see taxonomic remarks, Chapter 3), *Dorothia* ex gr. *bulleta*, *Gaudryina* *laevigata*, *Pseudogaudryinella* ex gr. *capitosa* and *Recurvoides* ex gr. *globulosa* in the zonal assemblage. Furthermore, there are the last appearances of *Lenticulina* *revoluta*, at or near the Coniacian-Santonian boundary, and of *Globorotalites* *spinea* (probably total range zone in the basin).

Assigned age: late Coniacian to early-late Santonian.

Reference sections: wells 1-CRL-1-SE (core 1: 1176.40-1182.50m) and 1-SES-3 (2205-2250/2265m).

Associated microfauna: *Allomorphina* ex gr. *cretacea*, *Bolivina* ex gr. *incrassata*, *Buliminella brevispira*, *Bulim.* ex gr. *colonensis*, *Cibicides* ex gr. *beaumontianus*, *Citharina multicostata*, *Dentalina vistulae*, *Dentalina* ex gr. *legumen*, *Dent. megapolitana*, *Gavelinella thamanni*, *Gav.* ex gr. *velascoensis*, *Globorotalites elkensis*, *Glob'tes* ex gr. *micheliniana*, *Glob'tes* sp. cf. *G. multisepta*, *Gyroidina beisseli*, *Gyr'dina* sp. A, *Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*, *Gyr'des quadrata*, *Lenticulina revoluta*, *Lent.* ex gr. *rotulata*, *Neobulimina aspera*, *Neob. minima*, *Nodosaria limbata*, *Nuttallinella florealis*, *Orithostella* ex gr. *halfeldi*, *Osangularia cordieriana*, *Os. navarroana*, *Os. velascoensis*, *Praebulimina* ex gr. *fang*, *Praeb.* ex gr. *nannina*, *Praeb.* ex gr. *prolixa*, *Praeb. reussi*, *Pseudonodosaria obesa*, *Pyrulina cylindroides*, *Quadrimorphina* ex gr. *allomorphinoides*, *Ramulina aculeata*, *Valvulineria amarali*; *Ammodiscus cretaceus*, *Ammod. planus*, *Bathysiphon* ex gr. *vitta*, *Gaudr. pyramidata*, *Glomospira charoides*, *Hormosina* ex gr. *globulifera*, *Horm. ovulum*, *Kalamopsis grzybowskii*, *Marssonella trochus trochus*, *Marss. trochus turris*, *Psammosphaera scruposa*, *Rzehakina epigona*.
Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-SES-3 (2205-2250/2265m), 1-SES-9 [2124(?)-2160m] and 1-SES-24 [2310-2370(?)m].
Palaeo-environments: deep neritic to upper bathyal (well 1-CRL-1-SE), upper to middle bathyal (wells 1-SES-3, 1-SES-9 and 1-SES-24).

Nuttallinella texana- *Orthokarstenia clarki* Zone

[S-2.(B)]

Category: Oppel-zone.
Definition: This zone is characterised by the association of its nominate and associated species. It is important to note the first occurrences of *Bolivina* ex gr. *afra*, *Nuttallinella texana*, *Orthokarstenia clarki*, *Orthok. clavata* and *Verneuilina cretacea* in the zonal assemblage.
Assigned age: late Santonian.
Reference sections: wells 1-CA-1-SE [465(?)-555m] and 1-SES-3 (2175-2205m).

Associated microfauna: *Allomorphina* ex gr. *cretacea*, *Bandyella* ex gr. *greatvalleyensis*, *Bol.* ex gr. *incrassata*, *Buliminella brevispira*, *Bulim.* ex gr.

colonensis, Bulim. quadrilobata, Citharina navarroana, Dentalina ex gr. legumen, Eponides aracajuensis, Gavelinella correcta, Gav. sandidgei, Gav. spissocostata, Gav. ex gr. velascoensis, Globorotalites ex gr. micheliniana, Gyroidina beisseli, Gyroidinoides quadrata, Lagena paucicostata, Lenticulina ex gr. rotulata, Neobulimina aspera, Neobulimina canadensis, Nodosaria ex gr. affinis, Orithostella ex gr. halfeldi, Osangularia cordieriana, Praebulimina ex gr. bantu, Praeb. kickapooensis, Praeb. ex gr. prolixa, Praeb. reussi, Pseudouvigerina plummerae, Pullenia jarvisi, Quadrimorphina ex gr. allomorphinoides, Ramulina aculeata, Reussella ex gr. szajnochae, Stensioeina sp. A, Valvulineria amarali; Ammobaculites ex gr. coprolithiformis, Asanospira ex gr. glabra, Asan. walteri, Bathysiphon ex gr. vitta, Cribrostomoides ex gr. trinitatensis, Dorothia ex gr. bulleta, Gaudryina laevigata, Gaudr. pyramidata, Haplophragmoides ex gr. bulloides, Hapl'des rugosa, Hormosina ex gr. globulifera, Horm. ovulum, Psammosphaera scruposa, Recurvoides ex gr. globulosa, Spiroplectammina chicoana, Trochammina gatesensis, Trochamminoides flageri, Trochospira(?) sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from well 1-SES-9 [1980(?)-2052m].

Palaeo-environments: deep neritic to upper bathyal (well 1-CA-1-SE), upper to middle bathyal (wells 1-SES-3, 1-SES-9).

Reussella ex gr. szajnochae-Siphogenerinoides bramlettei Zone

[Ca-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. There are the first occurrences of Ellipsoglandulina velascoensis, Gavelinella nacatochensis, Globorotalites subconica, Gyroidinoides loetterlei, Siphogenerinoides bramlettei, Hagenowella ex gr. subsphaerica and Recurvoides sp. cf. R. subturbinata in the zonal assemblage. The upper limit is marked by the last appearances of Osangularia navarroana, Pullenia jarvisi and Reussella ex gr. szajnochae.

Assigned age: early Campanian.

Reference section: well 1-SES-3 (2085-2175m).

Associated microfauna: *Allomorphina* ex gr. *cretacea*, *Bolivina* ex gr. *afra*, *Buliminella* ex gr. *colonensis*, *Bulim. quadrilobata*, *Cibicides* sp. B, *Dentalina* ex gr. *legumen*, *Eponides aracajuensis*, *Frondicularia microdisca*, *Gavelinella* ex gr. *beccariiformis*, *Gav. lorneiana*, *Gav. sandidgei*, *Gav. spissocostata*, *Globorotalites* ex gr. *micheliniana*, *Gyroidina beisseli*, *Gyroidinoides* ex gr. *globosa*, *Gyr'des quadrata*, *Lenticulina* ex gr. *rotulata*, *Neobulimina canadensis*, *Nuttallinella florealis*, *Orithostella* ex gr. *halfeldi*, *Orthokarstenia clavata*, *Orth. clarki*, *Osangularia cordieriana*, *Os. velascoensis*, *Planulina taylorensis*, *Praebulimina* ex gr. *bantu*, *Praebulimina* ex gr. *fang*, *Praeb. kickapooensis*, *Praeb.* ex gr. *prolixa*, *Praeb. reussi*, *Valvulineria amarali*; *Ammobaculites* ex gr. *coprolithiformis*, *Bathysiphon* ex gr. *vitta*, *Gaudryina pyramidata*, *Glomospira charoides*, *Haplophragmoides* ex gr. *bulloides*, *Spiroplectammina laevis*, *Trochospira*(?) sp. A.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-AU-1-SE (510-540/555m), 1-CN-1-SE (0-21/42m) and 1-SES-24 [2220(?)-2310m].

Palaeo-environments: upper bathyal (wells 1-AU-1-SE, 1-CN-1-SE); middle to lower bathyal (wells 1-SES-3, 1-SES-24).

Lacosteina gouskovi-
Orthokarstenia clavata Zone
[Ca-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last appearances of *Gavelinella correcta*, *Gav.* lorneiana, *Gav. sandidgei*, *Lacosteina gouskovi*, *Neoflabelina rugosa* (probably total range zone in the basin), *Orithostella* ex gr. *halfeldi*, *Orthokarstenia clavata* and *Valvulineria amarali*. It is important to note the last appearance in the zonal assemblage of *Planulina taylorensis*, and the first occurrences of *Epistomina supracretacea*, *Gavelinella monterelensis*, *Praebulimina spinata* and *Ammoglobigerina* ex gr. *globigeriniformis*. There is a marked increase in the abundance of specimens of *Bolivina* ex gr. *afra*, which disappear regionally at the upper limit of the zone in response to environmental changes and facies variations. The specimens only reappear, rarely, higher in the stratigraphic sequence, in the upper Maastrichtian (well 1-SES-1A).

Assigned age: early to late Campanian.

Reference sections: loca·lity A-19, well 1-SES-9 [1638-1980(?)m].

Associated microfauna:

(1) deep neritic to upper bathyal biofacies: Bolivina ex gr. incrassata, Buliminella ex gr. colonensis, Bulim. pseudoelegantissima, Epistomina supracretacea, Eponides aracajuensis, Gavelinella ex gr. beccariiformis, Gav. nacatochensis, Lenticulina ex gr. rotulata, Neobulimina aspera, Neobulimina canadensis, Nodosaria ex gr. affinis, Nod. limbata, Nonionella austinana, Orthokarstenia clarki, Orthok. ewaldi, Praebulimina ex gr. bantu, Praeb. crassa, Praeb. ex gr. fang, Praeb. kickapooensis, Praeb. ex gr. prolixa, Praeb. reussi, Pseudouvigerina plummerae, Pyramidina rudita, Quadrimorphina ex gr. allomorphinoides, Siphogenerinoides bramlettei.

(2) upper to middle bathyal biofacies: Allomorphina ex gr. cretacea, Bolivina ex gr. incrassata, Buliminella ex gr. colonensis, Bulim. quadrilobata, Cibicides ex gr. beaumontianus, Dentalina basiplanata, Dent. ex gr. gracilis, Dent. megapolitana, Dent. vistulae, Ellipsoglandulina velascoensis, Eponides aracajuensis, Gavelinella ex gr. beccariiformis, Gav. spissocostata, Gav. ex gr. velascoensis, Globorotalites ex gr. micheliniana, Glob'tes sp. cf. G. multisepta, Glob'tes subconica, Gyroidina beisseli, Gyr'dina sp. A, Gyroidinoides loetterlei, Gyr'des ex gr. nitida, Gyr'des nonionoides, Karreria sp. A, Lacosteina gouskovi, Lagena paucicostata, Lenticulina ex gr. rotulata, Neobulimina aspera, Neobulimina canadensis, Nodosaria ex gr. affinis, Nodosaria limbata, Nuttallinella florealis, Nutt. texana, Orthokarstenia clarki, Osangularia cordieriana, Os. velascoensis, Praebulimina ex gr. bantu, Praeb. ex gr. fang, Praeb. kickapooensis, Praeb. ex gr. prolixa, Praeb. reussi, Pseudonodosaria ex gr. humilis, Pseudonod. obesa, Pseudouvigerina plummerae, Pullenia cretacea, Quadrimorphina ex gr. allomorphinoides, Ramulina aculeata, Siphogenerinoides bramlettei; Ammobaculites ex gr. coprolithiformis, Ammodiscus glabratus, Ammovertellina sp. A, Asanospira ex gr. glabra, Bathysiphon ex gr. vitta, Budashevaella trinitatensis, Cribrostomoides ex gr. trinitatensis, Dorothia ex gr. bulleta, Gaudryina laevigata, Gaudr. pyramidata, Glaphyrammina sp. A, Glomospira charoides, Glom. gordialis, Glomospirella gaultina, Hagenowella ex gr. subsphaerica, Haplophragmoides ex gr. bulloides, Hapl'des rugosa, Hormosina ex gr.

globulifera, Karreriella ex gr. conversa, Marssonella trochus oxycona, Marss. trochus trochus, Marss. trochus turris, Pilulina sp. A, Psammosphaera scruposa, Pseudogaudryinella ex gr. capitosa, Recurvoides ex gr. globulosa, Rec. sp. cf. R. subturbinata, Rhabdammina ex gr. discreta, Rzehakina epigona, Saccammina sphaerica, Spirolocammina sp. A, Spiroplectammina chicoana, Trochamminoides flageri.

Distribution: Sedimentary rocks of this zone have also been recovered from locality A-18, wells 1-AU-1-SE (143-510m) and 1-CA-1-SE [0/84(?)-465m], and 1-SES-1A (1920/1980-2070m).

Palaeo-environments: deep neritic to upper bathyal (locality A-18, A-19, wells 1-AU-1-SE, 1-CA-1-SE), upper to middle bathyal (wells 1-SES-1A, 1-SES-9).

Cibicides ex gr. beaumontianus-Gyroidinoides nonionoides Zone

[M-1.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate species. The upper limit is marked by the last appearances of Cibicides ex gr. beaumontianus, Gyroidinoides nonionoides, Neoflabelina reticulata, Praebulimina ex gr. fang, Praeb. ex gr. prolixa and Praeb. spinata. It is important to note the last appearances of Neoflabelina semireticulata and Neof. ex gr. pilulifera , near the lower limit of the zone, and the first occurrence of Ammobaculites sp. cf. A. fragmentaria in the zonal assemblage.

Assigned age: early Maastrichtian.

Reference section: well 1-SES-9 (1350-1638m).

Associated microfauna: Allomorphina ex gr. cretacea, Dentalina ex gr. legumen, Eponides aracajuensis, Frondicularia clarki, Gavelinella ex gr. beccariiformis, Gav. nacatochensis, Gav. spissocostata, Gav. ex gr. velascoensis, Globorotalites ex gr. micheliniana, Gyroidina beisseli, Gyroidinoides quadrata, Lenticulina ex gr. rotulata, Neobulimina aspera, Neob. canadensis, Nodogenerina stephensoni, Nuttallinella florealis, Nutt. texana, Orthokarstenia clarki, Praebulimina ex gr. bantu, Praeb. kickapooensis, Quadrimorphina ex gr. allomorphinoides, Ramulina aculeata, Siphogenerinoides bramlettei, Stomatorbina sp. A; Alveolophragmium sp. A, Ammobaculites ex gr. coprolithiformis, Ammodiscus cretaceus, Ammoglobigerina ex gr. globigeriniformis, Bathysiphon ex gr. vitta, Cribrostomoides ex gr. trinitatensis, Dorothia ex gr. bulleta, Gaudryina laevigata, Gaudr. pyramidata, Glomospira charoides, Glomospirella gaultina, Hagenowella ex gr. subsphaerica, Haplophragmoides ex gr. bulloides, Hormosina ex gr. globulifera, Hyperammina ex gr. gaultina, Karreriella ex gr. conversa, Marssonella trochus trochus, Marss. trochus turris, Psammosphaera scruposa, Recurvoides ex gr. globulosa, Rzehakina epigona, Rzeh. fissistomata, Silicosigmoilina californica, Spiroplectammina sigmoidina, Trochamminoides flageri, Verneuilina cretosa.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-AU-1-SE (0-143m) and 1-SES-24 [2190(?)-2220m].

Palaeo-environments: middle to deep neritic (well 1-AU-1-SE), upper to middle bathyal (well 1-SES-9), middle to lower bathyal (well 1-SES-24).

Gyroidinoides loetterlei- Osangularia velascoensis Zone

[M-2.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last appearances of Gyroidinoides loetterlei, Nodogenerina stephensoni, Osangularia velascoensis, Praebulimina ex gr. bantu, Ammobaculites sp. cf. A. fragmentaria, Rzehakina fissistomata and Verneuilina cretosa.

Assigned age: late Maastrichtian.

Reference section: well 1-SES-24 (2100-2190m).

Associated microfauna: Allomorphina ex gr. cretacea, Bandyella clavata, Band. ex gr. greatvalleyensis, Bolivina ex gr. incrassata, Buliminella ex gr. colonensis, Bulim. quadrilobata, Dentalina ex gr. gracilis, Dent. ex gr. legumen, Eponides aracajuensis, Gavelinella ex gr. beccariiformis, Gav. monterelensis, Gav. nacatochensis, Gav. spissocostata, Gav. ex gr. velascoensis, Guttulina communis, Gyroidina beisseli, Gyr'dina megastoma, Gyroidinoides ex gr. globosa, Gyr'des quadrata, Lenticulina ex gr. rotulata, Marginulinopsis sp. A, Neobulimina aspera, Neob. canadensis, Nodosaria ex gr. affinis, Nonionella austinana, Orthokarstenia clarki, Osangularia cordieriana, Praeb. kickapooensis, Praeb. reussi, Pseudonodosaria ex gr.

humilis, Pseud. obesa, Pullenia cretacea, Quadrimorphina ex gr. allomorphinoides; Alveolophragmium sp. A, Ammobaculites ex gr. coprolithiformis, Bathysiphon ex gr. vitta, Cribrostomoides ex gr. trinitatensis, Dendrophyra ex gr. excelsa, Dorothia ex gr. bulleta, Gaudryina laevigata, Gaudr. pyramidata, Glomospira gordialis, Hagenowella ex gr. subsphaerica, Haplophragmoides ex gr. bulloides, Hormosina ex gr. globulifera, Horm. ovulum, Hyperammina ex gr. gaultina, Marssonella trochus oxycona, Marss. trochus turris, Psammosphaera scruposa, Pseudogaudryinella ex gr. capitosa, Recurvoides ex gr. globulosa, Rec. sp. cf. R. subturbinata, Reophax texanus, Rhizammina ex gr. indivisa, Rzehakina epigona, Spiroplectammina laevis, Spir. ex gr. spectabilis, Tritaxia ellisorae.

Distribution: Sedimentary rocks of this zone have also been recovered from wells 1-SES-1A (1530-1920m), 1-SES-3 (1995-2085m) and 1-SES-9 (1314-1350m).

Palaeo-environments: upper to middle bathyal (wells 1-SES-1A, 1-SES-9), middle to lower bathyal (wells 1-SES-3, 1-SES-24).

Bolivinoides draco- Orthokarstenia clarki Zone

[M-3.(B)]

Category: Oppel-zone.

Definition: This zone is characterised by the association of its nominate and associated species. The upper limit is marked by the last appearances of Bolivinoides draco, Orthokarstenia clarki, Praebulimina kickapooensis and Praeb. reussi. It is important to note the first occurrences of Clavulinoides ex gr. trilatera, Gaudryinopsis glabrata and Pseudoclavulina arenata in the zonal assemblage.

Assigned age: latest Maastrichtian.

Reference section: well 1-SES-3 (1905-1995m).

Associated microfauna: Allomorphina ex gr. cretacea, Bolivina ex gr. afra, Bol. ex gr. incrassata, Buliminella brevispira, Bulim. ex gr. colonensis, Cibicides sp. B, Eponides aracajuensis, Gavelinella ex gr. beccariiformis, Gav. clementiana, Gav. monterelensis, Gav. nacatochensis, Gav. spissocostata, Gav. ex gr. velascoensis, Globorotalites ex gr. micheliniana, Guttulina communis, Gyroidina beisseli, Gyr'dina megastoma, Gyroidinoides ex gr. globosa, Gyr'des ex gr. nitida, Gyr'des quadrata, Lagena acuticostata, *Lenticulina* ex gr. *rotulata*, *Neobulimina aspera*, *Neobulimina canadensis*, *Nodosaria* ex gr. *affinis*, *Nuttallinella florealis*, *Nutt. texana*, *Osangularia cordieriana*, *Pseudonodosaria* ex gr. *humilis*, *Pseudouvigerina plummerae*, *Pullenia cretacea*, *Pyrulina cylindroides*, *Quadrimorphina* ex gr. *allomorphinoides*, *Ramulina aculeata*, *Siphogenerinoides bramlettei*, *Vaginulina trilobata*; *Ammobaculites* ex gr. *coprolithiformis*, *Ammodiscus cretaceus*, *Ammod. glabratus*, *Ammoglobigerina* ex gr. *globigeriniformis*, *Asanospira* ex gr. *glabra*, *Bathysiphon* ex gr. *vitta*, *Cribrostomoides* ex gr. *trinitatensis*, *Dorothia* ex gr. *bulleta*, *Gaudryina laevigata*, *Gaudr. pyramidata*, *Glomospira charoides*, *Hagenowella* ex gr. *subsphaerica*, *Haplophragmoides* ex gr. *bulloides*, *Hormosina* ex gr. *globulifera*, *Hyperammina* ex gr. *gaultina*, *Karreriella* ex gr. *conversa*, *Marssonella trochus oxycona*, *Marss. trochus trochus*, *Psammosphaera scruposa*, *Pseudogaudryinella* ex gr. *capitosa*, *Quasispiroplectammina navarroana*, *Recurvoides* ex gr. *globulosa*, *Rec.* sp. cf. *R. subturbinata*, *Reophax texanus*, *Rhizammina* ex gr. *indivisa*, *Rzehakina epigona*, *Saccammina sphaerica*, *Spiroplectammina chicoana*, *Spir. laevis*, *Tritaxia ellisorae*, *Trochamminoides flageri*, *Verneuilina cretacea*.

Distribution: Sedimentary rocks within this zone have also been recovered from wells 1-SES-1A (1410-1530m), 1-SES-9 (1170-1314m) and 1-SES-24 (1980-2100m).

Palaeo-environments: upper to middle bathyal (wells 1-SES-1A, 1-SES-9), middle to lower bathyal (wells 1-SES-3, 1-SES-24).

TABLES 4.1 TO 4.7

RANGE CHARTS

KEY

1-5% (rare)
6-10% (common)
11-20% (frequent)
21-30% (abundant)
>30% (very abundant)

(Based on 300-specimen counts of the fraction > 63µm)

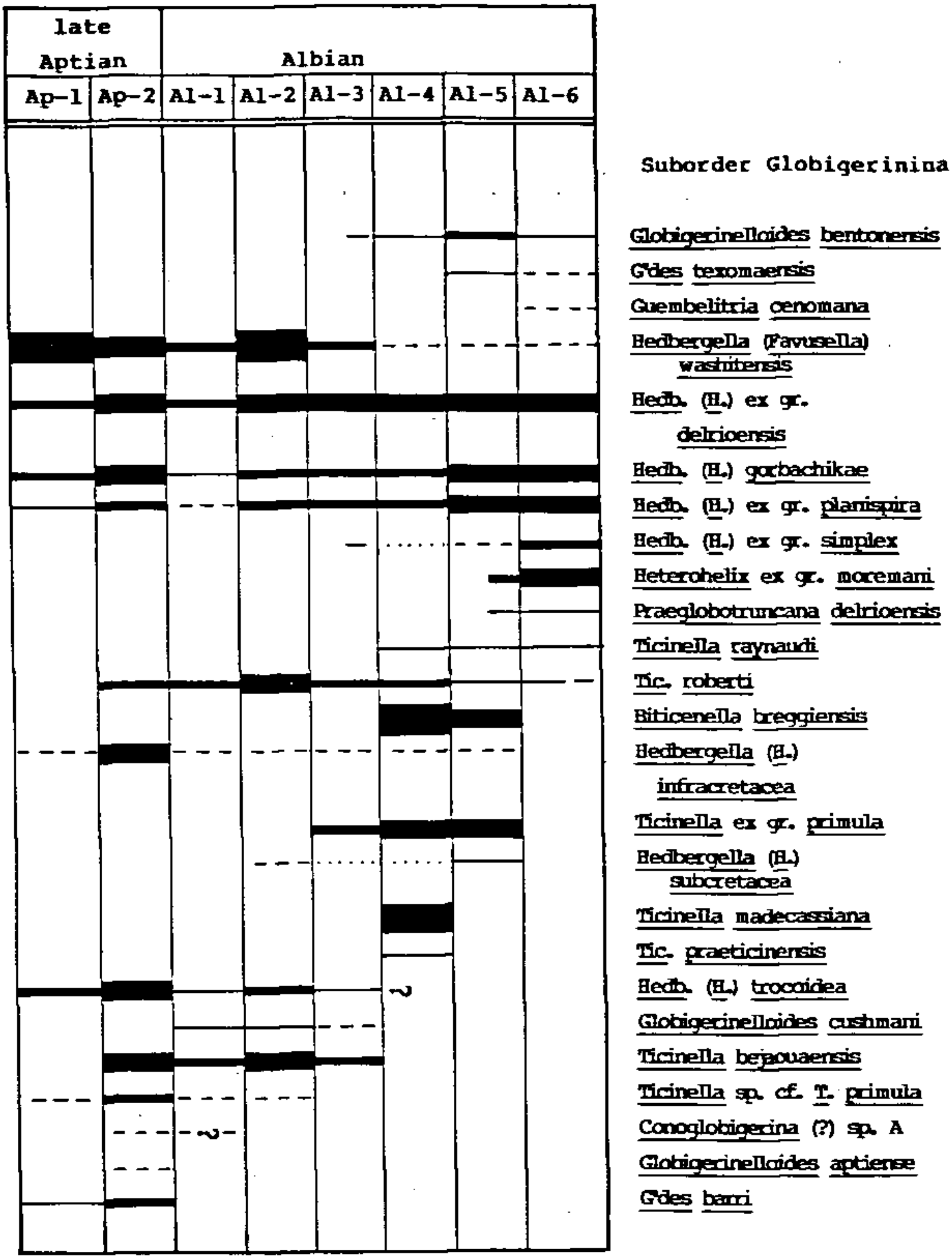


TABLE 4.1(A): Biostratigraphic distribution and relative abundances of planktonic foraminiferal assemblages (Suborder Globigerinina) from the late Aptian to Albian.

late Aptian		Albian						
Ap-1	Ap-2	Al-1	Al-2	Al-3	Al-4	Al-5	Al-6	
	—							Globigerinelloides ferreolensis
	---							G'des macrocameratus
	—							G'des ex gr. maridalensis
	---							Hedb. (H.) labocaensis
	---							Hedb. (H.) maslakovae
	---							Hedb. (H.) semielongata
	---							Hedb. (H.) sigali
	—							Hedb. (H.) similis
—								Globuligerina sp. cf. G. hoterivica

TABLE 4.1(B): Biostratigraphic distribution and relative abundances of planktonic foraminiferal assemblages (Suborder Globigerinina) from the late Aptian to Albian.

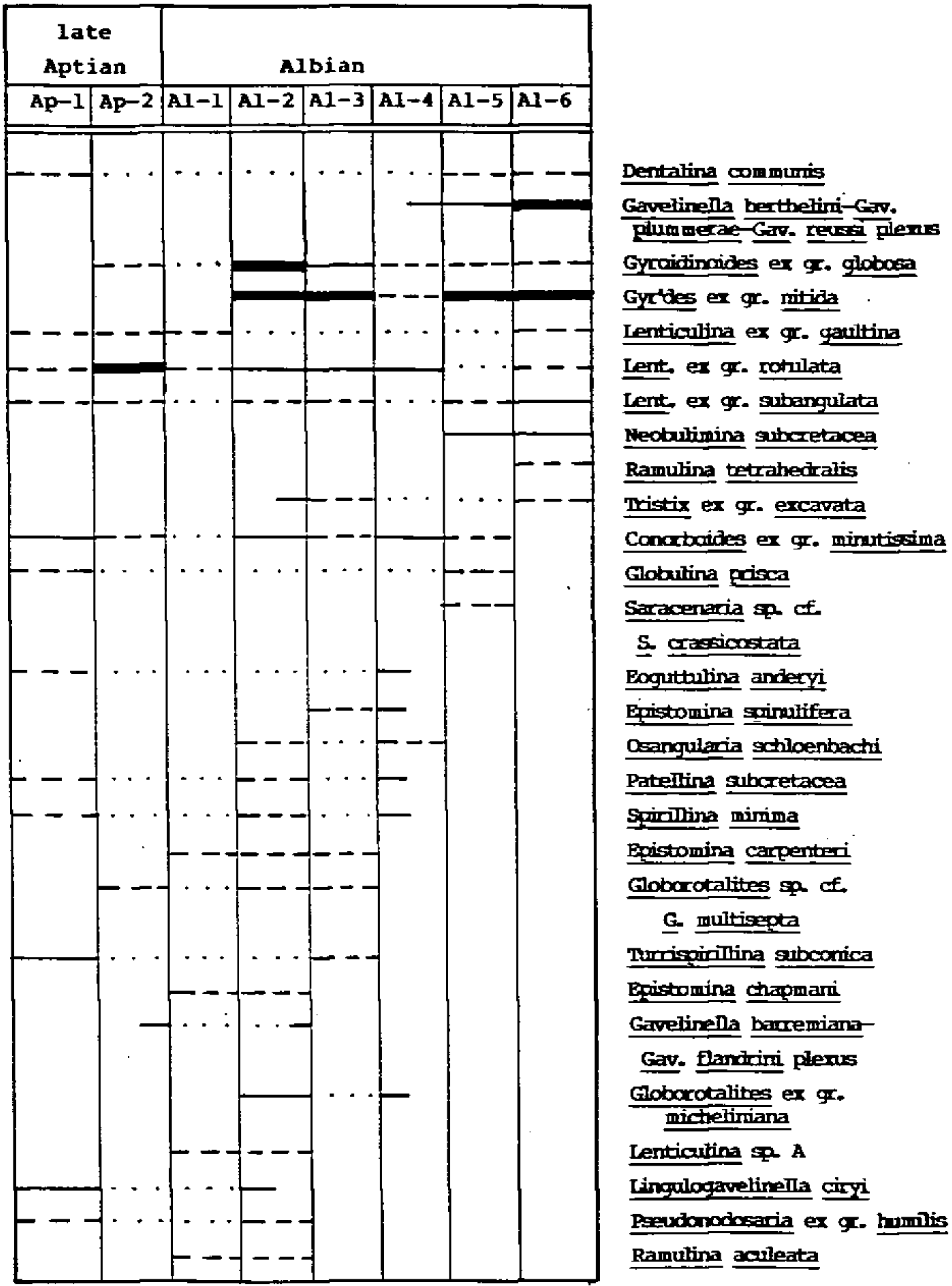


TABLE 4.2 (A): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina and Rotaliina) from the late Aptian to Albian

late Aptian		Albian						
Ap-1	Ap-2	Al-1	Al-2	Al-3	Al-4	Al-5	Al-6	
– – –	· · ·	· · ·	– – –					*Ramulina fusiformis*
		– – –						*Citharina* sp. A
		– – –						*Dentalina* ex gr. *legumen*
		– – –						*Trocholina* sp. A
	– – –							*Lenticulina* ex gr. *nodosa*
– – –								*Astacolus* sp. cf. *A. scitula*
———								*Astacolus* sp. A
– – –								*Dentalina raristriata*
– – –								*Globulina lacrima*
– – –								*Guttulina* sp. A
– – –								*Pyrulina cylindroides*
———								*Lingulonodosaria nodosaria*
– – –								*Marginulina* ex gr. *aequivoca*
– – –								*Vaginulina* ex gr. *debilis*
– – –								*Vaginulina* ex gr. *kochii*
								Suborder Miliolina
			– – –	———	· · ·	· · ·	———	*Pseudosigmoilina* (?) sp. A
– – –	· · ·	· · ·	· · ·	———	· · ·	· · ·	– – –	*Quinqueloculina* (?) sp. A
								Suborder Textulariina
———	▬▬▬	· · ·	▬▬▬	– – –	· · ·	– – –	– – –	*Marssonella trochus oxycona*
———	———	· · ·	▬▬▬	– – –	▬▬▬	· · ·	– – –	*Marss. trochus turris*
			– – –	· · ·	· · ·	· · ·	– – –	*Trochamminoides* sp. cf. *T. subcoronata*
	– – –	– – –	———	– – –	———	– – –		*Bathysiphon* ex gr. *vitta*
	– – –	· · ·	– – –	· · ·	– – –			*Ammodiscus incertus*
		———	– – –	· · ·	—			*Gaudryinopsis* sp. cf. *G. gradata*
			– – –	· · ·	– – –			*Glomospirella gaultina*
	– – –	· · ·	– – –	– – –	– – –			*Hyperammina* ex gr. *gaultina*
	– – –	· · ·	– – –	· · ·	—			*Marssonella trochus trochus*

TABLE 4.2 (B): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina, Rotaliina, Miliolina and Textulariina) from the late Aptian to Albian.

late Aptian		Albian						
Ap-1	Ap-2	Al-1	Al-2	Al-3	Al-4	Al-5	Al-6	
– – –	– – –	· · ·	– – –	· · ·	—			*Quasispiroplectammina* ex gr. *alexanderi*
	– – –	– – –	– – –	– – –	—			*Quas.* sp. cf. *Q. anceps*
– – –	· · ·	– – –	· · ·	– – –	—			*Quas.* ex gr. *goodlandana*
– – –	– – –	· · ·	· · ·	– – –	—			*Quas. linki*
					—			*Textularia* ex gr. *subconica*
	– – –	· · ·	· · ·	– – –	—			*Text. minuta*
	– – –	· · ·						*Budashevaella nonioninoides*
	– – –	· · ·	– – –					*Eggerellina mariae*
		– – –	– – –					*Marssonella kummi*
– – –	– – –	· · ·						*Marss. ozawai*
			– – –					*Paracoskinolina* (?) sp. A
			– – –					*Pseudogaudryinella* / *Spiroplectinata* ex gr. *dividens*
		– – –						*Ammobaculites* sp. A.
– – –	· · ·	– – –						*Buccicrenata* sp. cf. *B. libyca*
– – –	· · ·	– – –						*Gaudryinopsis filiformis*
								Haplophragmium ex gr. *foedissimum*
		– – –						*Trochamminoides* ex gr. *dubia*
		– – –						*Valvulammina* (?) sp. A
	– – –							*Ammodiscus tenuissimus*
	– – –							*Trochammina* ex gr. *minuta*
– – –								*Ammobaculites* sp. cf. *A. coprolithiformis*
– – –								*Ammob. reophacoides*
– – –								*Haplophragmium lueckei*

TABLE 4.2 (C): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborder Textulariina) from the late Aptian to Albian.

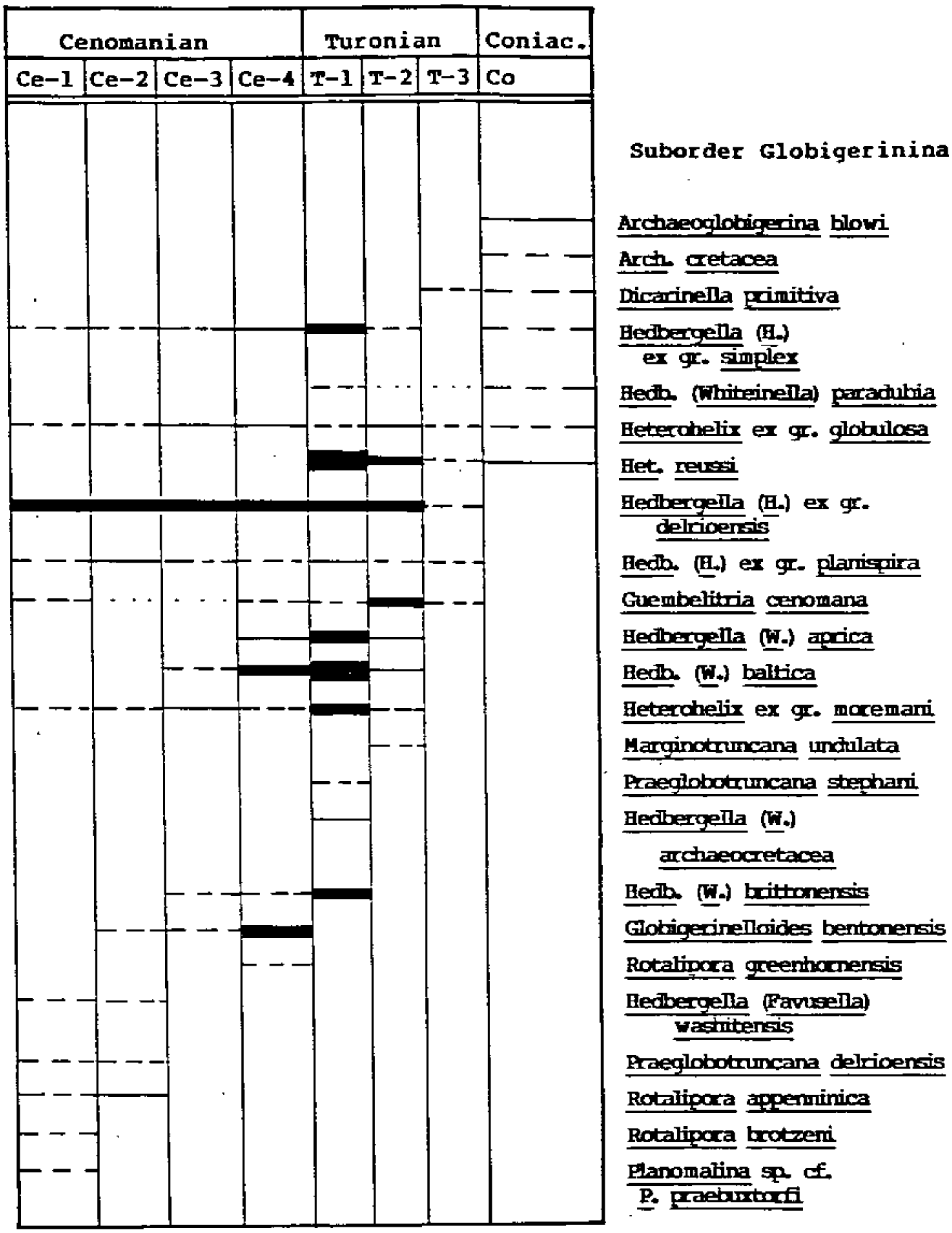


TABLE 4.3 : Biostratigraphic distribution and relative abundances of planktonic foraminiferal assemblages (Suborder Globigerinina) from the Cenomanian to late Coniacian.

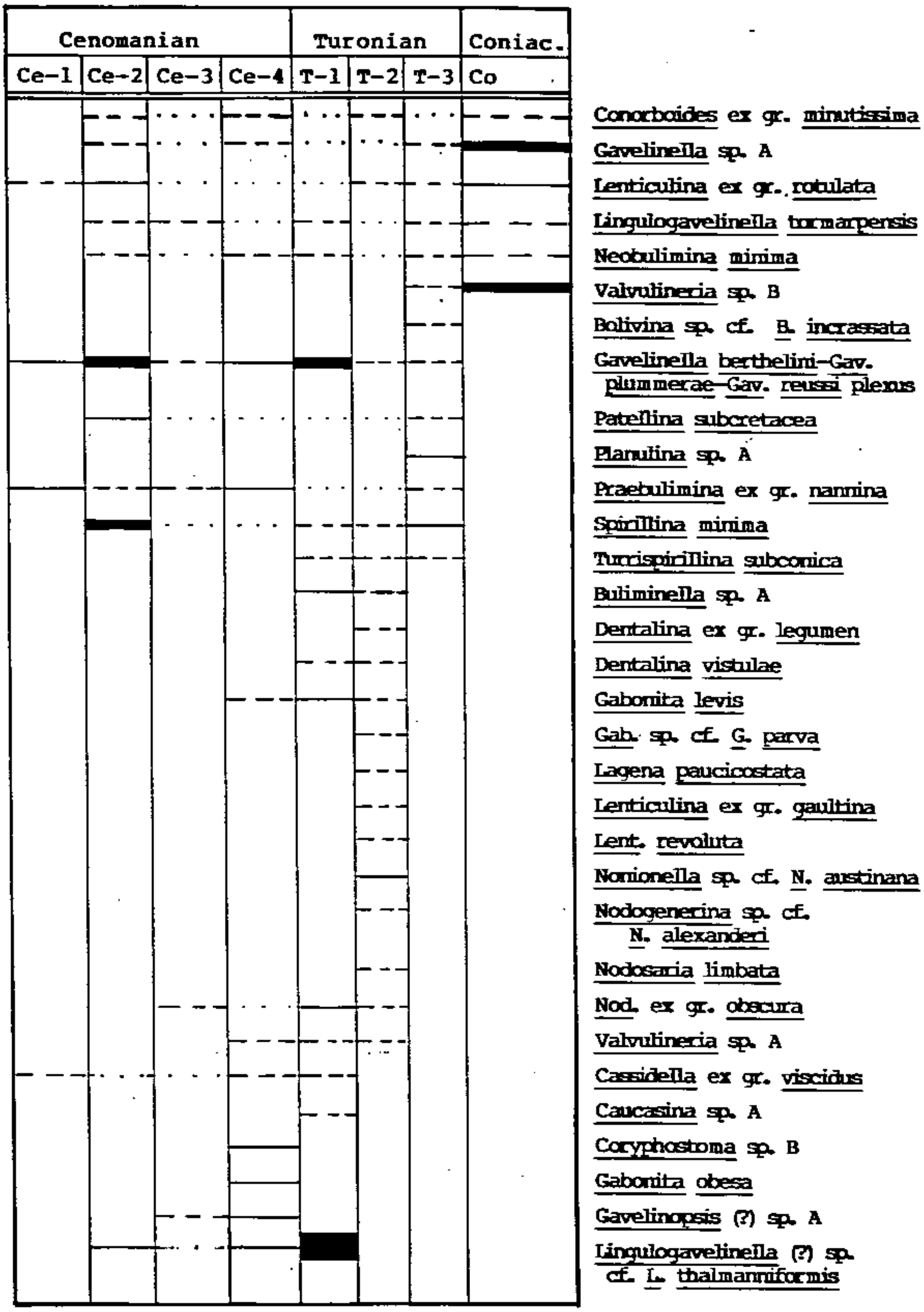


TABLE 4.4 (A): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina and Rotaliina) from the Cenomanian to late Coniacian.

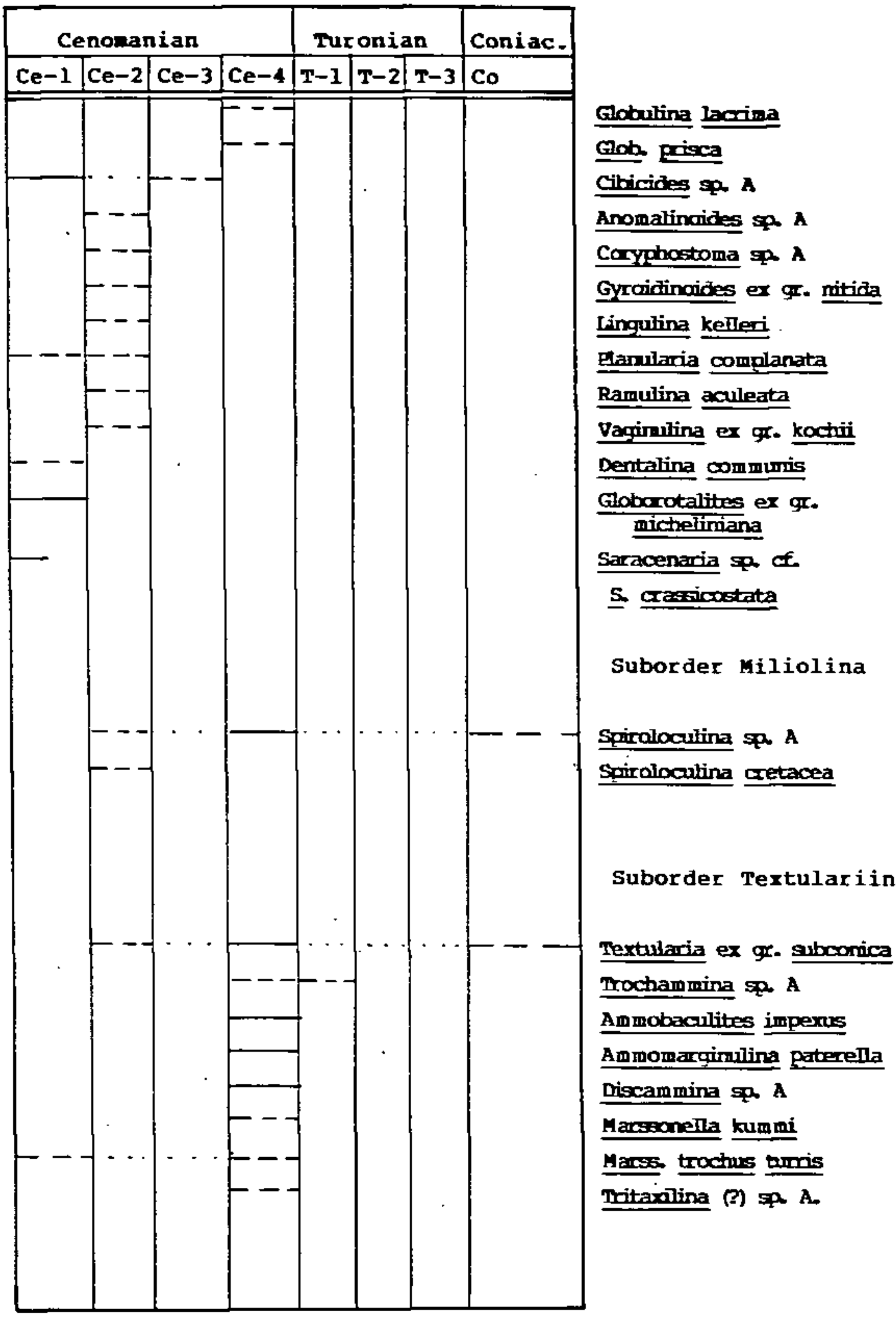


TABLE 4.4 (B): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina, Rotaliina, Miliolina and Textulariina) from the Cenomanian to late Coniacian.

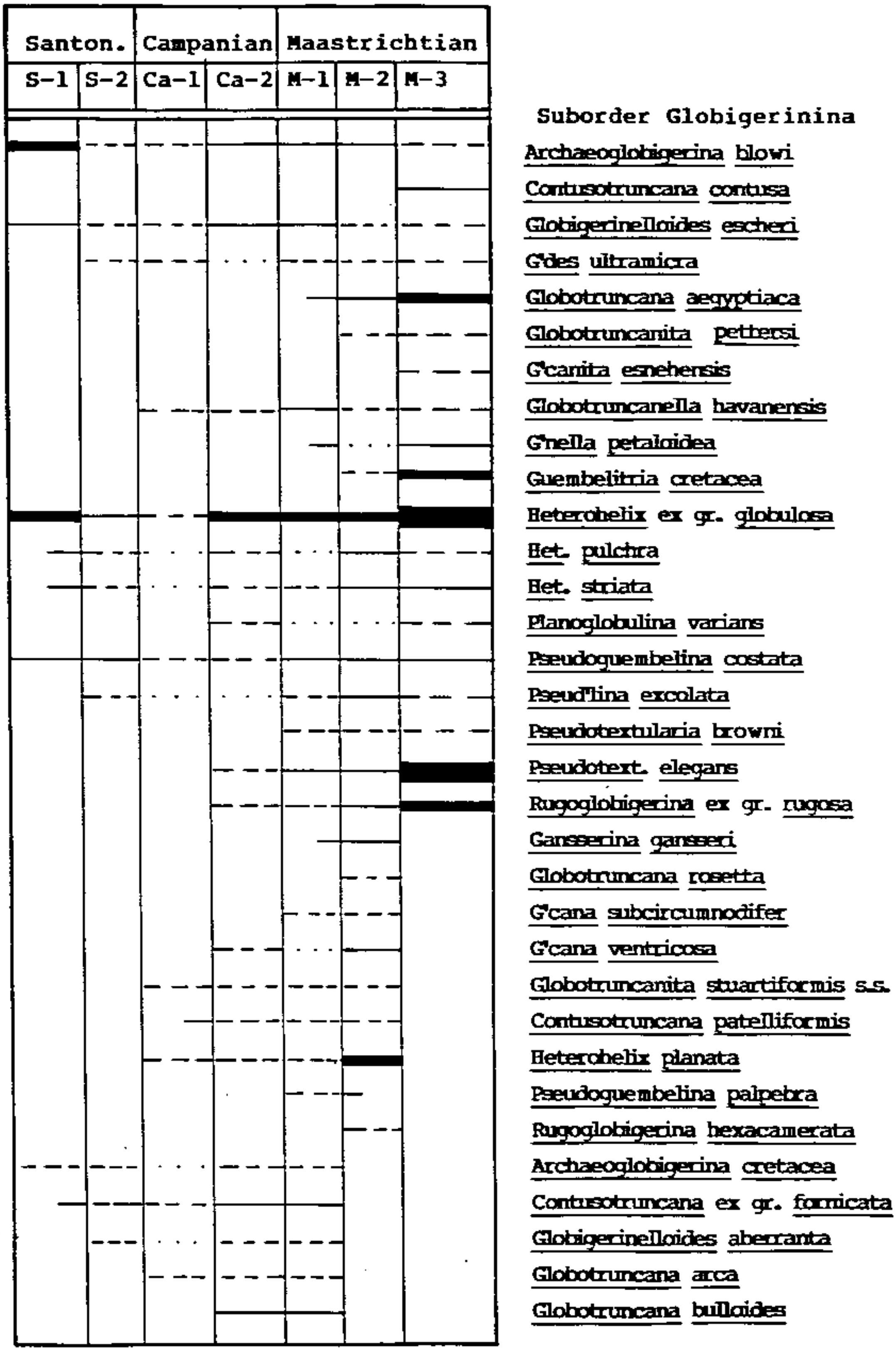


TABLE 4.5 (A): Biostratigraphic distribution and relative abundances of planktonic foraminiferal assemblages (Suborder Globigerinina) from the late Coniacian-Santonian to Maastrichtian.

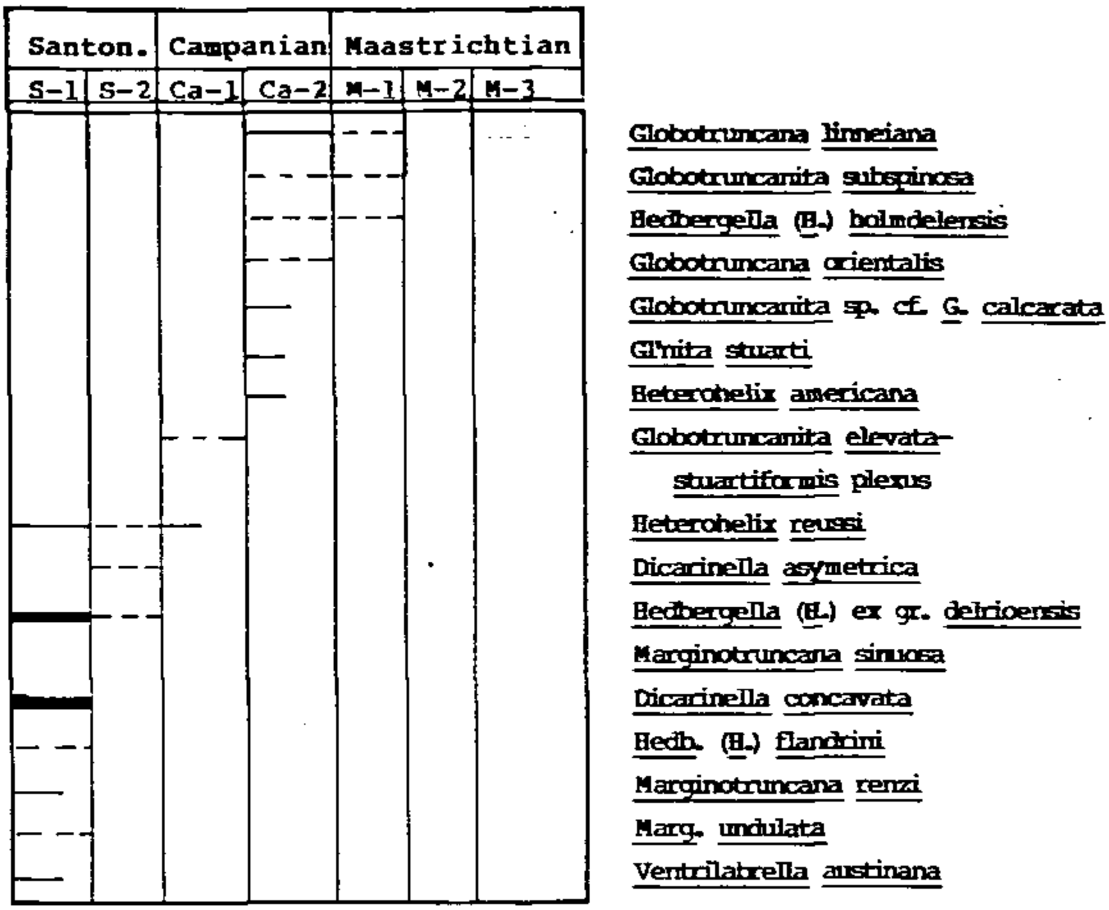


TABLE 4.5(B): Biostratigraphic distribution and relative abundances of planktonic foraminiferal assemblages (Suborder Globigerinina) from the late Coniacian-Santonian to Maastrichtian.

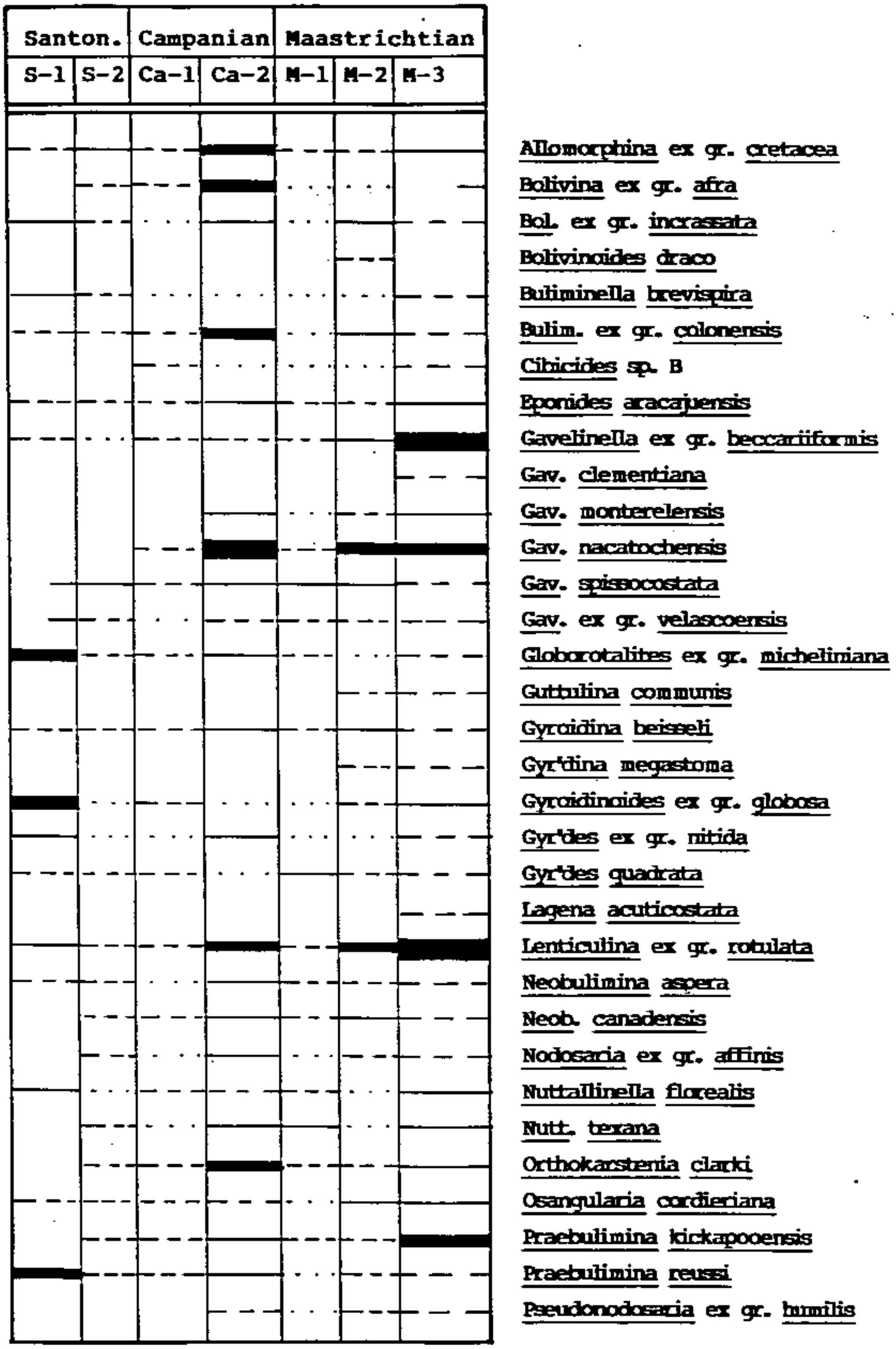


TABLE 4.6 (A): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina and Rotaliina) from the late Coniacian-Santonian to Maastrichtian.

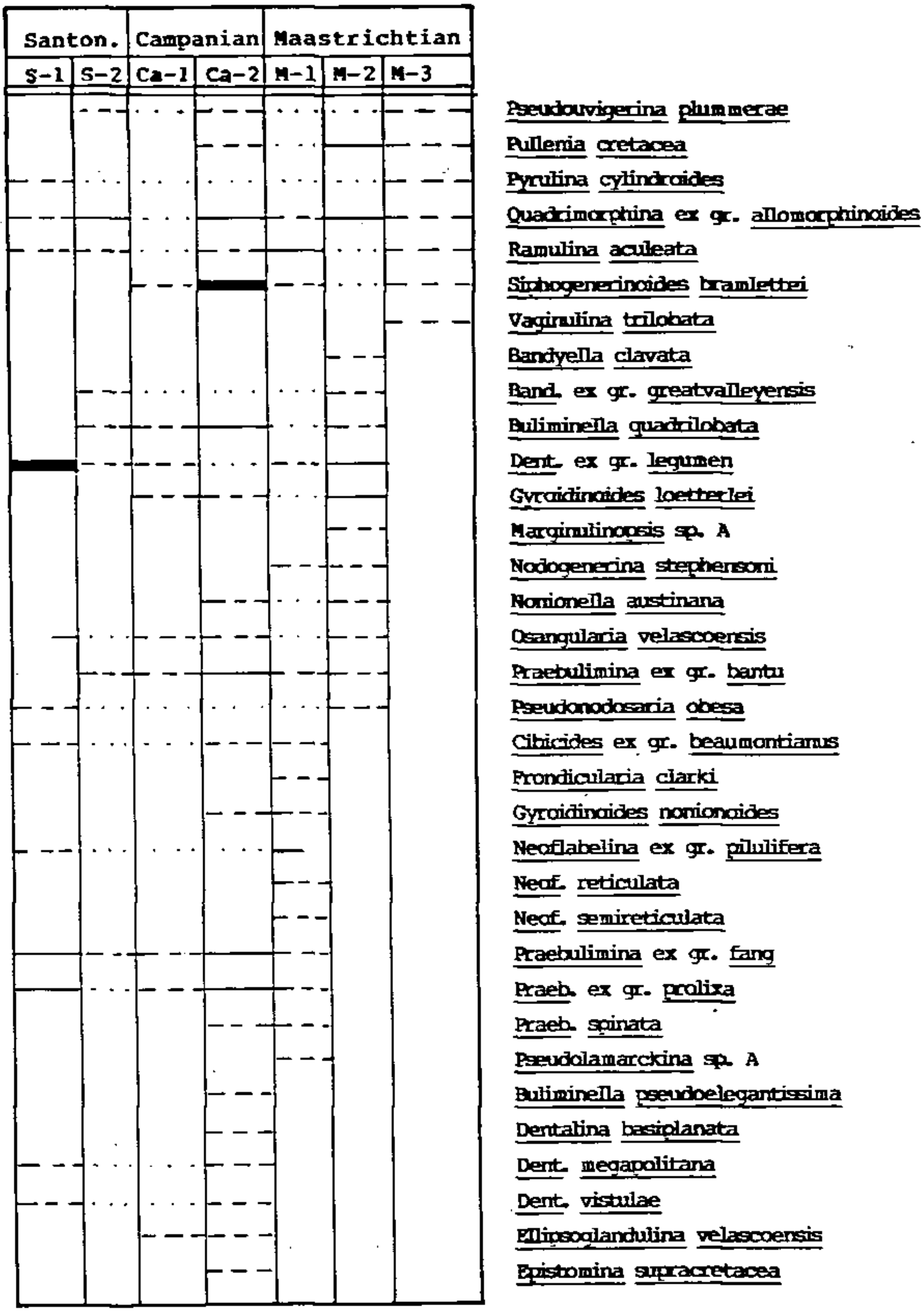


TABLE 4.6 (B): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina and Rotaliina) from the late Coniacian-Santonian to Maastrichtian.

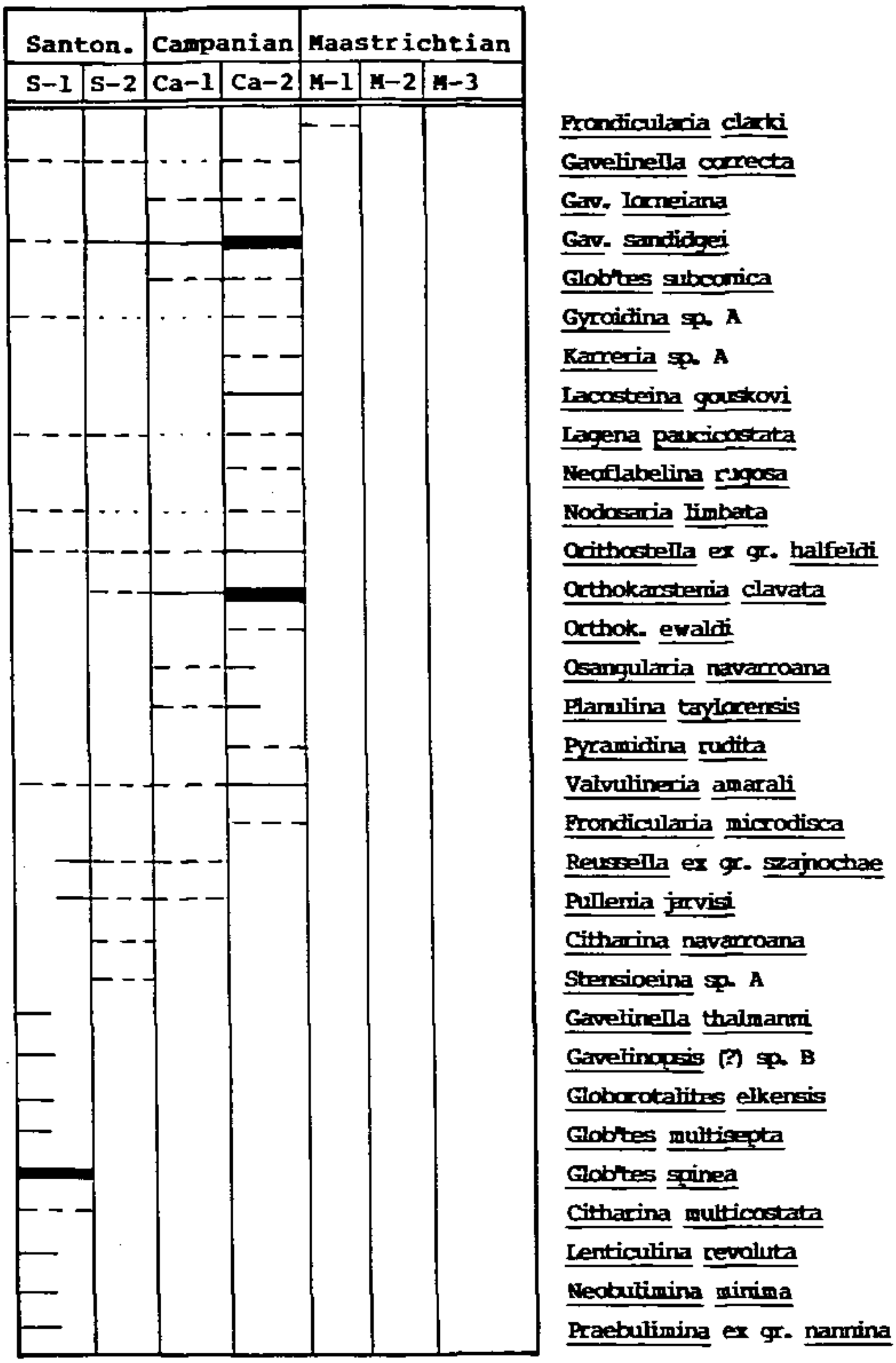


TABLE 4.6 (C): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborders Spirillina, Involutinina, Lagenina, Robertinina and Rotaliina) from the late Coniacian-Santonian to Maastrichtian.

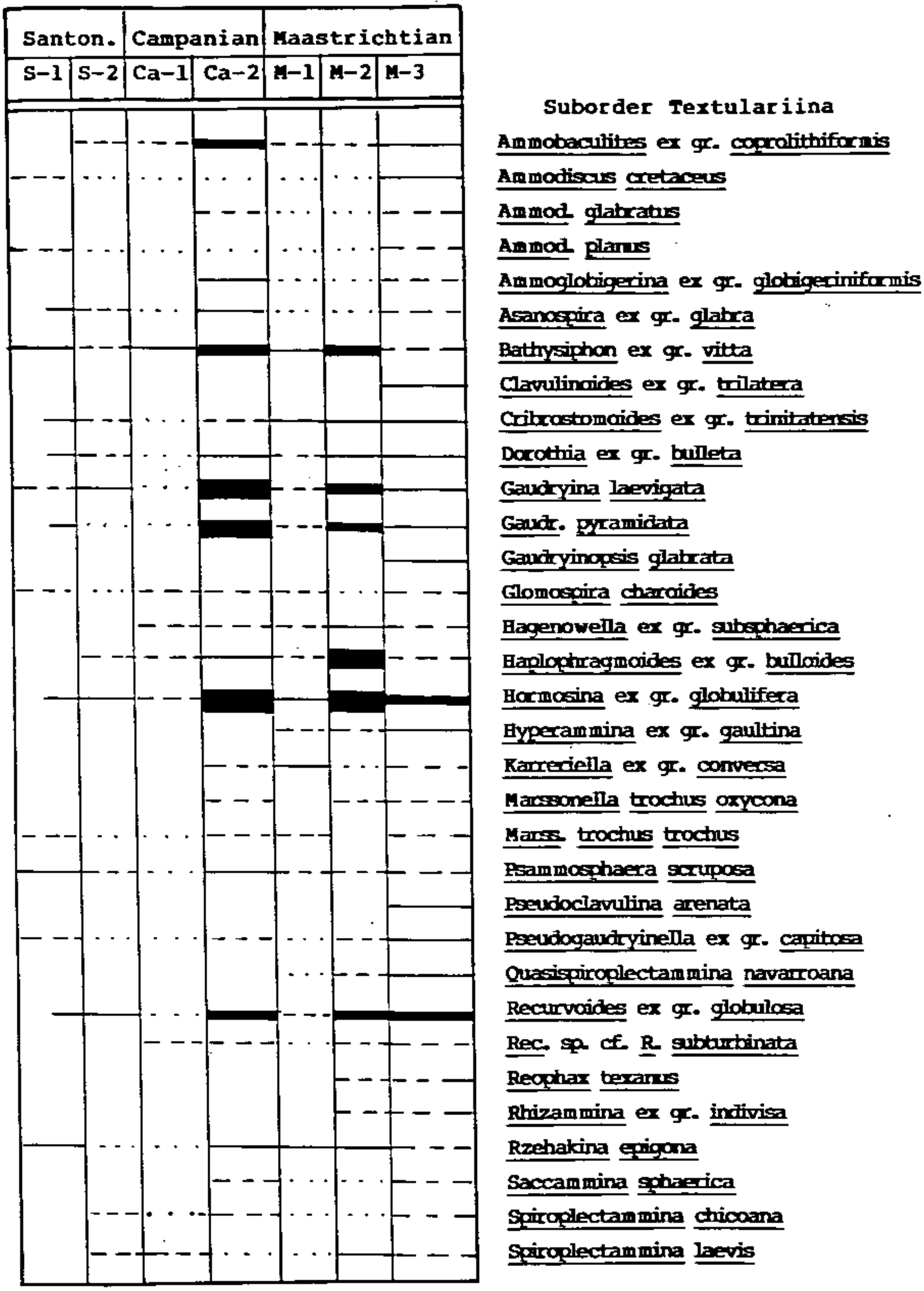


TABLE 4.7 (A): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborder Textulariina) from the late Coniacian-Santonian to Maastrichtian.

Santon.		Campanian		Maastrichtian			
S-1	S-2	Ca-1	Ca-2	M-1	M-2	M-3	
					- - -	———	*Tritaxia ellisorae*
		- - -	- - -	- - -	· · ·	- - -	*Trochamminoides flageri*
- - -	- - -	· · ·	· · ·	· · ·	· · ·	———	*Verneuilina cretacea*
				- - -	- - -		*Alveolophragmium* sp. A
				- - -	- - -		*Ammobaculites* sp. cf. *A. fragmentaria*
					- - -		*Dendrophyra* ex gr. *excelsa*
			- - -	· · ·	- - -		*Glomospira gordialis*
	- - -	· · ·	· · ·	· · ·	- - -		*Hormosina ovulum*
- - -	· · ·	· · ·	- - -	- - -	- - -		*Marssonella trochus turris*
				- - -	- - -		*Rzehakina fissistomata*
					- - -		*Spiroplectammina* ex gr. *spectabilis*
				- - -	- - -		*Verneuilina cretosa*
			- - -	- - -			*Glomospirella gaultina*
				- - -			*Silicosigmoilina californica*
				- - -			*Spiroplectammina sigmoidina*
	- - -						*Ammovertellina* sp. A
	- - -						*Budashevaella trinitatensis*
	- - -						*Glaphyrammina* sp. A
	- - -						*Haplophragmoides rugosa*
	- - -						*Pilulina* sp. A
	- - -						*Rhabdammina* ex gr. *discreta*
	- - -						*Spirolocammina* sp. A
		- - -	- - -				*Trochospira* (?) sp. A
	- - -						*Asanospira walteri*
	- - -						*Trochammina gatesensis*
	- - -						*Trochamminoides* ex gr. *dubius*
- - -							*Kalamopsis grzybowskii*

TABLE 4.7 (B): Biostratigraphic distribution and relative abundances of benthonic foraminiferal assemblages (Suborder Textulariina) from the late Coniacian-Santonian to Maastrichtian.

TABLES 4.8 TO 4.12

Correlation of various zonal schemes. No attempt has been made to modify the original zone names, which are presented as proposed by the several authors.

Stages	Ammonite Zones (after Beurlen, 1967a-b, 1970)	Koutsoukos, this study		
			Planktonic Foraminifera	Benthonic Foraminifera
Albian	*Mortoniceras sergipensis*	(Al-6)	*Hedbergella (H.) gorbachikae-* *Heterohelix* ex gr. *moremani* Zone	*Neobulimina subcretacea-* *Tristix* ex gr. *excavata* Zone
	Elobiceras maruimensis	(Al-5)	*Biticinella breggiensis-* *Globigerinelloides texomaensis* Zone	*Neobulimina subcretacea-* *Saracenaria* sp. cf. *S. crassicostata* Zone
	Oxytropidoceras buarquianum	(Al-4)	*Biticinella breggiensis-* *Ticinella* ex gr. *primula* Zone	*Osangularia schoenbachi-* *Gavelinella berthelini-* *Gav. plummerae-Gav. reussi* plexus Zone
		(Al-3)	*Ticinella bejaouaensis-* *Tic.* ex gr. *primula* Zone	*Epistomina carpenteri-* *Ep. spinulifera* Zone
	Douvilleiceras eurebioi	(Al-2)	*Ticinella bejaouaensis* Zone	*Osangularia schoenbachi-* *Pseudogaudryinella/Spiroplectinata* ex gr. *dividens* Zone
		(Al-1)	*Globigerinelloides cushmani-* *Ticinella bejaouaensis* Zone	*Epistomina carpenteri-* *Gaudryinopsis filiformis* Zone
upper Aptian	*Cheloniceras* spp.	(Ap-2)	*Globigerinelloides* ex gr. *maridalensis-* *Hedbergella (H.) similis-* Zone	*Lenticulina* ex gr. *nodosa-* *Lent.* ex gr. *subangulata* Zone
		(Ap-1)	*Globigerinelloides barri-* *Hedbergella (H.) gorbachikae* Zone	*Ammobaculites* sp cf. *A. coprolithiformis-* *Buccicrenata* sp. cf. *B. libyca-* *Haplophragmium lueckei* Zone (Assemblage-zone)
				Lingulogavelinella ciryi- *Lingulonodosaria nodosaria-* *Marginulina* ex gr. *aequivoca* Zone (Assemblage-zone)

TABLE 4.8: Correlation between the ammonite zonation (after Beurlen, 1967 a, b, 1970) and the foraminiferal zonal schemes proposed in this study for the upper Aptian to Albian succession.

<table>
<tr><th>Stages</th><th colspan="2">Koutsoukos, this study</th><th colspan="2">Sliter, 1989</th><th>Caron, 1985</th><th colspan="2">Leckie, 1984</th><th>Wonders, 1980</th><th>Robaszynski & Caron, 1979</th><th>Sigal, 1977</th><th colspan="2">Premoli-Silva & Boersma, 1977</th></tr>
<tr><td rowspan="11">Albian</td><td rowspan="2">(Al-6)</td><td rowspan="2">Hedbergella (H.) gorbachikae-Heterohelix ex gr. moremani Zone</td><td colspan="2" rowspan="4">R. appenninica</td><td rowspan="4">R. appenninica</td><td rowspan="4">Planomalina praebuxtorfi- buxtorfi</td><td rowspan="3">R. appenninica</td><td>T. appenninica s.l.</td><td>R. brotzeni</td><td rowspan="4">R. appenninica/ P. buxtorfi</td><td colspan="2" rowspan="2">S. moliniensis</td></tr>
<tr><td>T. appeninica - P. buxtorfi</td><td rowspan="4">R. appenninica</td></tr>
<tr><td rowspan="4">(Al-5)</td><td rowspan="4">Biticinella breggiensis-Globigerinelloides texomaensis Zone</td><td>P. ticinensis - P. buxtorfi</td><td colspan="2" rowspan="2">P. buxtorfi</td></tr>
<tr><td>P. praebuxtorfi</td><td>P. praebuxtorfi</td></tr>
<tr><td colspan="2">R. ticinensis</td><td>R. ticinensis</td><td rowspan="2">Biticinella breggiensis</td><td>R. ticinensis</td><td>P. ticinensis</td><td rowspan="3">T. breggiensis</td><td rowspan="3">T. breggiensis</td><td>R. ticinensis</td></tr>
<tr><td rowspan="2">R. breggiensis</td><td>R. subticinensis</td><td>R. subticinensis</td><td>R. subticinensis</td><td>P. subticinensis</td><td>R. subticinensis- R. ticinensis</td><td rowspan="2">T. praeticinensis</td></tr>
<tr><td>(Al-4)</td><td>Biticinella breggiensis-Ticinella ex gr. primula Zone</td><td>T. praeticinensis</td><td>R. breggiensis</td><td colspan="2">T. praeticinensis</td><td rowspan="8"></td><td rowspan="8"></td></tr>
<tr><td>(Al-3)</td><td>Ticinella bejaouaensis-Tic. ex gr. primula Zone</td><td colspan="2">T. primula</td><td>T. primula</td><td rowspan="5">T. roberti s.l.</td><td>T. primula</td><td>H. rischi/ T. primula</td><td colspan="2" rowspan="7"></td></tr>
<tr><td rowspan="2">(Al-2)</td><td rowspan="2">Ticinella bejaouaensis Zone</td><td colspan="2">H. planispira</td><td rowspan="4">T. bejaouaensis</td><td rowspan="3">G. gyroidinaeformis</td><td>H. planispira</td></tr>
<tr><td colspan="2" rowspan="3">T. bejaouaensis</td><td rowspan="3">T. bejaouaensis</td></tr>
<tr><td>(Al-1)</td><td>Globigerinelloides cushmani-Ticinella bejaouaensis Zone</td></tr>
<tr><td rowspan="3">upper Aptian</td><td>(Ap-2)</td><td>Globigerinelloides ex gr. maridalensis-Hedbergella (H.) similis-Zone</td><td>P. cheniourensis</td></tr>
<tr><td rowspan="2">(Ap-1)</td><td rowspan="2">Globigerinelloides barri-Hedbergella (H.) gorbachikae Zone</td><td colspan="2">H. gorbachikae</td><td>H. gorbachikae</td><td colspan="2">H. trocoidea</td><td>H. trocoidea</td></tr>
<tr><td colspan="2">G. algerianus</td><td>G. algeriana</td><td colspan="2">G. algerianus</td><td>G. algerianus</td></tr>
</table>

TABLE 4.9(A): Correlation of various planktonic foraminiferal zonal schemes proposed for the upper Aptian to Albian.

Stages	Koutsoukos, this study	Longoria & Gamper, 1977 and Longoria, 1974	van Hinte, 1976	Bolli, 1966	Azevedo et al., 1987 (Campos Basin)	Beurlen & Regali 1987 (Para-Maranhao Basin)	Viviers, 1986, 1987 (Santos Basin)	Beurlen & Koutsoukos (in Beurlen et al., 1986)	Viviers, 1982 (Ceara Basin)	Noguti & Santos, 1972
Albian	Hedbergella (H.) gorbachikae-Heterohelix ex gr. moremani Zone	T. ticinensis	P. buxtorfi - R. appenninica	R. appenninica appenninica	T. raynaudi	?	?	H. minima	T. primula	F. washitensis
	Biticinella breggiensis-Globigerinelloides tormaeensis Zone		R. ticinensis - P. buxtorfi					H. gorbachikae		
			T. (R.) breggiensis	R. ticinensis ticinensis			R. ticinensis			
		T. breggiensis		H. roberti		H. aff. gorbachikae	P. washitensis		P. washitensis	
	Biticinella breggiensis-Ticinella ex gr. primula Zone		T. praeticinensis							
	Ticinella bejaouaensis-Tic. ex gr. primula Zone	T. primula	T. bejaouaensis - T. primula		F. washitensis					
	Ticinella bejaouaensis Zone	T. bejaouaensis	T. bejaouaensis					F. washitensis		
	Globigerinelloides cushmani-Ticinella bejaouaensis Zone		G. ferreolensis - T. bejaouaensis		Trocolina sp.					
upper Aptian	Globigerinelloides ex gr. maridalensis-Hedbergella (H.) similis Zone			P. rohri	?	?	?			
	Globigerinelloides barri-Hedbergella (H.) gorbachikae Zone	H. trocoidea	H. trocoidea - G. ferreolensis							
		H. gorbachikae								
		G. algerianus	G. algerianus							
				S. barri						

TABLE 4.9(B): Correlation of various planktonic foraminiferal zonal schemes proposed for the upper Aptian to Albian.

TABLE 4.10: Correlation between the ammonite zonation (after Bengtson, 1983) and the foraminiferal zonal schemes proposed in this study for the Cenomanian to lower Coniacian succession.

Stages	Ammonite Zones (after Bengtson, 1983, and Reyment & Bengtson, 1986)	Koutsoukos, this study		
		Planktonic Foraminifera		Benthonic Foraminifera
Coniacian	*Solgerites*	(Co)	*Archaeoglobigerina cretacea-Dicarinella primitiva* Zone	*Gavelinella* sp. A-*Valvulineria* sp. A Zone
Turonian	*Subprionocyclus*	(T-3)	*Dicarinella primitiva* Zone	*Gavelinella berthelini-Gav. plummerae-Gav. reussi* plexus - *Valvulineria* sp. A Zone
	Hoplitoides	(T-2)	*Hedbergella (Whiteinella) aprica-Hedb. (W.) baltica* Zone	*Gabonita levis-Nodosaria* ex gr. *obscura* Zone
	Pseudotissotia	(T-1)	*Hedbergella (W.) archaeocretacea-Heterohelix reussi* Zone	*Gabonita levis-Gab. obesa* Zone
Cenomanian	*E. (Kanabiceras)*	(Ce-4)	*Globigerinelloides bentonensis-Hedbergella (W.) aprica* Zone	*Gabonita levis-Discammina* sp. A Zone
	Acathoceras *Dunveganoceras*	(Ce-3)	*Hedbergella (W.) baltica-Hedb. (W.) brittonensis* Zone	*Cibicides* sp. A-*Nodosaria* ex gr. *obscura* Zone
	Graysonites	(Ce-2)	*Praeglobotruncana delrioensis-Rotalipora appenninica* Zone	*Lingulogavelinella* (?) sp. cf. *L. thalmanniformis-Spiroloculina cretacea* Zone
	?	(Ce-1)	*Rotalipora brotzeni* Zone	*Cibicides* sp. A-*Planularia complanata* Zone

Stages	Koutsoukos, this study		Sliter, 1989	Caron, 1985	Leckie, 1984	Wonders, 1980	Robaszynski & Caron, 1979	Sigal, 1977	Premoli-Silva & Boersma, 1977
Coniacian	(Co)	*Archaeoglobigerina cretacea-Dicarinella primitiva* Zone	*M. sigali*	*D. primitiva*	▨	*M. primitiva*	*M. schneegansi*	*G. sigali/* *G. schneegansi*	*"G." schneegansi*
Turonian	(T-3)	*Dicarinella primitiva* Zone							
	(T-2)	*Hedbergella (Whiteinella) aprica-Hedb. (W.) baltica* Zone	*H. helvetica*	*M. sigali* *H. helvetica*		*M. sigali* *H. helvetica*	*P. helvetica*	*G. helvetica*	*P. helvetica*
	(T-1)	*Hedbergella (W.) archaeocretacea-Heterohelix reussi* Zone	*W. archaeocretacea*	*W. archaeocretacea*		*W. archaeocretacea*	*W. archaeocretacea*	▨	*P. lehmani*
Cenomanian	(Ce-4)	*Globigerinelloides bentonensis-Hedbergella (W.) aprica* Zone	*D. algeriana*		*W. archaeocretacea*				*W. alpina*
	(Ce-3)	*Hedbergella (W.) baltica-Hedb. (W.) brittonensis* Zone	*R. greenhornensis*	*R. cushmani*	*R. cushmani*	*R. cushmani*	*R. cushmani*	*R. cushmani*	*R. greenhornensis* *R. cushmani*
	(Ce-2)	*Praeglobotruncana delrioensis-Rotalipora appenninica* Zone	*R. reicheli*	*R. reicheli*	*R. reicheli*	*R. globotruncanoides*	*R. reicheli*	*R. globotruncanoides* *R. brotzeni*	*R. montsalvensis*
	(Ce-1)	*Rotalipora brotzeni* Zone	*R. brotzeni*	*R. brotzeni*	*R. gandolfii*	*T. appenninica s.l.*	*R. brotzeni*		*R. brotzeni*

TABLE 4.11(A): Correlation of various planktonic foraminiferal zonal schemes proposed for the Cenomanian to lower Coniacian.

Stages	this study	Longoria & Gamper, 1977	van Hinte, 1976	Bolli, 1966	Azevedo et al., 1987 (Campos Basin)	Beurlen & Regali 1987 (Para-Maranhao Basin)	Viviers & Regali, 1987 (Potiguar Basin)	Viviers, 1986, 1987 (Santos Basin)	Beurlen & Koutsoukos (in Beurlen et al., 1986) (Sergipe/Alagoas Basin)	Viviers, 1982 (Ceara Basin)	Noguti & Santos, 1972
Coniacian	(Co)	*M. renzi*	*G. renzi - G. sigali*	*G. schneegansi*	*D. imbricata*	?	without diagnostic microfossils	*M. undulata*	without diagnostic microfossils	*M. undulata*	*R. delrioensis*
Turonian	(T-3)	*M. helvetica*				*G. inornata*		*D. hagai*		?	
	(T-2)		*"G." helvetica*	*G. helvetica*	*Whiteinella* spp.			*P. helvetica*		*P. helvetica*	
	(T-1)		*H. lehmani*	*P. gigantea*		*W. brittonensis*	*W. brittonensis*	*Whiteinella* spp.		?	
Cenomanian	(Ce-4)	*R. cushmani-* *R. greenhornensis*	*R. cushmani*	*R. cushmani*			*G. bentonensis*				
	(Ce-3)					?					
	(Ce-2)	*R. evoluta*	*R. gandolfii - R. reicheli*	*R. reicheli*	?		*Trocholina* spp.	?		*P. delrioensis*	
	(Ce-1)		*R. gandolfii* *R. greenhornensis*	*R. brotzeni*							

TABLE 4.11(B): Correlation of various planktonic foraminiferal zonal schemes proposed for the Cenomanian to lower Coniacian.

Stages	Koutsoukos, this study		Sliter, 1989	Caron, 1985	Wonders, 1980	Robaszyuski et al., 1984	Sigal, 1977	Premoli-Silva & Boersma, 1977	van Hinte, 1976	Bolli, 1966
Maastrichtian	(M-3)	*Contusotruncana contusa-Globotruncana aegyptiaca* Zone	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*	*A. mayaroensis*
	(M-2)	*Gansserina gansseri-Globotruncanita stuartiformis* Zone								
			G. gansseri	*G. gansseri*	*G. contusa*	*G. gansseri*	*G. gansseri*	*G. contusa*	*G. contusa*	*G. gansseri*
					G. gansseri			*G. tricarinata*	*G. stuarti*	
	(M-1)	*Contusotruncana fornicata-G'cana linneiana* Zone							*G. gansseri*	
			G. aegyptiaca	*G. aegyptiaca*	"*G. tricarinata*"	*G. falsostuarti*	*G. stuarti/* *G. falsostuarti*		*G. scutilla*	*G. lapparenti tricarinata*
			G. havanensis	*G. havanensis*						
Campanian	(Ca-2)	*Globotruncana orientalis-G'cana ventricosa* Zone	*G. calcarata*	*G. calcarata*	*G. calcarata*	*G. calcarata*	*G. calcarata*	*G. calcarata*	*G. calcarata*	*G. calcarata*
			G. ventricosa	*G. ventricosa*	*G. ventricosa*	*G. ventricosa*	*G. elevata/* *G. stuartiformis*	*G. elevata*	*G. subspinosa*	*G. stuarti s.l.*
	(Ca-1)	*Globotruncana linneiana-Globotruncanita elevata/stuartiformis plexus* Zone	*G. elevata*	*G. elevata*	*G. elevata*	*G. elevata*			*G. stuartiformis*	
									G. elevata	*G. fornicata*
Santonian	(S-2)	*Dicarinella asymetrica* Zone	*D. asymetrica*	*D. Asymetrica*	*G. elevata - M. carinata*	*D. asymmetrica*	*G. concavata carinata*	"*G.*" *concavata carinata*	*G. concavata -* *G. elevata*	*G. concavata*
	(S-1)	*Dicarinella concavata-Marginotruncana sinuosa* Zone			*M. carinata*					
			D. concavata	*D. concavata*	*M. concavata*	*D. concavata*	*G. concavata*	"*G.*" *concavata concavata*	*G. sigali -* *G. concavata*	
Coniacian										

TABLE 4.12(A): Correlation of various planktonic foraminiferal zonal schemes proposed for the upper Coniacian-Santonian to Maastrichtian.

TABLE 4.12(B): Correlation of various planktonic foraminiferal zonal schemes proposed for the upper Coniacian-Santonian to Maastrichtian.

Stages	Koutsoukos, this study		Azevedo et al., 1987 (Campos Basin)	Beurlen & Regali 1987 (Para-Maranhao Basin)	Viviers & Regali, 1987 (Potiguar Basin)	Viviers, 1986, 1987 (Santos Basin)	Beurlen & Koutsoukos (*in* Beurlen *et al.*, 1986)	Viviers, 1982 (Ceara Basin)	Noguti & Santos, 1972
Maastrichtian	(M-3)	*Contusotruncana contusa-Globotruncana aegyptiaca* Zone	*A. mayaroensis*	*R. reicheli*	?	?	*G. contusa*	*G. aegyptiaca*	*G. contusa*
	(M-2)	*Gansserina gansseri-Globotruncanita stuartiformis* Zone	*G. gansseri*	*G. gansseri*		*G. gansseri*		*G. gansseri*	
			G. elevata						
	(M-1)	*Contusotruncana fornicata-G'cana linneiana* Zone	*G. fornicata*	*G. fornicata*		*G. plummerae-G. fornicata*	*G. bulloides*	*G. fornicata*	*G. fornicata*
Campanian	(Ca-2)	*Globotruncana orientalis-G'cana ventricosa* Zone	*G. lapparenti*	?		without diagnostic microfossils			
	(Ca-1)	*Globotruncana linneiana-Globotruncanita elevata/stuartiformis* plexus Zone			*G. fornicata*		*G. fornicata*		*G. coarctata*
Santonian	(S-2)	*Dicarinella asymetrica* Zone	*D. concavata*	*D. concavata*	without diagnostic microfossils		*G. asymetrica*	*D. cocavata*	*H. delrioensis*
	(S-1)	*Dicarinella concavata-Marginotruncana sinuosa* Zone					*G. concavata*		
Coniacian			*D. imbricata*			*N. undulata*		*N. undulata*	

Biochronostratigraphic Summary

Stages		Zonal Scheme	Well - Sections									
			1-CA-1-SE	1-CM-1-SE	CP-252-SE	CPB-1R-SE	CRL-1-SE	1-US-1-SE	1-SES-1A	1-SES-3	1-SES-9	1-SES-24
Maastrichtian	u	M-3	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	1410m	1905m	1170m	1980m
		M-2	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	1530m	1995m	1314m	2100m
	l	M-1	- - - -	- - - -	- - - -	- - - -	== ? ==	- - - -	" ? "	" ? "	1350m	2190m
Campanian	u	Ca-2	0/84m(?)	- - - -	- - - -	- - - -	== ? ==	- - - -	1920/80m	" ? "	1638m	" ? "
	l	Ca-1	" ? "	0m	- - - -	- - - -	== ? ==	- - - -	" ? "	2085m	" ? "	2220m(?)
Santonian	u	S-2	465m(?)	- - - -	- - - -	- - - -	== ? ==	- - - -	- - - -	2175m	1980m(?)	" ? "
	l	S-1	" ? "	- - - -	- - - -	- - - -	1176.40m	- - - -	- - - -	2205m	2124m(?)	2310m
Coniacian	u l	Co	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Turonian	u	T-3	- - - -	21/42m	- - - -	- - - -	- - - -	== ? ==	- - - -	- - - -	- - - -	- - - -
	m	T-2	555/585m	" ? "	- - - -	- - - -	- - - -	== ? ==	- - - -	- - - -	- - - -	- - - -
	l	T-1	604.20m	" ? "	- - - -	- - - -	- - - -	98.50m	- - - -	- - - -	- - - -	- - - -
Cenomanian	u	Ce-4	615m	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
		Ce-3	645m	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
	m	Ce-2	705m	162m	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	2370m(?)
	l	Ce-1	735m	537m	- - - -	- - - -	- - - -	366m	- - - -	- - - -	- - - -	" ? "
Albian	u	Al-6	761.80m	552/560m	- - - -	- - - -	1182.50m	381m	- - - -	- - - -	- - - -	2460m(?)
		Al-5	765m	582m	- - - -	- - - -	1200.80m	396m	- - - -	- - - -	- - - -	- - - -
		Al-4	855m	612m	- - - -	- - - -	== ? ==	426m	- - - -	2250m(?)	- - - -	2490m(?)
	m	Al-3	915m	672m	- - - -	- - - -	== ? ==	621m	- - - -	- - - -	- - - -	- - - -
	l	Al-2	945m	732m	== ? ==	== ? ==	== ? ==	711m	2070m(?)	- - - -	2160m(?)	- - - -
		Al-1	1035m	- - - -	== ? ==	198m	== ? ==	891m	" ? "	- - - -	2412m(?)	- - - -
upper Aptian		Ap-2	1095m	811m	== ? ==	" ? "	== ? ==	981m	== ? ==	2325m	2628m(?)	2670m(?)
		Ap-1	1275m	1002m	466.00m	320m(?)	== ? ==	" ? "	== ? ==	" ? "	" ? "	" ? "

Legend:

hiatus - - - - (erosional and/or non-depostional)	no-diagnostic microfossils " ? " (section of uncertain biostratigraphic position)	not-studied section == ? == (probable record of the zone)

TABLE 4.13: Biochronostratigraphic summary of the studied well-sections.

CHAPTER 5

FORAMINIFERAL MORPHOGROUP DISTRIBUTION PATTERNS, PALAEOCOMMUNITIES AND TROPHIC STRUCTURES

5.1 - INTRODUCTION

One of the main objectives of micropalaeontological studies is to record, interpret and attempt to predict changing patterns and interactions between rates of biotic diversification and evolution throughout stratigraphic sequences. Foraminiferal assemblages have been extensively used for biostratigraphic and palaeo-environmental interpretations throughout the Mesozoic and Cenozoic sedimentary successions of the world ocean. There has been a particular emphasis on the Cretaceous Period, with studies presenting global and regional schemes of bathymetric and biogeographic distributions of benthonic assemblages (e.g., Sliter, 1972; Sliter & Baker, 1972; Scheibnerová, 1971a, 1976, 1978a; Olsson, 1977; Haig, 1979; Koutsoukos, 1984; Nyong & Olsson, 1984; Olsson & Nyong, 1984; Dias-Brito & Azevedo, 1986; Koutsoukos & Merrick, 1986; Viviers, 1986; Azevedo et al., 1987; Koutsoukos & Dias-Brito, 1987; Reiss, 1988). However, the approach in palaeo-ecological studies is usually restricted to the report of occurrence patterns of individual taxa and/or major groups. Only very rarely is the biological background behind the distribution of these "empty" (protoplasma-free) tests, which are one of the main biotic constituents in marine sediments, discussed. As was clearly pointed out by Marszalek et al. (1969, p. 342) 'The major efforts of micropaleontologists have been directed toward a description of the pattern of distribution of foraminiferal tests, not toward an understanding of where and how foraminifers live.' Since that time little has changed.

The present chapter aims to delineate the general distribution patterns of Cretaceous foraminiferal morphogroups and palaeocommunities in the Sergipe basin. Although it would be very difficult, if not impossible at all, to write in detail on the behavioural physiology of fossil foraminifera, an attempt is made to discuss the probable main environmental and physiological controlling forces behind their distribution. On the principle of inferring from the better known to the lesser known, i.e., by reference to well documented studies on extant foraminiferal assemblages, a model is proposed in order to explain the relationship of trophic structures and distribution patterns of Cretaceous foraminiferal palaeocommunities. Within this chapter the subject is considered in four parts. (1) Firstly, it is necessary to discuss some concepts of foraminiferal palaeo-ecology and the models adopted in the present study; some of the known functions of the test; and the inferred trophic groups of the foraminiferal assemblages recorded in the Cretaceous marine succession of Sergipe. (2) In the subsequent part the assemblages are arranged into morphological groups, based on common external features of the test, with an assessment of their palaeo-environmental distribution, substrate types and inferred modes of life. (3) The third part includes a discussion of the ditribution patterns of foraminiferal assemblages from mid-Cretaceous oxygen depleted environments and of the foraminiferal response to hypoxia. (4) Finally, there is a summary of the foraminiferal palaeocommunity structure, primarily focusing on the distribution patterns observed and their possible controlling factors.

5.2 - FORAMINIFERAL PALAEO-ECOLOGY

Foraminifera are, like all the marine microfossil groups, affected by changes in environment and palaeoceanographic conditions. The prime force behind the distribution, evolution and regional extinction events of foraminiferal fossil communities is the differential influence of depth-related factors, amongst which are included stability of the environment, water temperature, dissolved oxygen concentration, salinity, availability of calcium carbonate, nutrient resources, substrate type, and wave and current activity (Fig. 5.1). These factors, however, are not necessarily purely depth-related, but may be linked to other processes. It must also be emphasised that caution, and criticism, must be used when applying foraminiferal depth distribution models established elsewhere in the geological record to the Cretaceous assemblages. Benthonic foraminiferal communities would have extended their distribution when particular environmental factors allowed, and therefore cannot be simply related to depth niches. The complex interplay of abiotic and biotic components (the nature of microbenthos) does not conform to a generalised palaeo-environmental model of widespread application based on the distribution of particular foraminiferal genera or species. However, shelf environments of low-latitude regions (such as in the Cretaceous of Sergipe) have the greatest potential for environmental stability because insolation is more consistent seasonally. Moreover, the upper Aptian-Maastrichtian foraminiferal assemblages from Sergipe are apparently representative of a single biogeoprovince (see Chapter 9). In that context, highly adapted/

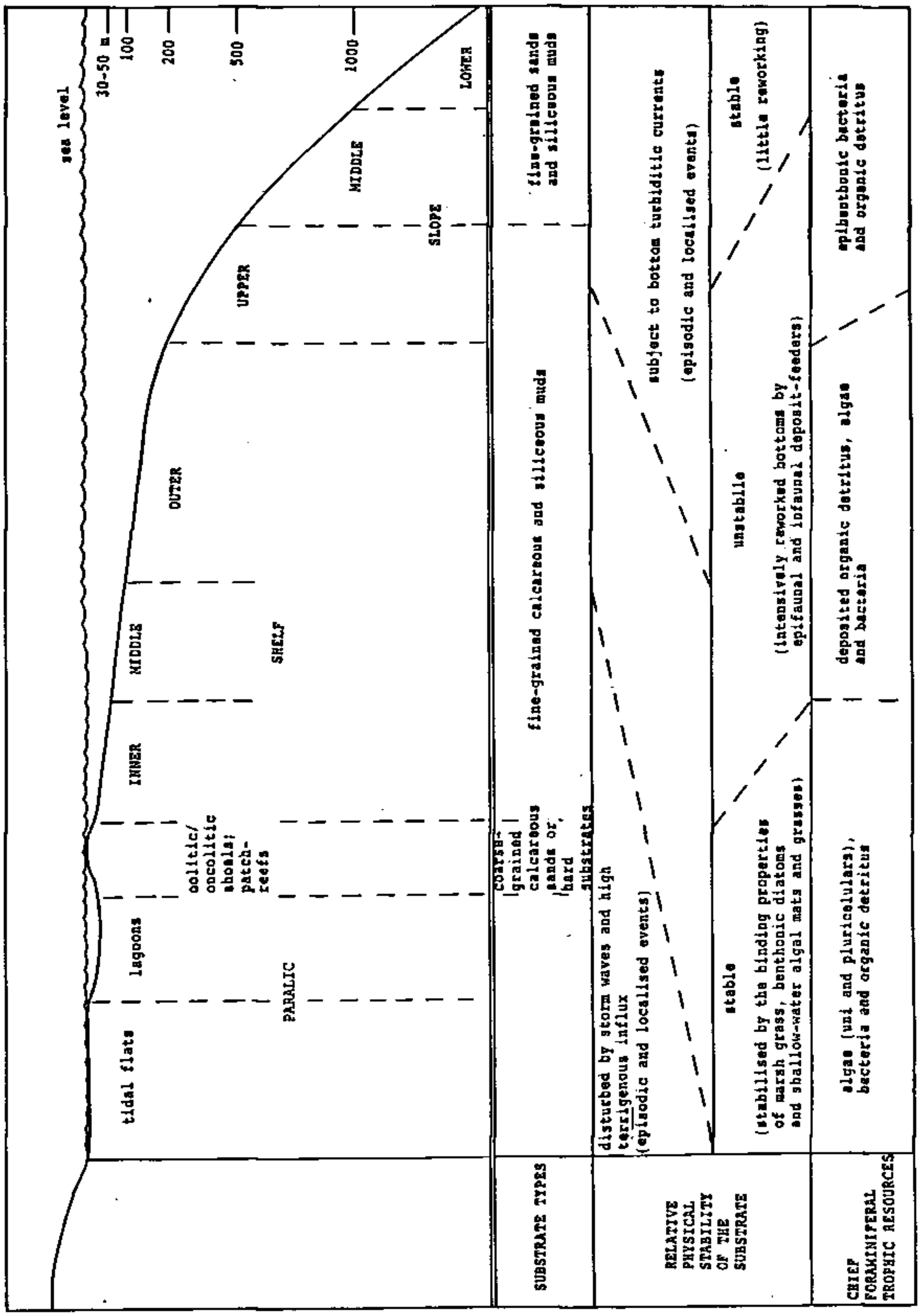


FIGURE 5.1: Major foraminiferal trophic resources and substrates (type and relative physical stability) in the marine environments (inferred for the Cretaceous of Sergipe).

specialised morphotypes (which normally show higher rates of extinction as the environment changes with time) may be expected to endure for a longer time-interval and to have preferentially inhabited a characteristic biofacies within the basin (where no major physical barriers to microfaunal migration existed).

In order to assess the palaeo-environmental significance of the microfossil assemblages present in the studied sections, mid- to late Cretaceous (Aptian to Maastrichtian) palaeobathymetric models of benthonic foraminifera (e.g., Sliter & Baker, 1972; Scheibnerová, 1976, 1978a; Olsson, 1977; Haig, 1979; Petters & Ekweozor, 1982 a, b; Olsson & Nyong, 1984; Nyong & Olsson, 1984; and Koutsoukos & Merrick, 1986) and planktonic foraminifera (e.g., Sliter, 1972, 1975; Hart & Bailey, 1979; Hart, 1980; Wonders, 1980; Caron, 1983; Caron & Homewood, 1983; Leckie, 1987) were used for comparison. The palaeo-environmental interpretations were made within the regional Cretaceous palaeogeography of the basin, and supported by the sedimentological evidence and depositional models documented elsewhere (see Chapter 8, Figs 8.6-7, 8.9, 8.15-18, 8.23-24).

5.2.1 - Function of the Foraminiferal Test

Studies of living specimens in laboratory cultures and of fixed, frozen and dried test-protoplasm have suggested various possible functions of the test in foraminifera. Four basic functions are here considered to be the most important:

(i) Protection against predation.

There is very little information on predation of foraminifera by other organisms, although some foraminifera are known to be adapted for feeding on other foraminifera (Christiansen, 1971; Lipps, 1983). As pointed out by Marszalek et al. (1969, p. 346), from observations of living foraminifera in culture, 'it would seem that very few animals larger than foraminifers are interested in them as food'. Predation by microgastropods could be potentially considered, especially when a large population of these molluscs is present (as in the shallow to middle neritic deposits of the upper Aptian to middle Albian section of Sergipe). Observations of guts contents of various marine organisms indicate that more often they are incidentally ingested by metazoans while feeding on, or in, the substrate (Brand & Lipps, 1982; Lipps, 1983; Buzas et al., 1989). Although no certain evaluation exists on how they constitute important trophic resources, it has been shown that predators play an important role in regulating foraminiferal densities (Brand & Lipps, op. cit.; Buzas, 1978, 1982; Buzas et al., op. cit.). Intense consumption on foraminiferal assemblages by invertebrate grazers and detrital feeders reduces the foraminiferal standing crop, whereas foraminiferal densities were significantly higher in the scarcity or absence of macrofaunal predators (Phleger & Soutar, 1973; Buzas, op. cit.; Douglas & Heitman, 1979; Buzas et al., op. cit.).

(ii) To provide protection against adverse physical or chemical conditions.

Marszalek et al. (1969) have suggested that the test of foraminifera may serve as a chemical shelter against adverse changes in environment (e.g., physical disturbance, particularly flow stress). For instance, multichambered foraminiferal tests with small apertures would offer a good refuge for the organism under conditions of physico-chemical stress, and would allow time for osmoregulatory adjustment to the new conditions while the main body of protoplasm is withdrawn into the inner chambers.

(iii) To control the bouyancy of the organism.

Foraminiferal tests are obviously heavier than sea water and it is evident that they serve as bouyancy regulators in planktonic specimens. They would serve the same function in benthonic organisms, as a means of counteracting the natural bouyancy of the protoplasm (cf. Marszalek et al., op. cit.).

(iv) To favour mode of life (dwelling habits and feeding strategy) in a particular substrate niche.

5.2.2 - Foraminiferal Trophic Groups

The trophic structures (feeding strategy-dwelling habits-substrate niche patterns) of foraminiferal palaeocommunities seem to be influenced by the overall environmental conditions (e.g., bathymetry, sedimentation rates, oxygen concentrations, temperature, calcium carbonate availability), food resources (Rhoads & Young, 1970; Sokolova, 1972) and substrate (type and physical stability) (Scott, 1978; Rhoads & Young, op. cit.) - see Fig. 5.1.

Foraminiferal pseudopodia are characteristic of the different trophic mechanisms used by the species in obtaining their food. The foraminiferal test (its morphology and wall composition) plays an important role in the deployment of pseudopodia in the feeding process (Lipps, 1983). In turn, trophic strategy dictates, to some extent, the test morphology of the foraminifera, which can be grossly inferred from the basic requirements of finding food in the sediments (Lipps, 1975, 1976; Haynes, 1981; Jones & Charnock, 1985).

Planktonic foraminifera appear to have a variable trophic strategy as they are known to feed on planktonic diatoms, dinoflagellates, copepods, amphipods, and other microplankton (cf. Bé, 1977). Benthonic foraminifera show a wide range of feeding types. The most common known types of feeding strategy are herbivory (ingestion of algae and/or bacteria), carnivory, omnivory, bacterial and detrital scavenging, and suspension feeding (cf. Lee, 1980; Lipps, 1983). Symbiosis with various types of unicellular algae has been reported in larger foraminifera from subtropical/tropical oligotrophic shelf carbonate environments (e.g., Lee, 1974, 1980; Lipps, 1983; Reiss & Hottinger, 1984; Hallock, 1984, 1985, 1988; Lee & Hallock, 1987), and has also been shown to be an important driving force in their morphological evolution (Lee et al., 1979; Lee & Hancock, op. cit.).

The benthonic foraminifera from the Cretaceous succession of Sergipe thrived in pelagic carbonate and siliciclastic environments and were, mostly, not light dependent (non algal symbiont-bearing taxa). The assemblages can be broadly arranged into three major categories of trophic groups, according to their general dwelling and feeding strategies: deposit feeders (epifaunal and infaunal); passive herbivores (browsers) - represented by rare specimens; and suspension feeders. They are individually characterised and discussed below.

Deposit feeders

Deposit feeders are foraminifera that feed over the substrate (epifaunal), in and near the sediment-water interface (shallow burrowers), or within (infaunal) the substrate. They remove food from sediment either selectively or randomly (cf. Walker & Bambach, 1974). This trophic group would be expected to attain maximum diversity and high densities on soft, fine-grained, organic muds containing an abundant food supply (Rhoads & Young, 1970).

The main trophic types of deposit-feeding foraminifera are as follows:

(1) **Infaunal deposit feeders**

Bacterial and detrital scavengers: feeding infaunally on particulate organic detritus or bacteria; mostly common in fine-grained (mud and silt) sediments. Infaunal deposit feeders have elongate tests, a morphology that minimises the strength required by the specimen to drive itself through the sediment in order to feed infaunally (Lipps, 1983).

(2) **Epifaunal deposit feeders**

Active herbivores: grazing on algae (diatoms) and bacteria as they move over the substrate (the latter the only living flora below the photic zone). **Detritivores:** feed on organic detritus from bottom sediments. These seem to be scavengers taking in particulate organic material such as dead diatoms, small pieces of sea-weed, aggregates and faecal pellets, fine clay-sized organic particles and/or parts of decaying metazoans (= herbivorous, omnivorous or carnivorous scavenging). **Omnivores:** opportunistic feeders that could eat both algae and bacteria but also combinations of these and animal matter or organic detritus (= detritivores). **Carnivores:** feeding on other living and/or dead protozoans, small arthropods and occasionaly scavenging on corpses of larger organisms. Carnivorous foraminifera have very long and narrow adhesive pseudopodia or extrude a deployed pseudopodial network on the mud surface, capable of holding and immobilise small metazoans and other protozoans (Christiansen, 1971; Lipps, 1983). Epifaunal deposit feeders were probably capable of only very slow movement (possibly on the order of cms per day; cf. Boltovskoy & Wright, 1976).

Similar general strategies utilised for the capture of food can be found amongst all feeding types of epifaunal deposit feeders of foraminifera. Therefore, a wide variety of similar test morphologies may be expected to occur within this trophic group (cf. Lipps, 1983). The distinction between epifaunal and shallow-infaunal modes of life may also be subtle for soft muddy substrates.

Most of the foraminifera that have been kept in cultures, are shallow-water forms and they seem to be rather omnivorous (Christiansen, 1971). However, it has been reported that at least some forms are more specialised in their food requirements and ingest only certain material, such as particular species of diatoms or only living diatoms. Others have always been observed browsing on the same sea-weed species (Christiansen, op. cit.).

Passive Epifaunal Herbivores

Passive epifaunal herbivores are attached or semi-attached (temporarily attached to the surfaces of macrophytes or hard substrates) species that feed on plant material. They harvest with their pseudopodia at, or near, the site of attachment (browsers). As far as feeding behaviour is concerned, passive herbivores can only be found beneath the photic zone. However, many semi-attached forms feed also on bacteria and organic detritus in environments beneath and below the photic zone, so that this category grades into epifaunal deposit feeding (cf. Walker & Bambach, 1974). Passive epifaunal herbivores have mostly irregular, flattened or low to high trochoid tests (Brasier, 1975; Lipps, 1983).

Suspension Feeders

Suspension feeders are individuals that subsist on fine suspended or re-suspended particulate organic matter (e.g., swimming and floating organisms, re-suspended organic detritus) from the near-bottom water-layer. Many suspension feeding foraminifera may also directly utilise dissolved and colloidal organic molecules (filter feeding; cf. Turpaeva, 1959; Walker & Bambach, 1974), especially those taxa thriving in oligotrophic environments (Lipps, 1983). Suspension feeders predominate in regions where the sedimentation rate is either very high or extremely low (Angel, 1988), as in middle-lower slope environments. Foraminifera that suspension-feed in the water column produce a very extensive pseudopodial network to catch food particles which passively fall or are drifted into it. They have mostly an erect long, tubular test, partially buried in the sediment. Some have a large number of branches (cf. Christiansen, 1971; Lipps, 1983).

5.3 - MORPHOGROUPS AND INFERRED MODES OF LIFE

The morphotypic classification adopted here for the benthonic foraminiferal assemblages and inferred modes of life are summarised in Table 5.1. The classification is based on external characteristics such as chamber arrangement, coiling pattern and general configuration of the test. Its application in the diagnoses of environmental conditions follows the same basic concept as used by Chamney (1976), Severin (1983), Jones & Charnock (1985), Berhnard (1986) and Jones (1986). Feeding strategies and dwelling habits in relation to test morphology of benthonic foraminifera have been inferred based upon the models proposed by Myers (1943), Bandy (1964), Boltovskoy (1966), Marszalek et al. (1969), Lipps & Valentine (1970), Christiansen (1971), Murray (1973), Brasier (1975), Lipps (1975, 1976, 1982, 1983), Lee (1980), Haynes (1981), Kitazato (1984, 1988), Shirayama (1984), Corliss (1985), Jones & Charnock (1985), Gooday (1986, 1988), Jones (1986), Bernhard (1986) and Kaminski et al. (1988). The foraminiferal genera are arranged into groups informally named after Family designation (see Chapter 3: 'Systematic Palaeontology').

The morphological characteristics that separate some categories are not totaly exclusive and seem to overlap (e.g., CH-A.4 and CH-A.7, AG-B.2 and AG-B.3; Table 5.1). They were separated on the basis that the taxa belonging to two sub-morphogroups have, mostly, distinctive compositions, the morphological affinities are not so close and they vary in distribution patterns (composition/relative abundances vs. environment; see Fig. 5.2 A and B). Their overlap in morphological features is acknowledged by their clustering into the same morphogroup.

It must be stressed here that inferred life positions represent only preferential habits. Most free-living deposit-feeding specimens, for example, of an epifaunal/shallow infaunal life habit, are characteristically mobile and rework and wander in soft muddy substrates throughout the whole unconsolidated upper part and even in the sediment/water interface in the search for food. Distinct microhabitat differences have also been shown to exist between benthonic foraminiferal species of the same genus (e.g., Gary & Healy-Williams, 1988). Detailed information on the vertical distribution of

TABLE 5.1: Summary of morphogroups categories of benthonic foraminiferal assemblages, inferred mode of life and representative taxonomic groups (Family level) from the upper Aptian to Maastrichtian succession of Sergipe.

MORPHO GROUPS		SUB-MORPHO GROUPS	GENERAL MORPHOTYPES	CHAMBER NUMBER	INFERRED MICROHABITAT	INFERRED TROPHIC GROUP	TAXA GROUPS
CH	A	1	plano-convex, low/high trochospiral broad	multilocular	epifaunal	deposit feeders	gavelinellids, rosalinids and conorboidids
		2	concavo-convex, low trochospiral broad				gavelinellids and bagginids
		3	inflated, biconvex periphery broadly rounded		epifaunal/ shallow infaunal		gavelinellids, alabaminids and nonionids
		4	conical, low trochospiral		epifaunal	deposit feeders and passive herbivores (browsers)	epistomariids, alabaminids, globorotalitids, gavelinellids and cibicidids
		5	lenticular, low trochospiral periphery subacute/carinate			deposit feeders	epistominids, osangulariids, gavelinellids, eponidids and planulinids
		6	lenticular, planispiral periphery subacute/carinate		epifaunal/ shallow infaunal		coiled vaginulinids
		7	conical, low/high trochospiral	bilocular/ multilocular	epifaunal	deposit feeders and passive herbivores (browsers)	involutinids, spirillinids and patellinids
		8	discoidal-flattened	bilocular		deposit feeders	spirillinids
	B	1	globular/ovate to elongate/fusiform	bilocular/ multilocular	epifaunal/ infaunal		polymorphinids, chilostomellids, quadrimorphinids pleurostomellids, lagenids and ellipsolagenids
		2	broad to palmate, compressed planispiral to uncoiled uniserial	multilocular			uncoiled vaginulinids
		3	elongate, straight to arcuate uniserial or planispiral-uniserial				uncoiled vaginulinids, nodosariids, ichthyolariids, elongate polymorphinids and stilostomellids
		4	tapered rounded-elongate triserial-biserial-uniserial		infaunal		turrilinids, bolivinids, buliminellids, lacosteinids, siphogenerinoidids, fursenkoinids, caucasinids, reussellids
		5	tapered flattened-elongate biserial				bolivinids, bolivinoidids and fursenkoinids
CP	A		fusiform, compressed broad		epifaunal		spiroloculinids
	B		elongate to ovate quinqueloculine		epifaunal/ shallow infaunal		hauerinids
AG	A		elongate, variable coiling uniserial and multiserial		infaunal		lituolids, haplophragmiids, hormosinids, eggerellids verneuilinids, pseudogaudryinids, textulariids
	B	1	low trochospiral/planispiral, broad		epifaunal	deposit feeders and passive herbivores (browsers)	trochamminids, haplophragmoidids, discamminids, cyclamminids and valvulamminids
		2	low trochospiral/streptospiral/ planispiral, spherical/subspherical		epifaunal/ shallow infaunal	deposit feeders	haplophragmoidids, ammosphaeroidinids and lituotubids
		3	streptospiral/planispiral, subspherical/flattened	bilocular/ multilocular			ammodiscids and rzehakinids
		4	globular	unilocular			psammosphaerids, saccamminids
	C.		tubular or branching		epifaunal	suspension feeders	bathysiphonids, hippocrepinids, rhabdamminids and aschemocellids

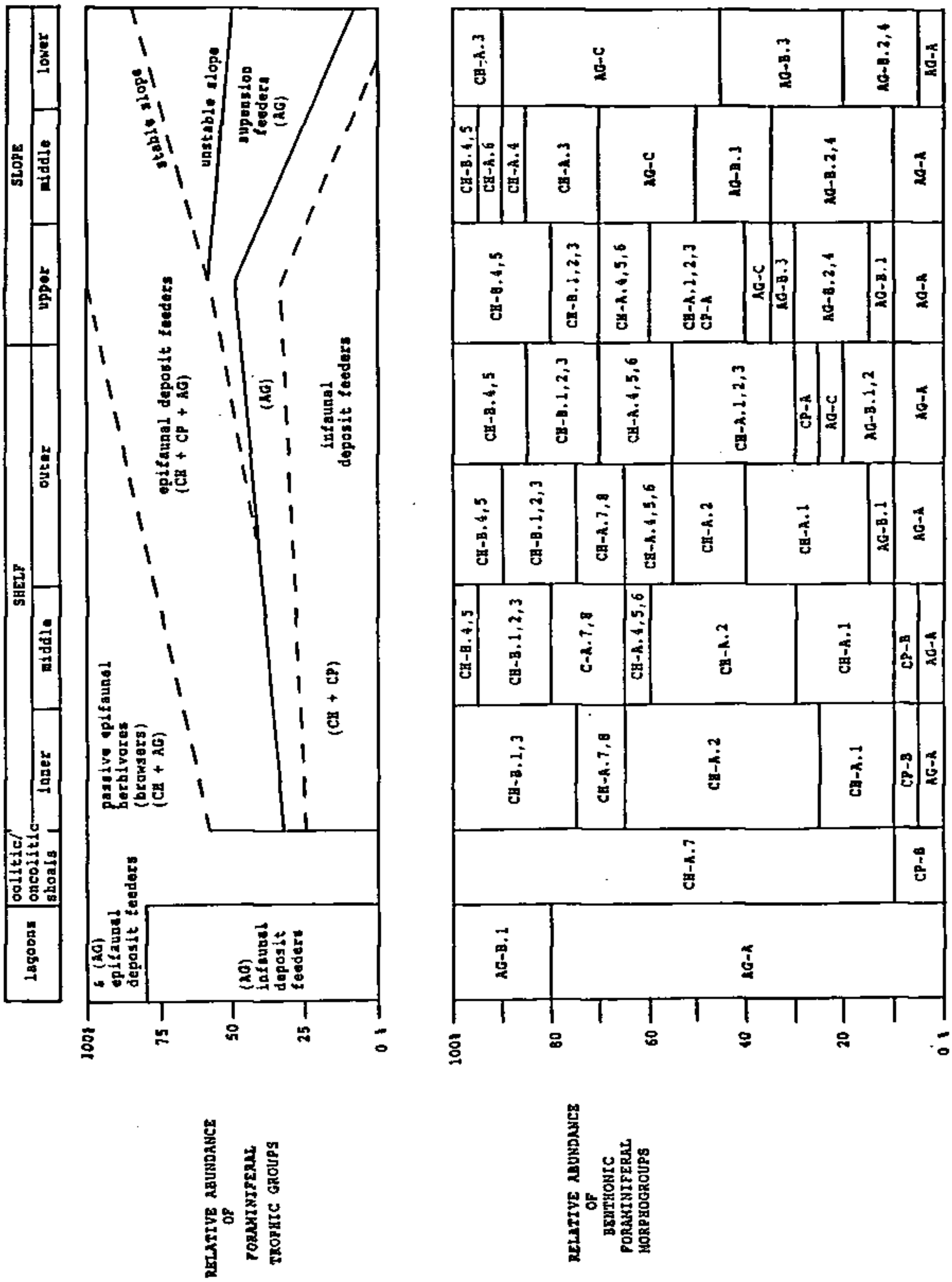


FIGURE 5.2: Palaeo-environmental distribution and relative abundance of major foraminiferal trophic groups (A) and morphogroups (B) - see Table 5.1. Inferred for the Cretaceous of Sergipe.

foraminiferal species within deep-sea sediments have been given recently by Shirayama (1984), Corliss (1985) and Gooday (1986, 1988) and indicate a degree of species vertical segregation (vertical microhabitat partitioning) among infaunal dwelling assemblages. Corliss (op. cit.) has demonstrated that foraminiferal distributions within the sediments vary with water depth and has also suggested that several infaunal taxa are primarily controlled by the different physicochemical conditions within the substrate, as this microhabitat is geochemically distinct from the sediment/water interface. On the other hand, overlying bottom-water conditions probably also played an important role in the microhabitat distribution of certain foraminifera, which do not seem to be restricted to infaunal niches. For instance, some extant foraminiferal assemblages adapted to infaunal life in the deep sea (Corliss, 1985) have been found to occur in the surface of sediments from oxygen depleted environments (Douglas & Heitman, 1979). In the presence of oxygen, the overall distribution of the foraminifera is probably dictated largely by the distribution of utilisable food within the sediment (cf. Gooday, 1986).

5.3.1 - Definition of the Morphogroups

The foraminiferal assemblages recovered from the upper Aptian to Maastrichtian succession of Sergipe show, basically, the following types of morphogroups (distinguished and subdivided according to wall structure and morphological similarity) - (summary in Table 5.1):

Remarks:

Specimen Dimensions : **H** = Height of Test (height of the trochospire, measured along the coiling axis of broad asymmetrical and elongate tests); **D** = Diameter of Test (maximum width, measured along the coiling plane of asymmetrical forms; D > H); **W** = Width of Test (measured across the coiling plane of elongate forms - W < H, and along the coiling axis of biconvex specimens - W < D).

Calcareous-Hyaline (CH) Foraminifera

Morphogroup (CH-A)

Morphogroup (CH-A) includes low/high trochospiral and planispiral morphotypes, with plano/concave-convex to biconvex tests, and periphery subacute/carinate to broadly rounded. The variable morphologies and generally low surface area-to-volume ratios (low H/D and W/D values; < 1) reflect adaptation to a primarily epifaunal microhabitat, with predominance of active deposit-feeding strategy.

Submorphogroup (CH-A.1)

(e.g., Pl. 14, Figs 17-25; Pl. 18, Figs 27-32; Pl. 19, Figs 1-4, 8-11)

(plano-convex trochospiral, broad morphotypes; usually a plano/concave umbilicus with a convex spiral side, of variable height; multilocular) - (H/D < 1)

Inferred mode of life: epifaunal (plano/concave umbilical face half buried in the substrate); active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: neritic and upper bathyal biotopes.

Taxa: gavelinellids [morphotypes of Gavelinella with a pronounced central rounded spiral boss: e.g., Gavelinella berthelini (Keller)-Gav. plummerae (Tappan)-Gav. reussi (Khan); Gavelinella ex gr. monterelensis (Marie); Gavelinella correcta (Carsey)], rosalinids [Gavelinopsis(?)] and conorboidids (Conorboides).

Submorphogroup (CH-A.2)

(e.g., Pl. 19, Figs 28-31; Pl. 20, Figs 26-31; Pl. 21, Figs 1-13)

(low trochospiral compressed morphotypes; asymmetrical, plano/concavo-convex tests; rounded to subacute periphery; multilocular) - (H/D < 1)

Inferred mode of life: epifaunal; browsing herbivores and active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: neritic and upper bathyal biotopes.

Taxa: gavelinellids [*Gavelinella nacatochensis* (Cushman); *Lingulogavelinella ciryi* Malapris-Bizouard; *Lingulogavelinella tormarpensis* (Brotzen); *Lingulogavelinella*(?) sp. cf. *L. thalmanniformis* (Plotnikova)], and bagginids (*Valvulineria*).

Remarks: A close morphological affinity exists between groups (CH-A.1) and (CH-A.2). The morphotypes occupied most of the undifferentiated shelf of Sergipe during the Cretaceous. Many of the special adaptations in shape and ornamentation seen in these foraminifera, characterised by relatively few broad adaptive morphotypes, appear to have developed in response to an unattached mode of life on soft sandy or muddy shelf sediments. The specimens were probably epibenthonic deposit feeders grazing on diatoms and bacteria, but also ingesting detrital organic matter by means of large cytoplasmic pseudopodia extending into the soft mud around and below them. The tests may have rested freely on the bottom with the plano-concave ventral side oriented lowermost and the convex posterior exposed at or above the sediment-water interface. The specimens could have been held on the sediment surface by the broad test width and the deployed pseudopodia, both acting to stabilise and prevent them from sinking into the fine-grained soft muddy sediment, where they are commonly found. In Cenomanian-Turonian sections deposited under oxygen depleted (dysaerobic/quasi-anaerobic) conditions, morphotypes of (CH-A.1) and (CH-A.2) are dominated by minute (c. 100-200µm in maximum diameter) specimens (see section 5.5.2).

Submorphogroup (CH-A.3)

(e.g., Pl. 16, Figs 28-33; Pl. 18, Figs 21-26; Pl. 20, Figs 11-16)

(low trochospiral/nearly planispiral/planispiral inflated morphotypes; biconvex; periphery broadly rounded; multilocular) - (W/D < 1)

Inferred mode of life: epifaunal/shallow infaunal; active deposit feeders (grazing herbivores/detritivores/omnivores and/or bacterial/detrital scavengers).

Substrate: siliceous muds.

Distribution: outer neritic and bathyal biotopes.

Taxa: gavelinellids [e.g., *Gavelinella* ex gr. *beccariiformis* (White); *Gavelinella velascoensis* (Cushman)], alabaminids [*Gyroidina*, *Gyroidinoides*: e.g., *Gyr'des nonionoides* (Bandy)] and nonionids (*Nonionella*, *Pullenia*).

Remarks: mobile habit particularly within soft muds in the deep sea bed; the more robust specimens are usually recorded in deeper (bathyal) environments.

Submorphogroup (CH-A.4)

(e.g., Pl.15, Figs 1-3, 9-10, 12-19; Pl.16, Figs 8-20; Pl.17, Figs 1-36)

(low-trochospiral, conical morphotypes; flattened to very low spiral side with a convex umbilicus, of variable height; multilocular) - (H/D < 1)

Inferred mode of life: epifaunal; passive herbivores (attached: Cibicides) and free-living deposit feeders (grazing herbivores/detritivores/omnivores)

Substrate: fine-grained sands, and calcareous or siliceous muds.

Distribution: middle-outer neritic and upper-middle bathyal biotopes.

Taxa: epistomariids (Nuttallinella), alabaminids (Gyroidina, Gyroidinoides), globorotalitids (Globorotalites), cibicidids (Cibicides), and gavelinellids [e.g., Orithostella ex gr. halfeldi (Petri)].

Submorphogroup (CH-A.5)

(e.g., Pl. 10, Figs 7-23; Pl. 18, Figs 1-16; Pl. 20, Figs 1-4)

(low trochospiral/nearly planispiral, compressed, nearly biconvex/lenticular morphotypes; periphery subacute to carinate; multilocular) - (W/D < 1)

Inferred mode of life: epifaunal; active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained sands and calcareous or siliceous muds.

Distribution: middle-outer neritic and upper bathyal biotopes.

Taxa: epistominids (Epistomina), osangulariids (Osangularia), gavelinellids [e.g., Gavelinella spissocostata (Cushman), Gavelinella barremiana Bettenstaedt-Gav. flandrini Moullade plexus], eponidids (Eponides), and planulinids (Planulina).

Remarks: morphotypes similar to (CH-A.2), from which they differ in being nearly biconvex with the periphery subacute to carinate.

Submorphogroup (CH-A.6)

(e.g., Pl. 8, Figs 14-32, 35-36; Pl. 9, Figs 15-18)

(lenticular morphotypes; biconvex, planispirally coiled; periphery subacute to carinate; multilocular) - (W/D < 1)

Inferred mode of life: epifaunal/shallow infaunal; active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained sands, and calcareous or siliceous muds.
Distribution: neritic and upper-middle bathyal biotopes.

Taxa: coiled vaginulinids (Astacolus, Lenticulina, Planularia, Saracenaria)

Remarks: The specimens were probably active deposit feeders that lived close to, and at, the sediment-water interface (epifaunal/shallow infaunal). Their generally smooth/little ornamented test and compressed shape also suggest that they were rapid burrowers and probably adapted to variable bottom conditions. The occurrence of these morphotypes, in variable numbers, in virtually all shelf and upper slope biotopes suggest adaptation for a wide variety of environmental conditions (eurytopic specimens). Their occurrence is always of subordinate importance, very rarely being found in significative abundance (exception, in dysaerobic/quasi-anaerobic environments of the upper Aptian-lower Albian; section 5.5.1, Chapter 8, Figs 8.3-5).

Submorphogroup (CH-A.7)
(e.g., Pl. 7, Figs 1-2, 5-11)
(high trochospiral, low/high conical morphotypes; bilocular to multilocular)
- (generally H/D < 1; H/D > 1 in some high conical trocholinids)

Inferred mode of life: epifaunal; semi-attached herbivorous (browsers) and deposit-feeders (grazing herbivores/ detritivores).
Substrate: bioclastic fine-grained sands and calcareous muds.
Distribution: oolitic/oncolitic shoals (Trocholina), algal patch-reefs, and neritic biotopes.

Taxa: involutinids (Trocholina), patellinids (Patellina) and spirillinids (Turrispirillina).

Remarks: the patellinids and conical spirillinids are supposed to have been semi-attached herbivores (browsers), but also probably epifaunal deposit feeders that lived free on the soft sediment surfaces, as did the plano/concavo-convex morphotypes (CH-A.1-2), resting on and partialy buried in the sediment/water interface, with the convex dorsal side projecting upwards.

Submorphogroup (CH-A.8)
(e.g., Pl. 3, Figs 3-4)
(discoidal-flattened morphotypes; bilocular) - (W/D < 1)

Inferred mode of life: epifaunal; active deposit feeders (grazing herbivores/ detritivores/omnivores)

Substrate: calcareous muds.

Distribution: neritic biotopes.

Taxa: spirillinids (Spirillina).

Remarks: the broadness of the flat spirillinid tests may have acted in a snowshoe manner to facilitate locomotion and prevent their sinking into the sediment.

Morphogroup (CH-B)

Morphogroup (CH-B) is represented by foraminiferal assemblages with elongate tests of generally high surface area-to-volume ratios (high H/W values; > 1), which may be a functional morphological adaptation to a predominantly infaunal deposit-feeding strategy.

Submorphogroup (CH-B.1)

(e.g., Pl. 9, Figs 23-36; Pl. 15, Figs 29-35)

(globular to ovate morphotypes; low trochospiral/triserial/ uniserial tests; tending to become elongate and fusiform; bilocular or multilocular) - (H/W > 1)

Inferred mode of life: epifaunal/infaunal; deposit feeders (grazing herbivores /omnivores and/or bacterial/detrital scavengers).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: neritic and upper-middle bathyal biotopes.

Taxa: polymorphinids (Eoguttulina, Globulina, Guttulina, Pyrulina), chilostomellids (Allomorphina), quadrimorphinids (Quadrimorphina), pleurostomellids (Ellipsoglandulina), lagenids (Lagena), and ellipsolagenids (Fissurina).

Remarks: mobile habit particularly within soft muddy substrates in the shelf and upper slope; polymorphinids, lagenids and ellipsolagenids occur mostly in low-diversity small-sized (c. 200-300um in maximum length) assemblages, of variable numbers, in fine-grained pelitic sediments of the shelf.

Submorphogroup (CH-B.2)

(e.g., Pl. 8, Figs 8-10; Pl. 9, Figs 1-6, 12-14, 19-22)

(palmate to subtriangular, broad, flattened morphotypes; planispiral to uniserial; multilocular) - (H/W > 1)

Inferred mode of life: epifaunal/shallow infaunal; deposit feeders (grazing herbivores/omnivores and/or bacterial/detrital scavengers).
Substrate: siliceous muds.
Distribution: outer neritic and upper bathyal biotopes.

Taxa: uncoiled vaginulinids (*Citharina*, *Neoflabelina*, *Vaginulina*), nodosariids (*Frondicularia*).

Submorphogroup (CH-B.3)

(e.g., Pl. 7, Figs 24-38; Pl. 8, Figs 1-7, 11-13, 33-34)

(elongate, straight to arcuate morphotypes; uniserial or planispiral to uniserial; multilocular) - (H/W >> 1)

Inferred mode of life: epifaunal/shallow infaunal; deposit feeders (grazing herbivores/omnivores and/or bacterial/detrital scavengers).
Substrate: fine-grained sands, and calcareous or siliceous muds.
Distribution: neritic and upper-middle bathyal biotopes.

Taxa: nodosariids (*Dentalina*, *Lingulina*, *Nodosaria*, *Pseudonodosaria*, *Tristix*), ichthyolariids (*Lingulonodosaria*), uncoiled vaginulinids (*Marginulina*, *Marginulinopsis*, *Vaginulina*), karreriids (*Karreria*), elongate polymorphinids (*Ramulina*) and stilostomellids (*Nodogenerina*).

Submorphogroup (CH-B.4)

(e.g., Pl. 10, Figs 29-33; Pl. 11, Figs 5-15, 17-30; Pl. 12)

[tapered rounded-elongate morphotypes; circular to ovate in cross section; triserial to biserial (or enrolled biserial) to uniserial; multilocular] - (H/W >> 1)

Inferred mode of life: infaunal; deposit feeders (bacterial/detrital scavengers).
Substrate: fine-grained calcareous or siliceous muds.
Distribution: middle-outer neritic and upper-middle bathyal biotopes.

Taxa: turrilinids (*Neobulimina*, *Praebulimina*, *Pyramidina*, *Pseudouvigerina*), lacosteinids (*Lacosteina*), bolivinids (*Bolivina*, *Gabonita*), siphogenerinoidids (*Orthokarstenia*, *Siphogenerinoides*), buliminellids (*Buliminella*), fursenkoinids (*Cassidella*), caucasinids (*Caucasina*), reussellids (*Reussella*) and pleurostomellids (*Bandyella*).

Submorphogroup (CH-B.5)

(e.g., Pl. 11, Figs 1-4, 16; Pl. 13, Figs 20-23)

(tapered flattened-elongate morphotypes; compressed, periphery subacute to acute; biserial; multilocular) - (H/W >> 1)

Inferred mode of life: infaunal; deposit feeders (bacterial/detrital scavengers).

Substrate: fine-grained calcareous and siliceous muds.

Distribution: middle-outer neritic and upper-middle bathyal biotopes.

Taxa: bolivinids (*Bolivina*), fursenkoinids (*Coryphostoma*), and bolivinoidids (*Bolivinoides*).

Remarks: groups (CH-B.4) and (CH-B.5) probably composed mobile assemblages of deposit feeders adapted to an infaunal microhabitat in soft, fine-grained, muddy sediments in areas of relative bottom stability and abundant nutrients (in the form of deposited organic detritus and bacteria); highest abundance and diversity of morphotypes are recorded in outer shelf and upper slope settings, near the shelf edge, close by and below the photic zone; common in upper Albian (turrilinids, fursenkoinids) and Cenomanian-Turonian sections (turrilinids, buliminellids, bolivinids, fursenkoinids, caucasinids) and abundant in upper Coniacian-Maastrichtian strata (turrilinids, bolivinids, buliminellids, siphogenerinoidids, lacosteinids, reussellids bolivinoidids).

Calcareous-Porcelaneous (CP) Foraminifera

Morphogroup (CP-A)

(e.g., Pl. 7, Figs 13-20)

(fusiform in outline, compressed morphotypes; periphery squarely truncate, broad; two chambers per whorl; multilocular)

Inferred mode of life: epifaunal/shallow burrowers; active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: middle-outer neritic and upper bathyal biotopes.

Taxa: spiroloculinids (Spiroloculina).

Remarks: The morphotypes also display adaptations to an epifaunal/shallow infaunal microhabitat in soft muddy bottoms, and were probably active deposit feeders. Their occurrence is not widespread in the basin, being abundant at only few localities, suggesting a very patchy distribution of favourable habitats. They are found mainly in fine-grained, organic-rich sediments in outer shelf and upper slope areas of the Cenomanian (e.g., locality A-9, uppermost Cenomanian; Fig. 8.16).

Morphogroup (CP-B)

(e.g., Pl. 7, Figs 21-23)

(elongate to ovate in outline, quinqueloculine morphotypes; axial periphery rounded to truncate; multilocular)

Inferred mode of life: epifaunal/shallow burrowers; active deposit feeders (grazing herbivores/detritivores/omnivores).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: inner-middle neritic biotopes.

Taxa: hauerinids [Pseudosigmoilina(?), Quinqueloculina(?)].

Agglutinated (AG) Foraminifera

Agglutinated foraminifera are mainly represented by specimens with a secreted organic or calcareous (Toksvad & Hansen, 1983) cement and agglutinated calcareous or silici-clastic particles and comprise the following morphotypes (sensu Jones & Charnock, 1985; Jones, 1986):

Morphogroup (AG-A)

(e.g., Pl. 3, Figs 24-39; Pl. 4, Figs 11-16, 28-40;
Pl. 5, Figs 1-4, 17-41, Pl. 1-5, 8-31, 34-35)
[Similar to (CH-B.3), (CH-B.4), and (CH-B.5)]

(elongate morphotypes; varied chamber arrangement and coiling mode; uniserial and multiserial; multilocular) - (H/W > 1)

Inferred mode of life: infaunal; deposit feeders (bacterial/detrital scavengers).

Substrate: fine-grained calcareous or siliceous muds.

Distribution: paralic, neritic and bathyal biotopes.

Taxa: uncoiled lituolids (Ammobaculites), haplophragmiids (Haplophragmium), hormosinids (Hormosina, Reophax), eggerellids (Dorothia, Karreriella, Marssonella), pseudogaudryinids (Clavulinoides, Pseudoclavulina), verneuilinids (Eggerellina, Gaudryina, Gaudryinopsis, Pseudogaudryinella, Pseudogaudryinella-Spiroplectinata plexus, Verneuilina), ataxophragmiids (Hagenowella), valvulinids [Tritaxilina(?)], spiroplectamminids (Quasispiroplectammina, Spiroplectammina), textulariids (Textularia) and tritaxiids (Tritaxia).

Morphogroup (AG-B)

[Similar to morphogroup (CH-A)]

Submorphogroup (AG-B.1)

(e.g., Pl. 2, Figs 19-24; Pl. 3, Figs 1-11; Pl. 4, Figs 20-25; Pl. 5, Figs 8-16)

[similar to (CH-A.2)]

(low trochospiral/planispiral, compressed, broad morphotypes; periphery narrowly rounded or subacute; multilocular) - (W/D or H/D < 1)

Inferred mode of life: epifaunal; passive herbivores (browsers) and active deposit feeders (grazing herbivores/detritivores/ omnivores).

Substrate: fine-grained siliceous muds.

Distribution: paralic, outer neritic and upper-middle bathyal biotopes.

Taxa: trochamminids (Trochammina), haplophragmoidids (Asanospira), discamminids (Discammina, Glaphyrammina), cyclamminids (Alveolophragmium, Buccicrenata) and valvulamminids (Valvulammina).

Submorphogroup (AG-B.2)

(e.g., Pl. 2, figs 25-35; Pl. 3, figs 12-21; Pl. 4, figs 1-10; Pl. 5, Figs 5-7)

[similar to (CH-A.3)]

(low trochospiral/streptospiral/planispiral, spherical to subspherical morphotypes; inflated; periphery broadly rounded; multilocular) - (W/D<1)

Inferred mode of life: epifaunal/shallow infaunal; active deposit feeders (grazing herbivores/omnivores and/or bacterial/detrital scavengers).

Substrate: fine-grained sands or siliceous muds.

Distribution: bathyal biotopes.

Taxa: haplophragmoidids (*Cribrostomoides*, *Haplophragmoides*), ammosphaeroidinids (*Budashevaella*, *Recurvoides*), lituotubids (*Trochamminoides*) and trochamminids (*Ammoglobigerina*).

Remarks: mobile habit particularly within soft muddy substrates and fine-grained sands on the deep sea bed; low-diversity agglutinated assemblages composed by infaunal deposit feeders (AG-B.2, AG-A), with subordinate numbers of epifaunal specimens (AG-B.1, AG-B.3), tend to appear in proportionally higher numbers (c. 20-100% in the upper Aptian-middle Albian, and c. 10-30% in the uppermost Cenomanian) during hypoxic/quasi-anoxic episodes over the outer shelf and upper slope (see section 5.5).

Submorphogroup (AG-B.3)

(e.g., Pl. 1, Figs 21-35; Pl. 2, Figs 1-8)

[similar to CH-A.8 and CP-A]

(planispiral/streptospiral coil, flattened/subsphaerical morphotypes; bilocular to multilocular)

Inferred mode of life: epifaunal/shallow infaunal; active deposit feeders (grazing herbivores/detritivores/omnivores and/or bacterial/detrital scavengers).

Substrate: fine-grained sands or siliceous muds.

Distribution: bathyal biotopes.

Taxa: ammodiscids (*Ammodiscus*, *Ammovertellina*, *Glomospira*, *Glomospirella*) and rzehakinids (*Rzehakina*, *Silicosigmoilina*, *Spirolocammina*).

Submorphogroup (AG-B.4)

(e.g., Pl. 1, Figs 11-16)

(single, globular chamber morphotypes; unilocular)

Inferred mode of life: epifaunal/shallow infaunal (half buried in the sediment surface); passive deposit feeders (herbivorous/ omnivorous detritivores) - (cf. Christiansen, 1971).

Substrate: fine-grained sands and siliceous muds.

Distribution: bathyal biotopes.

Taxa: psammosphaerids (*Psammosphaera*), saccamminids (*Pilulina*, *Saccammina*).

Morphogroup (AG-C)

(e.g., Pl. 1, Figs 1-10, 17-20)

(tubular or branching morphotypes; unilocular)

Inferred mode of life: epifaunal, attached to the sea floor or embedded in soft substrates; suspension feeders.
Substrate: fine-grained sands and siliceous muds.
Distribution: bathyal biotopes.

Taxa: bathysiphonids (Bathysiphon), hippocrepinids (Hyperammina), rhabdamminids (Dendrophyra, Rhabdammina, Rhizammina) and aschemocellids (Kalamopsis).

Remarks: The morphotypes were probably suspension feeders thriving in nutrient-poor (oligotrophic) deep-water environments from very near the sediment-water interface. The evidence from extant specimens (Christiansen, 1971; Gooday, 1983, 1986) suggests that they were either attached to the sea floor or embedded in soft sediments with apertures directed away from substrate. The specimens are usually associated with the silts and fine-grained hemipelagic layers of gravity flow deposits in outer neritic-upper bathyal environments of the upper Aptian to Albian (Angico Member, Riachuelo Formation), and in lower-middle bathyal settings of the upper Coniacian-Santonian to Maastrichtian (Calumbi Member, Piacabucu Formation). As these are episodic and localised events (Fig. 5.1) this particular biota could represent imigrant species from nearby sites, less affected by the turbidic currents, which would quickly repopulate vacant niches (e.g., Verdenius & van Hinte, 1983). However, the occurrence of tubular fragments (Bathysiphon and Hyperammina) as the more abundant, nearly exclusive, agglutinated component of some layers (e.g., well 1-US-1-SE, core 5:678.60m - Figs 8.5, 8.8; see section 5.4.3) may also suggest that these assemblages were transported and concentrated through sorting during a turbiditic event (e.g., Schroder, 1988).

5.4 - MORPHOGROUPS AND PALAEO-ENVIRONMENTS

Taphonomic processes (such as test dissolution, microfaunal mixing and condensation, caused by environmental, biotic or diagenetic factors) are widespread in the fossil record (e.g., Fursich, 1978). In upper Aptian-lower Albian of Sergipe dissolution of calcareous tests is commonly found in the darker, less calcareous shales, where only a "residual" microfauna composed exclusively by agglutinated forms was recovered (see Chapter 8; well 1-CA-1-SE, Fig. 8.3). Post-mortem transport, mostly by down-flow gravity currents, and mixing of assemblages also commonly occurred throughout the succession. For instance, no high-energy shallow carbonate platform was preserved from the upper Aptian to middle Albian of Sergipe. Although scarce, their representative sediments are mostly found reworked and drifted to outer neritic-upper bathyal environments by down-flow gravity currents (e.g., site of the well 1-US-1-SE, with a sedimentary sequence about 1000m thick of turbiditic deposits - Fig. 8.5). Despite all that, the microfossiliferous associations of the Cretaceous shelf deposits of the Sergipe Basin seem to be mostly locally derived and preserved without major large-scale post-mortem transportation and mixing being involved.

In the following paragraphs the observed distributional patterns of the benthonic foraminiferal morphogroups in the marine palaeo-environments of the Cretaceous succession of Sergipe are summarised. Assigned palaeobathymetries of the studied sections were based on the interpretation of the distribution of foraminiferal palaeocommunities and associated microfossils (radiolarians, diatoms and ostracods), lithofacies and regional palaeogeographic framework and are discussed in greater detail in Chapter 8 ('Palaeo-environmental Evolution and Palaeogeography') - see also discussion on section 5.2. The observed distribution patterns of the planktonic foraminiferal assemblages are also briefly discussed.

5.4.1 - Paralic Biotopes

Paralic (lagoonal) environments were recorded in upper Aptian well-sections (lowermost marine sediments of wells 1-CA-1-SE and 1-CN-1-SE; Figs 8.3-4) and lower Albian outcrops (locality A-32; Figs 8.1, 8.7). The microfauna is characteristically represented by abundant agglutinated specimens with a predominance (over 80% of the total microfauna) of large elongate multichambered specimens (lituolids:Ammobaculites, haplophragmiids:Haplophragmium; AG-A) with rare occurrences of flattened planispiral forms (cyclamminids: Buccicrenata; AG-B.1) - Figs 5.2-3. The assemblages include abundant infaunal taxa, with a passive bacterial/detrital scavenging feeding-strategy (AG-A). The minor constituents (AG-B.1) were probably epifaunal elements, with a trophic type of active herbivores/deposit feeders, browsing on seaweeds and/or grazing for diatoms and bacteria on the sediment.

5.4.2 - Shelf Biotopes

In general, as opposed to other environments, calcareous-hyaline (the dominant group) and agglutinated epifaunal browsers and deposit-feeding foraminiferal species with sharp (subacute to keeled) peripheries and broad, plano/concavo-convex, to low/high conical tests are preferentially distributed on shelf environments. Foraminiferal assemblages from inner to middle shelf environments, of late Aptian to early Albian age (e.g., Figs 8.1-7), are mostly represented by gavelinellids (Lingulogavelinella; CH-A.2), polymorphinids (Eoguttulina, Globulina, Pyrulina - CH-B.1; Ramulina - CH-B.3), nodosariids (Dentalina, Lingulina), vaginulinids (Astacolus - CH-A.6; Marginulina - CH-H.3; Citharina - CH-B.2), ichthyolariids (Lingulonodosaria), hauerinids (Quinqueloculina(?) - CP-B), and agglutinated specimens (lituolids: Ammobaculites; eggerellids: Marssonella, textulariids: Textularia, and spiroplectamminids: Quasispiroplectammina - AG-A) - Figs 5.2-3. The assemblages are representative of the inner-middle shelf Marssonella Association of Haig (1979).

The assemblages from middle-outer shelf environments, of late Aptian to early Coniacian age (e.g., Figs 8.1-7, 8.9, 8.12-18), are dominated by semi-attached passive herbivores and epifaunal deposit feeders (grazing herbivores and detritivores). The calcareous-hyaline foraminiferal morphogroups are (in decreasing order of abundance): (1) plano-convex/low trochospiral, broad morphotypes (gavelinellids, rosalinids, conorboidids, and bagginids - CH-A.1/2); (2) low/high spiro-conical (patellinids and spirillinids - CH-A.7) and discoidal flattened morphotypes (spirillinids - CH-A.8) - Figs 5.3-5.

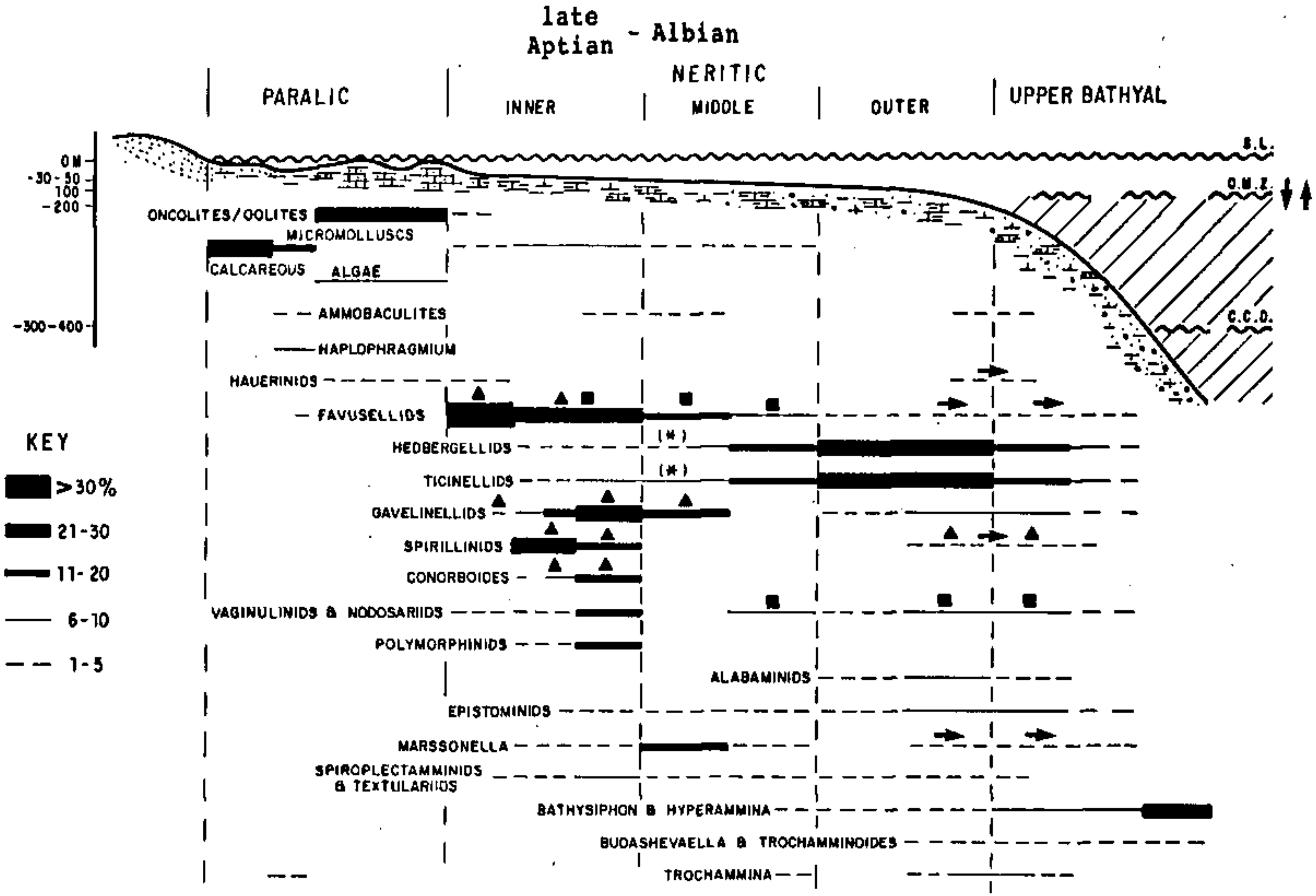


FIGURE 5.3: Schematic palaeo-environmental distribution of major taxonomic groups in the upper Aptian to Albian succession of Sergipe.

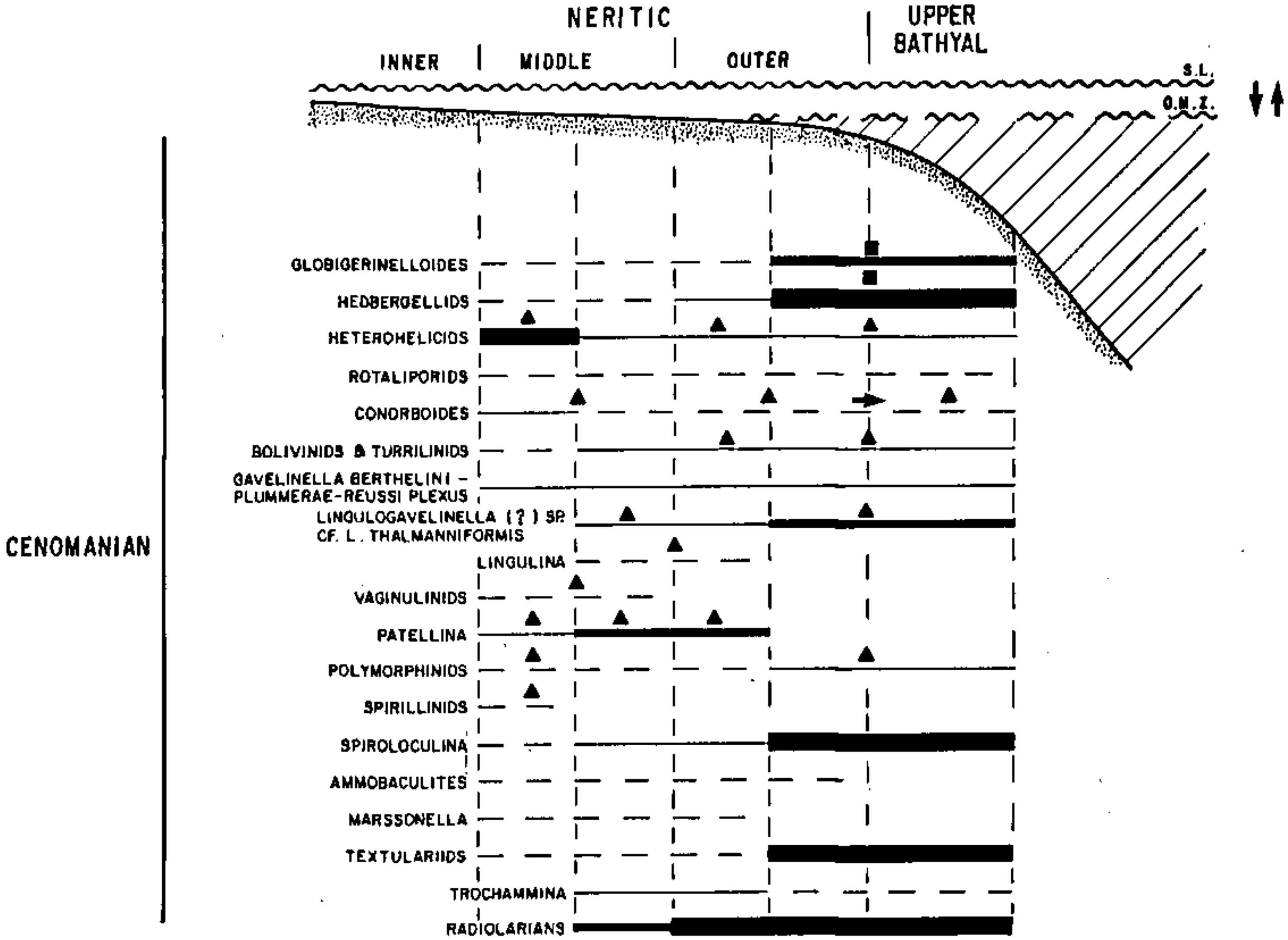


FIGURE 5.4: Schematic palaeo-environmental distribution of major taxonomic groups in the Cenomanian succession of Sergipe.

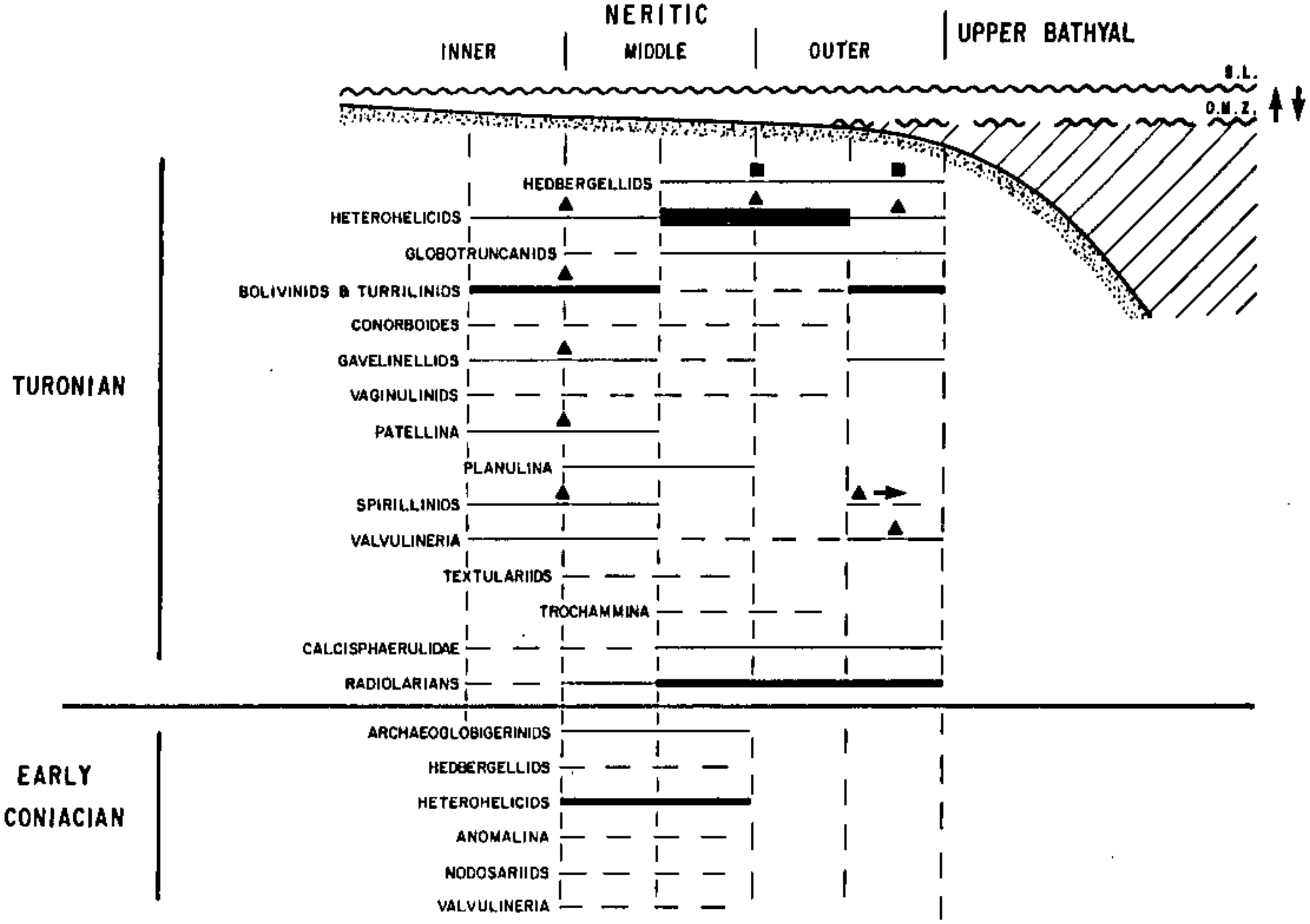


FIGURE 5.5: Schematic palaeo-environmental distribution of major taxonomic groups in the Turonian to Coniacian succession of Sergipe.

Outer shelf environments, of mid- to late Cretaceous age (late Aptian to Maastrichtian; e.g., Figs 8.3-5, 8.7, 8.12-18, 8.20-24), commonly have rich foraminiferal assemblages with predominance of calcareous-hyaline deposit-feeding specimens. The most abundant and high-diversity populations, with generally mixed trophic groups, occur in Campanian-Maastrichtian sections [e.g., Figs 5.13(B-D), 8.20-22]. The assemblages are commonly represented by: (1) epifaunal deposit feeders (grazing herbivores and detritivores): plano/concavo-convex, low trochospiral, broad morphotypes (gavelinellids - CH-A.1/2); (2) active epifaunal/shallow infaunal deposit feeders: lenticular, planispiral morphotypes (coiled vaginulinids - CH-A.6); (3) infaunal deposit-feeders (bacterial/detrital scavengers): elongate tapered morphotypes (turrilinids, buliminellids, bolivinids, lacosteinids, siphogenerinoidids, fursenkoinids and caucasinids - CH-B.4/5), and elongate, straight to arcuate morphotypes (nodosariids, uncoiled vaginulinids and elongate polymorphinids - CH-B.3); (4) epifaunal deposit feeders (herbivores and detritivores): low-trochospiral, asymmetrically low/high umbilico-conical (epistomariids, alabaminids, globorotalitids, cibicidids and gavelinellids - CH-A.4) and biconvex/lenticular morphotypes (epistominids, osangulariids, gavelinellids, eponidids and planulinids - CH-A.5) - Fig. 5.2. Late Cretaceous (late Coniacian-Santonian to Maastrichtian) outer shelf bolivinaceans and buliminaceans major components of morphogroups CH-B.4/5) have less ornamented test-surface than deeper assemblages; there is also progressive increase and differentiation of test-surface sculpture down the slope.

5.4.3 - Slope Biotopes

Rounded, inflated/globose morphotypes of calcareous-hyaline and agglutinated foraminifera, shallow-infaunal/infaunal deposit feeders, occur mostly in slope biotopes. Upper bathyal environments, of Albian age (Figs 8.3-5, 8.7), have different biotic composition from their Cenomanian and late Coniacian-Santonian to Maastrichtian counterparts. A shallow Calcite Compensation Depth (C.C.D.) to mesopelagic depths during the Albian [see Chapter 8, section 8.2.2.(ii)] contributed to distinct foraminiferal communities in the upper slope. The assemblages are commonly characterised by variable numbers of outer shelf deposit-feeding individuals (coiled vaginulinids, gavelinellids, alabaminids, globorotalitids, epistominids - Morphogroup CH-A; and elongate polymorphinids - CH-B.3) with increased amounts (c. 20-100%) of agglutinated specimens (lituolids, ammosphaeroidinids, eggerellids, verneuilinids, spiroplectamminids, textulariids - AG-A; ammosphaeroidinids, trochamminids - AG-B; bathysiphonids and hippocrepinids - AG-C) - Fig. 5.3. Hemipelagic layers deposited below the C.C.D. are completely devoid of calcareous microfauna (planktonic and benthonic), containing exclusively a "residual" siliceous agglutinated assemblage composed mostly by primitive types, i.e., tubular-shaped single-chambered specimens (bathysiphonids and hippocrepinids - AG-C), suspension feeders, with subordinate numbers of low trochospiral, multichambered morphotypes, epifaunal/shallow infaunal deposit feeders (ammosphaeroidinids: Budashevaella - AG-B.2) - (e.g., well 1-US-1-SE, core 5: 678.60m; Figs 8.5, 8.7-8; see also section 5.3, Remarks of Morphogroup AG-C).

Latest Cenomanian upper bathyal environments, deposited under dysaerobic/quasi-anaerobic bottom water conditions (see section 5.5.2, and Chapter 8, Figs 8.12-13, 8.19), are dominated by minute (c. 100-200μm in maximum diameter, width or length), low-diversity deposit-feeding calcareous (gavelinellids, conorboidids, rosalinids, bagginids - CH-A.1-2; coiled vaginulinids - CH-A.6; turrilinids, bolivinids, buliminellids, fursenkoinids, caucasinids, polymorphinids - CH-B; spiroloculinids - CP-A) and agglutinated foraminifera (lituolids: Ammobaculites, Ammomarginulina; eggerellids: Marssonella; valvulinids: Tritaxilina(?); textulariids - AG-A; discamminids: Discammina, and trochamminids - AG-B.1) - Fig. 5.4.

Foraminiferal assemblages from upper bathyal environments, of late Coniacian-Santonian to Maastrichtian age (Figs 8.20-24), are similar to outer shelf biotopes, but differing in composition - specific and intraspecific variations - and relative abundance of morphogroups. The assemblages have high abundance, high diversity and mixed trophic groups, with a predominance of calcareous-hyaline foraminifera. These are (in decreasing order of abundance) characterised by: (1) epifaunal/shallow infaunal deposit feeders (grazing herbivores/detritivores and/or

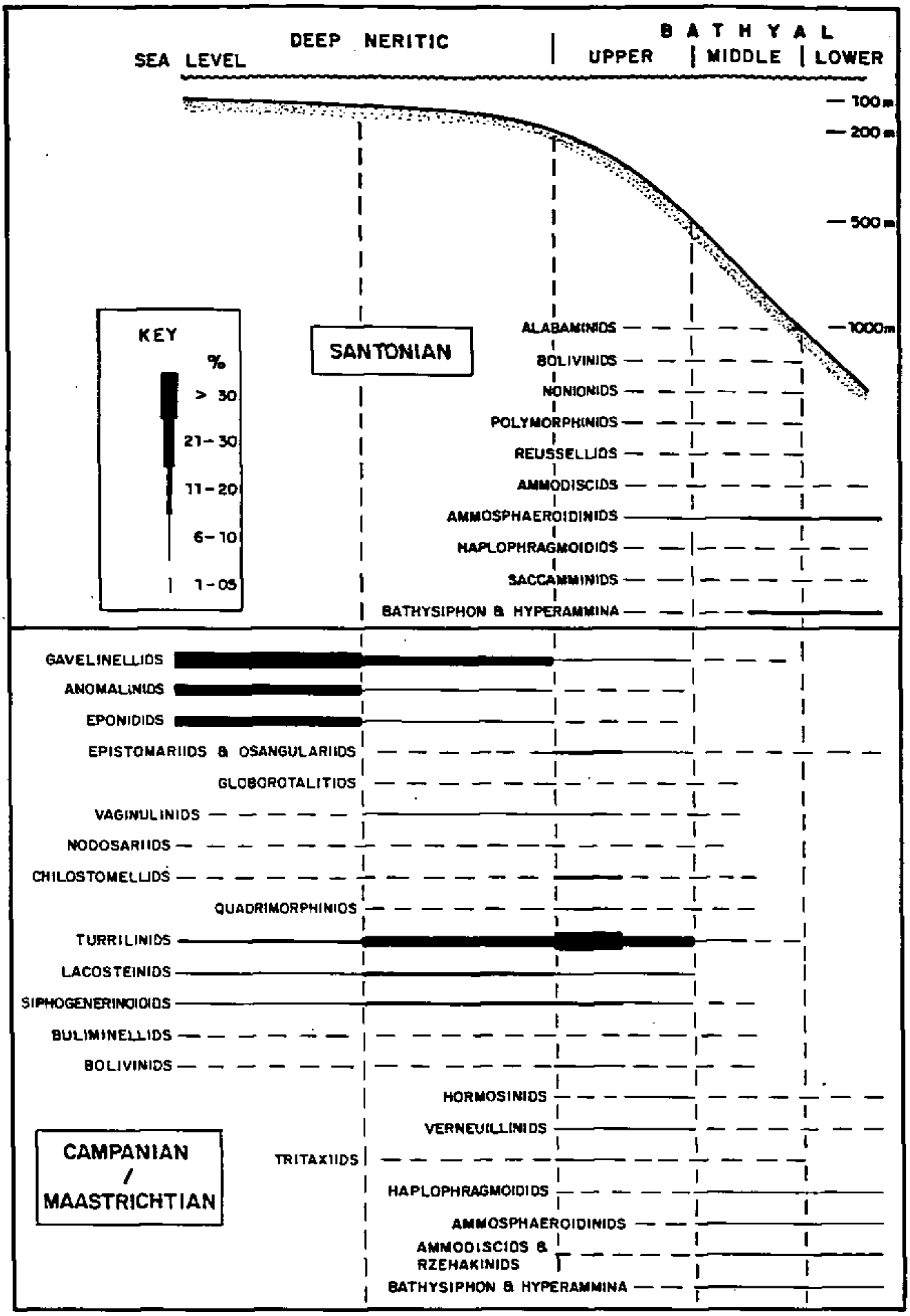


FIGURE 5.6: Schematic palaeo-environmental distribution of major taxonomic groups in the Santonian to Maastrichtian succession of Sergipe.

bacterial/detrital scavengers): low trochospiral/nearly planispiral/planispiral morphotypes with a broadly rounded periphery (gavelinellids, alabaminids, nonionids and bagginids - CH-A.3) - larger specimens (>300um in maximum diameter) occur at upper-middle bathyal depths; (2) infaunal deposit-feeders (bacterial/detrital scavengers): elongate tapered morphotypes (turrilinids, lacosteinids, siphogenerinoidids, bolivinids; CH-B.4-5); (3) epifaunal deposit feeders (herbivores and detritivores): low trochospiral, umbilico-conical (epistomariids, alabaminids, globorotaliids, gavelinellids - CH-A.4) and biconvex/lenticular morphotypes (epistominids, osangulariids, rotaliids, gavelinellids, eponidids and planulinids - CH-A.5); (4) active epifaunal/shallow infaunal deposit feeders: lenticular, planispiral morphotypes (coiled vaginulinids - CH-A.6). Variable numbers (c. 20-40%) of agglutinated specimens (morphogroups AG-A, AG-B.1-4, AG-C) are also present - Figs 5.2, 5.6).

Turrilinaceans, bolivinaceans and buliminaceans are most abundant and diverse in the outer neritic-upper bathyal, near the shelf edge (e.g., Figs 5.2, 5.6), where they make up approximately one-quarter of the foraminiferal fauna. They decline in both abundance and species richness up on the shelf and down the slope. Bathyal specimens are also generally larger and more ornamented than shelf individuals [e.g., Orthokarstenia clarki (Cushman & Campbell) in outer shelf to upper slope environments, and Orthokarstenia clavata (Chenouard, de Klasz & Meijer) in the upper to middle slope]. These trends also appear at the intraspecific level with, for example, morphotypes of Bolivina ex gr. afra (Reyment) showing an increase in overall length and strength of costae down the upper slope (see Chapter 3). The preference of the turrilinaceans, bolivinaceans and buliminaceans for deep water, often poorly oxygenated (shown to be able to tolerate levels as low as 0.10ml of O_2/l; Boltovskoy, 1972) environments, may be related to the exploitation of particulate, detrital organic matter (Haynes, 1981). Trophic resources decrease exponentially with depth and selection favours species that can find and utilise packaged detritus such as faecal pellets and carcases of metazoans (Haynes, op cit.). For instance, some deep-sea, low-diversity, extant benthonic foraminiferal assemblages have also been shown to be specialised feeders that bloom opportunistically when the appropriate food (phytodetritus) and associated microorganisms becomes available (Gooday, 1988).

Middle-lower bathyal foraminiferal assemblages, of late Coniacian-Santonian to Maastrichtian age (sections of wells 1-SES-3, 1-SES-24; Figs 8.22-24), are characteristically enriched in agglutinated specimens. The deepest biotopes are represented by an abundant microfauna of large (>300um in maximum length), single-chambered (straight or branched) morphotypes (bathysiphonids: Bathysiphon, hippocrepinids: Hyperammina; rhabdamminids: Dendrophrya, Rhabdammina, Rhizammina, and aschemocellids: Kalamopsis - AG-C), epifaunal suspension feeders, with variable assemblages of epifaunal and infaunal deposit feeders (bacterial/ detritivorous scavangers, and omnivores), such as hormosinids: Hormosina, Reophax; lituolids: Ammobaculites; verneuilinids: Gaudryina, Pseudogaudryinella; eggerellids: Dorothia, Karreriella; pseudogaudryinids: Clavulinoides, Pseudoclavulina - AG-A; haplophragmoidids: Asanospira, Cribrostomoides, Haplophragmoides; discamminids: Glaphyrammina; ammosphaeroidinids: Recurvoides; lituotubids: Trochamminoides - AG-B.2; ammodiscids: Ammodiscus, Ammovertellina, Glomospira, Glomospirella; rzehakinids: Rzehakina, Silicosigmoilina, Spirolocammina - AG-B.3; psammosphaerids: Psammosphaera; and saccamminids: Saccammina, Pilulina - AG-4) - Figs 5.2, 5.6.

5.4.4 - Pelagic Biotopes and Palaeoceanographic Conditions

The water-mass depth stratification of Cretaceous planktonic foraminiferal communities has been inferred by several works (e.g., Hart & Bailey, 1979; Wonders, 1980; Caron, 1983; Caron & Homewood, 1983; Hart & Ball, 1986; Leckie, 1987), mostly based by analogy with present depth distributions of living species (e.g., Bè, 1977) and from local palaeobiogeographic distributions (e.g., Eicher, 1969; Sliter, 1972; Hart & Bailey, op. cit.). Oxygen isotope studies (e.g., Douglas & Savin, 1978; Saito & van Donk, 1974; Corfield, Hall & Brasier, oral communication, Aston, December 1988) have also given support to the thought that the Cretaceous assemblages had depth distributions similar to modern analogs.

The planktonic assemblages recovered from the Cretaceous succession of Sergipe show the following distribution patterns (see Figs 5.3-5, 5.7-10, 6.3):

Inner neritic environments, of late Aptian age (e.g., locality A-38 and wells 7-CP-252-SE, 1-CPB-1R-SE; Figs 6.2, 8.1-2), are dominated by favusellids (specimens with a highly variable globigerine chamber shape and arrangement and a characteristic surface ornamentation of fine-to-coarse ridges forming an honeycomb-like pattern; the many morphotypes are intraspecific variants and different ontogenetic stages of a single hedbergellid taxon; Hedbergella (Favusella) washitensis - see Chapters 3 and 6, and Fig. 6.3). Abundant assemblages of favusellids, dominated by small specimens (100-250um in maximum diameter; mostly neanic forms) are found in the nearshore inner neritic paleoenvironments (Figs 5.3, 5.7, 6.3). In more open marine waters (inner to middle neritic environments - e.g., wells 1-CA-1-SE, 1-CN-1-SE, 1-US-1-SE; Figs 6.2, 8.1-5) and upwards in the succession, the favusellid population sharply decline in number and is dominated by larger specimens (300-500um; ephebic and gerontic forms), with less morphological variability. They are progressively replaced by numerous other planktonic foraminifera with a rugose/pustulose (pustules and/or costellae) chamber surface and in turn by abundant specimens of non-ornamented Hedbergella, Ticinella and Globigerinelloides (Figs 5.3, 5.7). Globigerinelloides ferreolensis (Moullade) appears to represent the deepest-dwelling planktonic taxon of the late Aptian, as specimens are only recorded from outer neritic-upper bathyal deposits (sections of wells 1-US-1-SE, 1-SES-3, 1-SES-9, 1-SES-24; Figs 5.7, 8.5-6). Higher up in the stratigraphic sequence, throughout the middle to upper Albian, deep-water dwelling (middle to outer neritic and deeper) planktonic assemblages are characterised by non-ornamented Hedbergella, Ticinella and Globigerinelloides, together with abundant specimens of Biticinella in the upper Albian (Figs 5.3, 8.1, 8.3-5, 8.7, 8.9). Middle to outer shelf biotopes of the uppermost Albian (Figs 8.3-5, 8.9) are characterised by calcareous mudstones containing numerous planktonic foraminifera with a rugose/pustulose chamber surface (Hedbergella, Ticinella, Praeglobotruncana) and other non-rugose hedbergellids, Ticinella, heterohelicids (Heterohelix) and guembelitriids (Guembelitria).

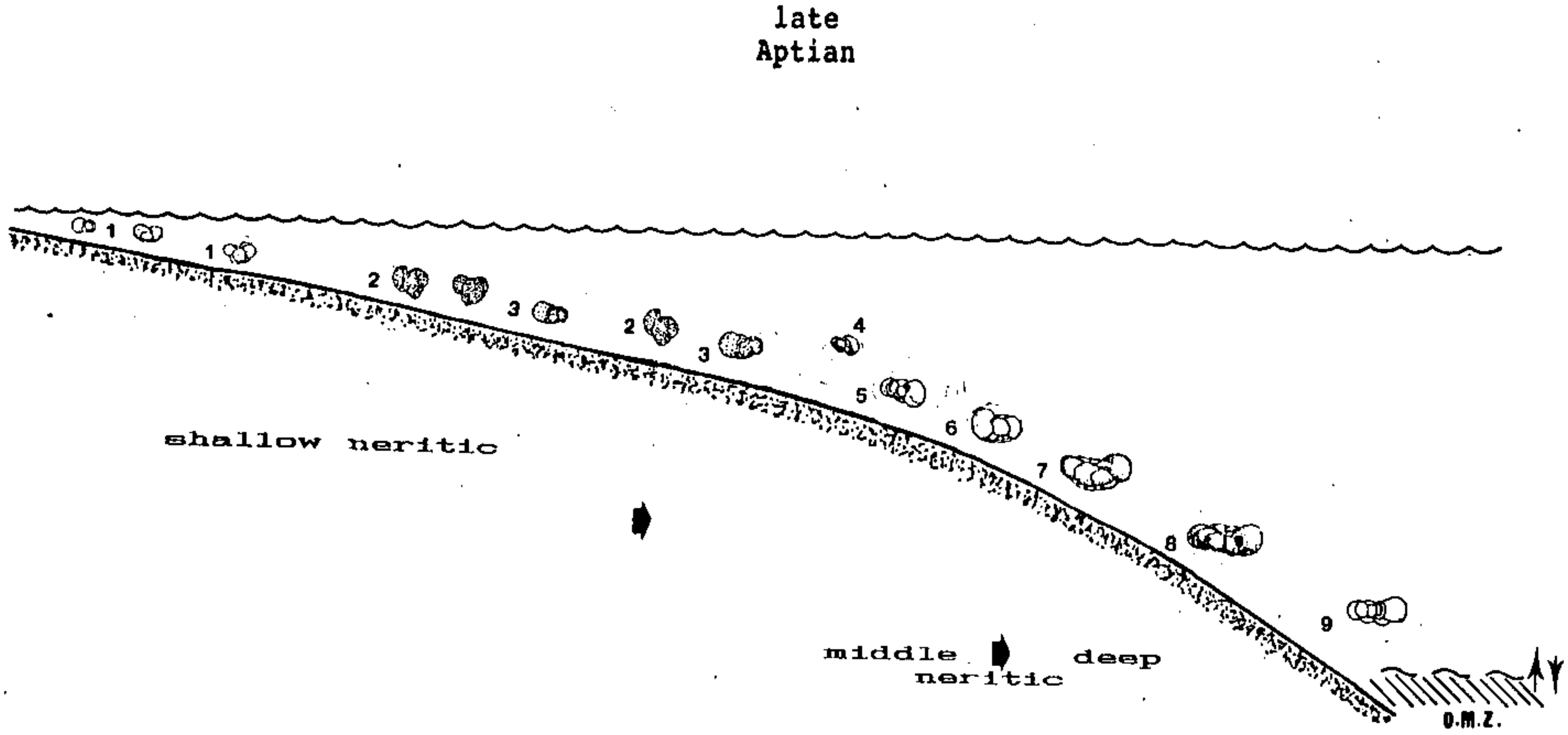


FIGURE 5.7: Planktonic foraminiferal assemblages and water-depth stratification during the late Aptian.
(1) neanic and early ephebic favusellids; (2) late ephebic and gerontic favusellids; (3) *H.* (*H.*) ex gr. *delrioensis*; (4) *H.* (*H.*) *gorbachikae*; (5) *H.* (*H.*) ex gr. *planispira*; (6) *H.* (*H.*) *trocoidea*; (7) *T.* *roberti*; (8) *T.* *bejaouaensis*; (9) *G.* *ferreolensis*.

Rare specimens of Rotalipora, a typical single-keeled Tethyan group (and deep water planktonic morphotype; cf. Hart and Bailey, 1978; Leckie, 1987), are first recorded in the lowermost Cenomanian (Figs 5.8, 8.4, 8.15). A maximum in sea-level occurred during the latest Cenomanian [Figs 5.13(E), 8.12-13, 8.16]. The sea-level rise is associated with an increase in botton oxygen-depletion to hypoxic/anoxic conditions over the shelf (see section 5.5 and Chapter 8), a probable consequence of periodic expansion and intensification of a mid-water oxygen-minimum zone. Similar conditions still persisted during the earliest Turonian (Fig. 5.10). The presence of rich and diverse planktonic biota (foraminifera and radiolarians), throughout the Cenomanian-Turonian succession, suggests widespread oxygenated epipelagic layers, of variable thickness in space and time in the basin. The rich latest Cenomanian-earliest Turonian planktonic foraminiferal assemblage (e.g., well 1-CA-1-SE, Fig. 8.13, and localities A-2, A-9, A-22, A-35, Fig. 8.12) is characteristically dominated by large (c. 300-400µm in maximum diameter) "globigerine-like" specimens [Hedbergella (Hedbergella), Hedbergella (Whiteinella) and Globigerinelloides; e.g., Globigerineloides bentonensis (Morrow), in the uppermost Cenomanian). A single small-sized (c. 295µm in maximum diameter) specimen of Rotalipora greenhornensis (Morrow) has been recorded in the onshore uppermost Cenomanian sections (locality A-9; Fig. 8.12). The first of the two-keeled morphotypes, Dicarinella primitiva (Dalbiez), are recorded in the uppermost Turonian (localities A-8; Figs 8.12, 8.18). Shallower environments, of the middle-late Turonian (Fig. 8.12), have variable numbers of minute (<200µm in maximum diameter, width or length) heterohelicids, guembelitriids and hedbergellids .

The lower Coniacian, as found in the outcrops of Sergipe (localities A-10, A-11, Tabocas 2; Figs 8.12, 8.18), represents a time of shallowing in the environment and of deposition under well oxygenated water mass conditions. This resulted in a biotope characterised by epipelagic planktonic foraminifera morphotypes (hedbergellids, heterohelicids and Archaeoglobigerina) of mixed test sizes.

The upper Coniacian-Santonian has been recorded in the onshore (wells 1-CA-1-SE, Fig. 8.20, and 1-CRL-1-SE) and offshore area of Sergipe (wells 1-SES-3, Fig. 8.22, 1-SES-9 and 1-SES-24) - Fig. 8.23. The planktonic

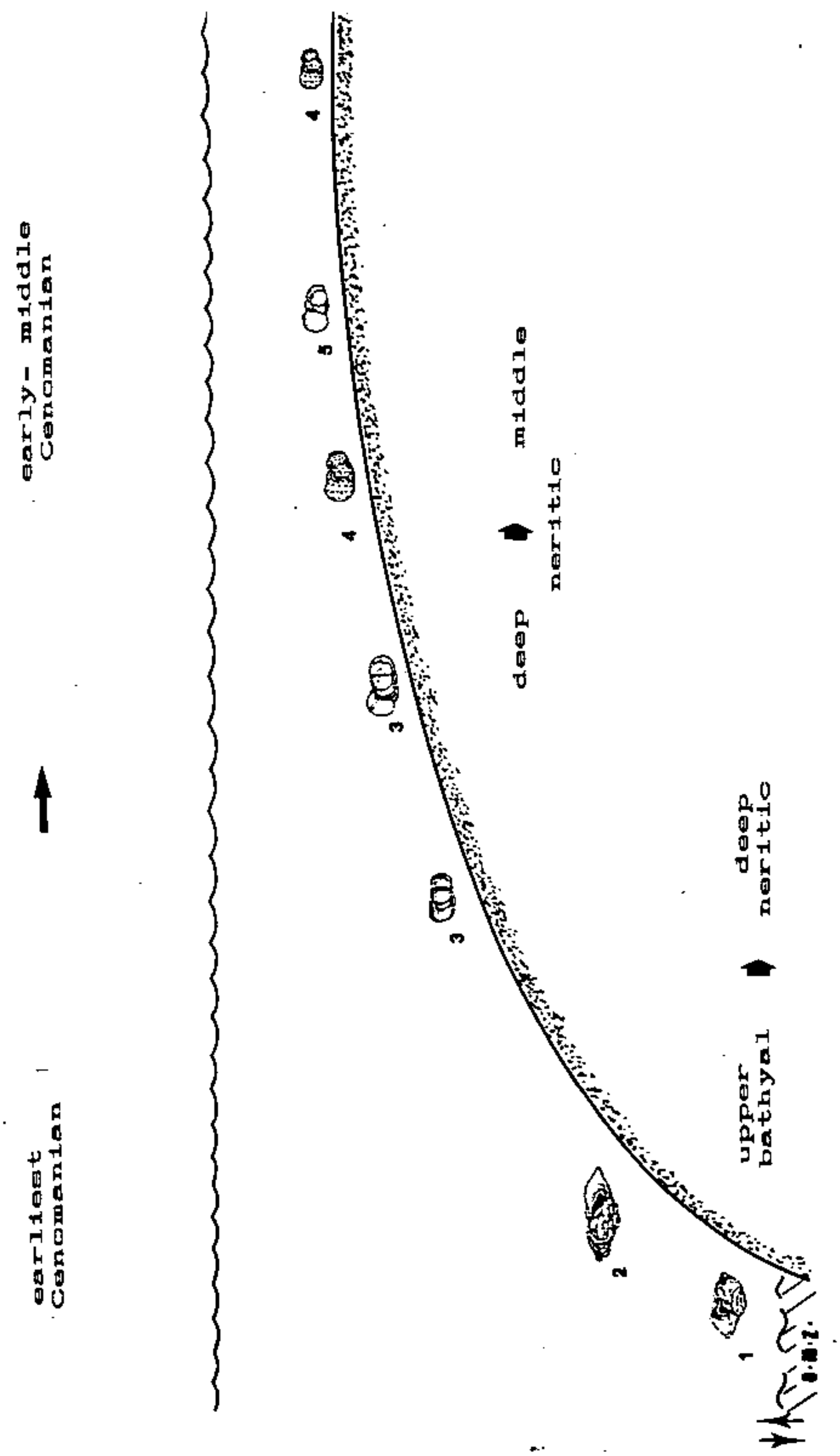


FIGURE 5.8: Planktonic foraminiferal assemblages and water-depth stratification during the earliest Cenomanian to early-middle Cenomanian. (1) R. brotzeni; (2) R. appenninica; (3) H. (H.) ex gr. planispira; (4) H. (W.) baltica; (5) H. (H.) ex gr. delrioensis.

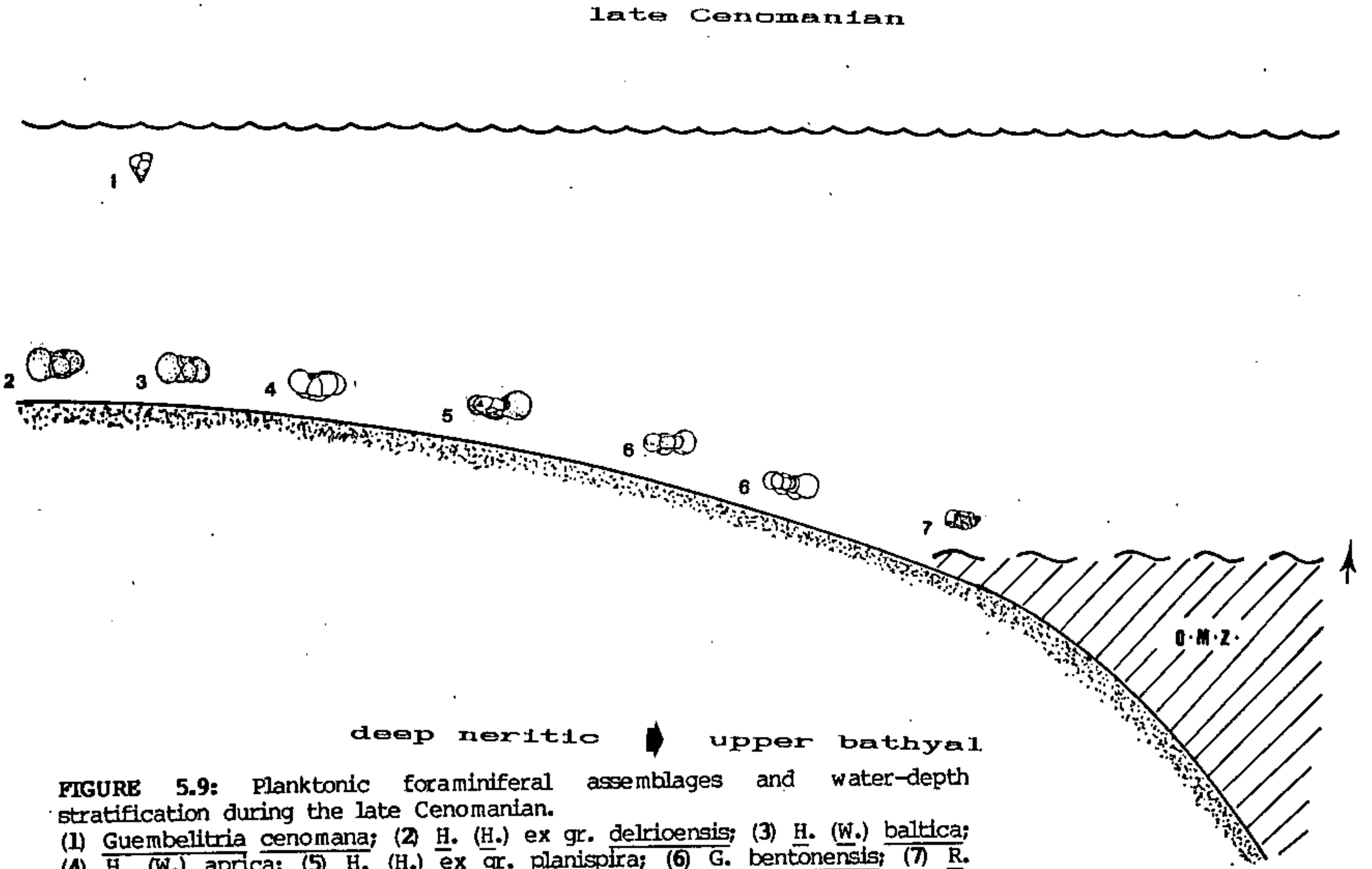


FIGURE 5.9: Planktonic foraminiferal assemblages and water-depth stratification during the late Cenomanian.
(1) *Guembelitria cenomana*; (2) *H.* (*H.*) ex gr. *delrioensis*; (3) *H.* (*W.*) *baltica*; (4) *H.* (*W.*) *aprica*; (5) *H.* (*H.*) ex gr. *planispira*; (6) *G.* *bentonensis*; (7) *R.* *greenhornensis*.

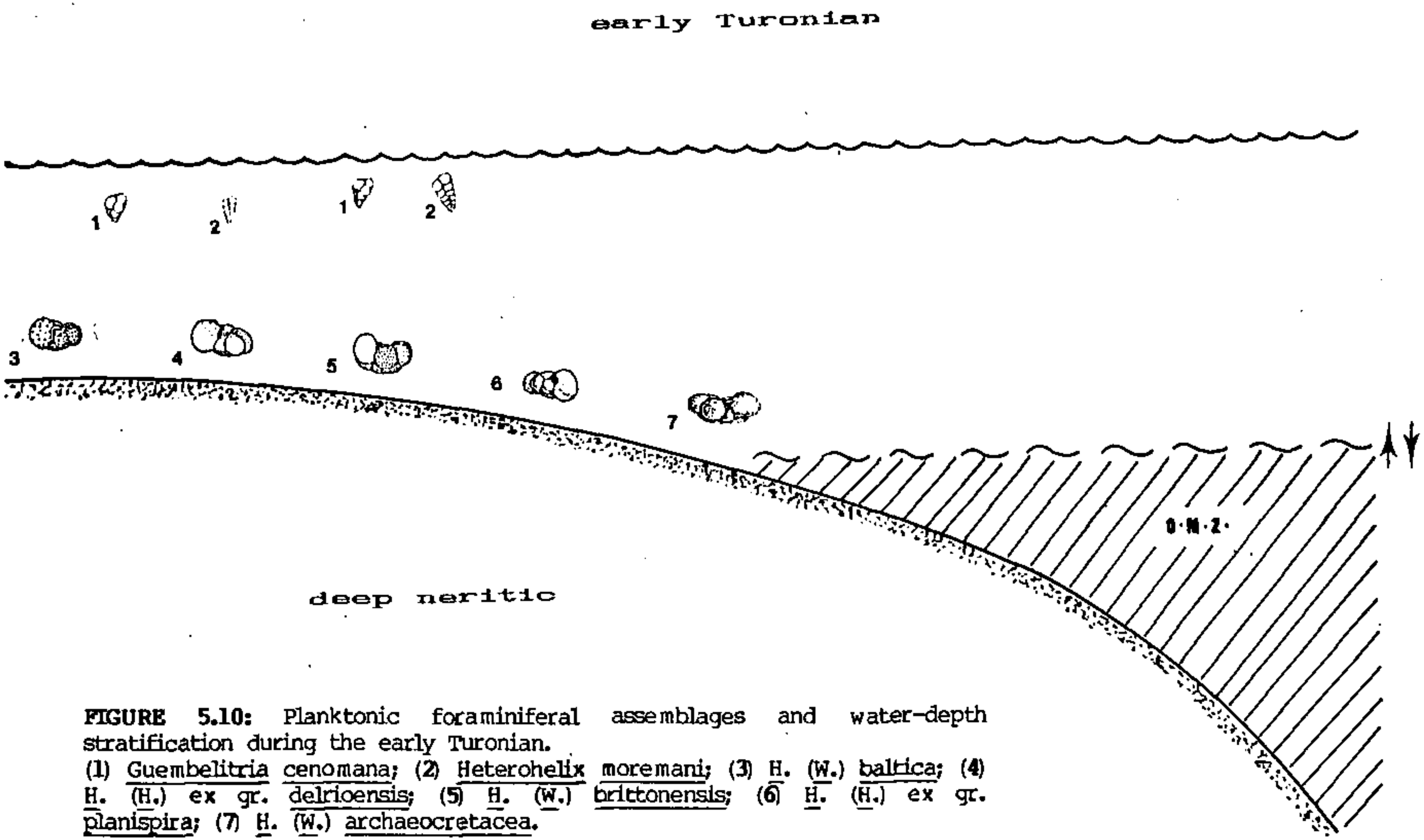


FIGURE 5.10: Planktonic foraminiferal assemblages and water-depth stratification during the early Turonian.
(1) Guembelitria cenomana; (2) Heterohelix moremani; (3) H. (W.) baltica; (4) H. (H.) ex gr. delrioensis; (5) H. (W.) brittonensis; (6) H. (H.) ex gr. planispira; (7) H. (W.) archaeocretacea.

assemblages, from outer shelf to middle-lower bathyal environments, have diverse keeled morphotypes (*Contusotruncana*, *Dicarinella*, *Marginotruncana*) with scarce hedbergellids, heterohelicids and *Archaeoglobigerina*.

Campanian-Maastrichtian planktonic assemblages show a more clear differentiation in composition. Middle-outer neritic environments (sections onshore Sergipe: localities A-18, A-19, wells 1-CA-1-SE, 1-AU-1-SE - see Figs 8.20, 8.24) are characterised by rich rugose/pustulose (with costellae and/or pustullae) assemblages of rugoglobigerinellids (*Archaeoglobigerina* and *Rugoglobigerina*) with abundant heterohelicids. Several small (<300µm in maximum diameter) rugose morphotypes [e.g., *Archaeoglobigerina blowi* Pessagno; *Archaeoglobigerina cretacea* (d'Orbigny); *Rugoglobigerina* ex gr. *rugosa* (Plummer); *Globotruncanella havanensis* (Voorwijk)] occur. Rugose keeled morphotypes [*Globotruncana aegyptiaca* Nakkady; *Globotruncana subcircumnodifer* (Gandolfi); *Globotruncanita* sp. cf. *G. calcarata* (Cushman), *Gansserina gansseri* (Bolli)] are recorded in variable numbers in outer neritic environments. Outer neritic-upper bathyal environments (e.g., wells 1-CA-1-SE, 1-SES-1A, 1-SES-9, Figs 8.20-21, 8.23-24) have sporadic rugose and non-rugose assemblages of keeled-planktonic morphotypes (*Gansserina*, *Globotruncana*, *Globotruncanita*, *Contusotruncana*), but all with low to moderately high trochospire. Specimens of rugoglobigerinellids, archaeoglobigerinellids and heterohelicids, larger-sized (>300µm in maximum diameter) and in variable numbers, occur associated with these assemblages. Middle-lower bathyal environments, from Campanian-Maastrichtian sections in distal offshore sites (wells 1-SES-3, 1-SES-24; see Figs 8.22, 8.24), yield abundant and high-diversity planktonic assemblages, together with several high trochospiral morphotypes [e.g., *Contusotruncana contusa* (Cushman), *Contusotruncana* ex gr. *fornicata* (Plummer) and *Contusotruncana patelliformis* (Gandolfi)], in lower numbers. Rare high trochospiral specimens of *Contusotruncana* ex gr. *fornicata* are further recorded from a scattered occurrence in an early-middle Maastrichtian upper bathyal section (well 1-SES-9; Fig. 8.24).

The characteristic patterns of distribution of the Cretaceous planktonic assemblages of Sergipe are, therefore, further evidence for the water-mass stratification of these foraminiferal communities in distinctive pelagic niches, which supports the conclusions of several previous authors.

5.5 - LOW-OXYGEN TOLERANT FORAMINIFERAL ASSEMBLAGES

Distinctive sedimentological, geochemical, isotopic and micropalaeontological responses characterise the nature of sediments deposited under hypoxic/anoxic bottom conditions during the mid-Cretaceous of the world's basins (e.g., Bernhard, 1986; Arthur et al., 1987; Schlanger et al., 1987; Jarvis et al., 1988 a, b; and references therein for review). Both the relative position of the mid-Cretaceous oxygen minimum zone and the degree of oxygen depletion seem to have had a differential effect on the selection (morphotypic composition), diversity, abundance and specimen sizes of the foraminifera in the water column and on the sea floor. The distribution characteristics of foraminiferal assemblages (primarily controlled by patterns of community trophic structures) permit an estimation of the extent of the oxygen-minimum layer over the shelf and slope, and an evaluation of the degree of oxygen depletion in the water column. The recognition of distribution patterns of low-oxygen tolerant microfauna is, therefore, of primary importance in evaluating and reconstructing the regional palaeoceanographic settings where such events took place.

5.5.1 - The upper Aptian to Albian succession

The upper Aptian-Albian succession is exemplified by the lower sections of wells 1-CA-1-SE, 1-CN-1-SE and 1-US-1-SE (Chapter 8; Figs 8.3-5. The microfossil content is characteristicaly rich in planktonic foraminiferal assemblages of globular chambered specimens with trochoidal, planispiral and, very rarely, biserial tests (favusellids, other hedbergellids, ticinellids, globigerinelloidids and heterohelicids). Such microfossil patterns are characteristic of water masses with well-oxygenated epipelagic layers. Impoverished, low-diversity, benthonic microfaunas, with limited intraspecific variations and variable numbers of agglutinated individuals (c. 20-100% in the upper Aptian-middle Albian), are typical features of low-oxygen biotopes. The benthonic foraminiferal morphotypes found (in variable assemblages of few mixed taxa per sample) in late Aptian-Albian sediments deposited in dysaerobic (>0.1-1.0ml oxygen/l water) to quasi-anaerobic (>0-0.1ml/l) bottom conditions are presented in Table 5.2(A-B). The assemblages are, in several ways, similar to the foraminiferal morphotypes recovered from Cenomanian-Turonian oxygen depleted sediments.

Palaeo-environments	Inferred Oxygen Levels	Microfauna
shallow-middle neritic	dysaerobic (TOC near 1%)	alabaminids [*Gyroidinoides* ex gr. *nitida*], conorboidids [*Conorboides* ex gr. *minutissima*], gavelinellids [*Gavelinella berthelini-Gav. plummerae-Gav. reussi* plexus], patellinids [*Patellina subcretacea*], polymorphinids [*Globulina prisca*], coiled vaginulinids [*Lenticulina* ex gr. *rotulata*, *Lenticulina* ex gr. *subangulata*, *Lenticulina* sp. A], ammodiscids [*Ammodiscus tenuissimus*] and eggerellids [*Marssonella kummi*, *Marss.* trochus var. *oxycona*, *Marss. trochus* var. *turris*].
middle-deep neritic	dysaerobic (TOC near 1%)	alabaminids [*Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*], gavelinellids [*Gavelinella barremiana-Gav. flandrini* plexus, *Gavelinella berthelini-Gav. plummerae-Gav. reussi* plexus], globorotalitids [*Globorotalites* ex gr. *micheliniana*, *Glob'tes* sp. cf. *G. multisepta*], coiled vaginulinids [*Lenticulina* ex gr. *gaultina*, *Lent.* ex gr. *rotulata*, *Lent.* ex gr. *subangulata*], egerellids [*Marssonella kummi*, *Marssonella trochus* var. *oxycona*], spiroplectamminids [*Quasispiroplectammina* ex gr. *alexanderi*], textulariids [*Textularia* ex gr. *subconica*, *Text. minuta*], trochamminids [*Trochammina gatesensis*, *Troch. minuta*], pseudogaudryinids [*Pseudogaudryinella/Spiroplectinata* ex gr. *dividens*], verneuilinids [*Eggerellina mariae*, *Gaudryinopsis filiformis*, *Gaudryinopsis* sp. cf. *G. gradata*] and valvulamminids [*Valvulammina(?)* sp.A].
	dysaerobic/ quasi-anaerobic (TOC near 2%)	alabaminids [*Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*], coiled vaginulinids [*Lent.* ex gr. *rotulata*, *Lent.* ex gr. *nodosa*], eggerellids [*Marss. trochus* var. *oxycona*, *Marss. trochus* var. *turris*], spiroplectamminids [*Quas.* ex gr. *alexanderi*, *Quas. linki*], textulariids [*Textularia* ex gr. *subconica*], trochamminids [*Trochammina gatesensis*], verneuilinids [*Gaudryinopsis filiformis*].

TABLE 5.2(A): Upper Aptian-Albian foraminiferal assemblages from hypoxic shallow to deep neritic environments.

Palaeo-environments	Inferred Oxygen Levels	Microfauna
deep neritic - upper bathyal	dysaerobic/ quasi-anaerobic (TOC near 2%)	alabaminids [*Gyroidinoides* ex gr. *globosa*, *Gyr'des* ex gr. *nitida*], coiled vaginulinids [*Lenticulina* ex gr. *gaultina*, *Lent.* ex gr. *rotulata*, *Lent.* ex gr. *subangulata*], ammodiscids [*Ammodiscus incertus*, *Glomospirella gaultina*], bathysiphonids [Bathysiphon ex gr. *vitta*], eggerellids [*Marssonella kummi*, *Marss. oxawai*, *Marss. trochus* var. *turris*], ammosphaeroidinids [*Budashevaella nonioninoides*], lituotubids [*Trochamminoides* sp. cf. *subcoronata*, *Trochamminoides* sp. A], hippocrepinids [*Hyperammina* ex gr. *gaultina*] and verneuilinids [*Gaudryinopsis filiformis*].
	quasi-anaerobic (TOC ranging 1-4% and higher)	bathysiphonids [*Bathysiphon* ex gr. *vitta*], ammosphaeroidinids [*Budashevaella nonioninoides*], hippocrepinids [*Hyperammina* ex *gaultina*] and verneuilinids [*Gaudryinopsis filiformis*].

TABLE 5.2(B): Albian foraminiferal assemblages from hypoxic deep neritic to upper bathyal environments.

Decreasing oxygen levels in bottom waters, at or near the sediment/ water interface, seem to have had a differential effect on the benthonic foraminiferal communities, contributing to a progressive impoverishment (in diversity and total abundance) and test-size diminution of the calcareous assemblages. A maximum in oxygen depletion (dysaerobic to anaerobic conditions) occurred during late Aptian-earliest Albian times, in middle-deep neritic to upper bathyal settings (e.g., Figs 8.3-5, 8.10). This event is characterised by organic-rich (TOC 2-12%, high hydrogen -HI- and low oxygen indexes - Chapter 8, section 8.2.4) dark grey marls and calcareous black shales containing a very impoverished low-diversity benthonic microfauna of calcareous (alabaminids - CH-A.3, and coiled vaginulinids - CH-A.6) and agglutinated foraminifera [usually represented by bathysiphonids, hippocrepinids - AG-C, ammosphaerodinids and eggerellids - AG-B.2, with minor occurrences of lituotubids - AG-B.2, spiroplectamminids, textulariids, verneuilinids - AG-A, and trochamminids - AG-B.1]. Some benthonic foraminifera genera (e.g., <u>Gyroidinoides</u>, <u>Lenticulina</u>) and most of the planktonic specimens show corrosion spots in their tests with pyrite infilling of the cavities. Such features are probably due to post-mortem dissolution under reducing conditions, shortly after burial or during the early stages of diagenesis of the more susceptible (thinner and porous) calcareous tests. A "residual" microfauna composed exclusively by agglutinated forms (ammosphaeroidinids, bathysiphonids, hippocrepinids, verneuilinids and textulariids) characterises the darker, less calcareous layers. Agglutinated foraminifera are both solution-resistant and have greater tolerance to poorly-oxygenated conditions and low pH (e.g., Saidova, 1960, 1965; Moorkens, 1976; Berggren, 1984). Sediments with no benthonic specimens and a rich planktonic biota suggest deposition under highly oxygen-depleted bottom conditions but with well oxygenated epipelagic layers above.

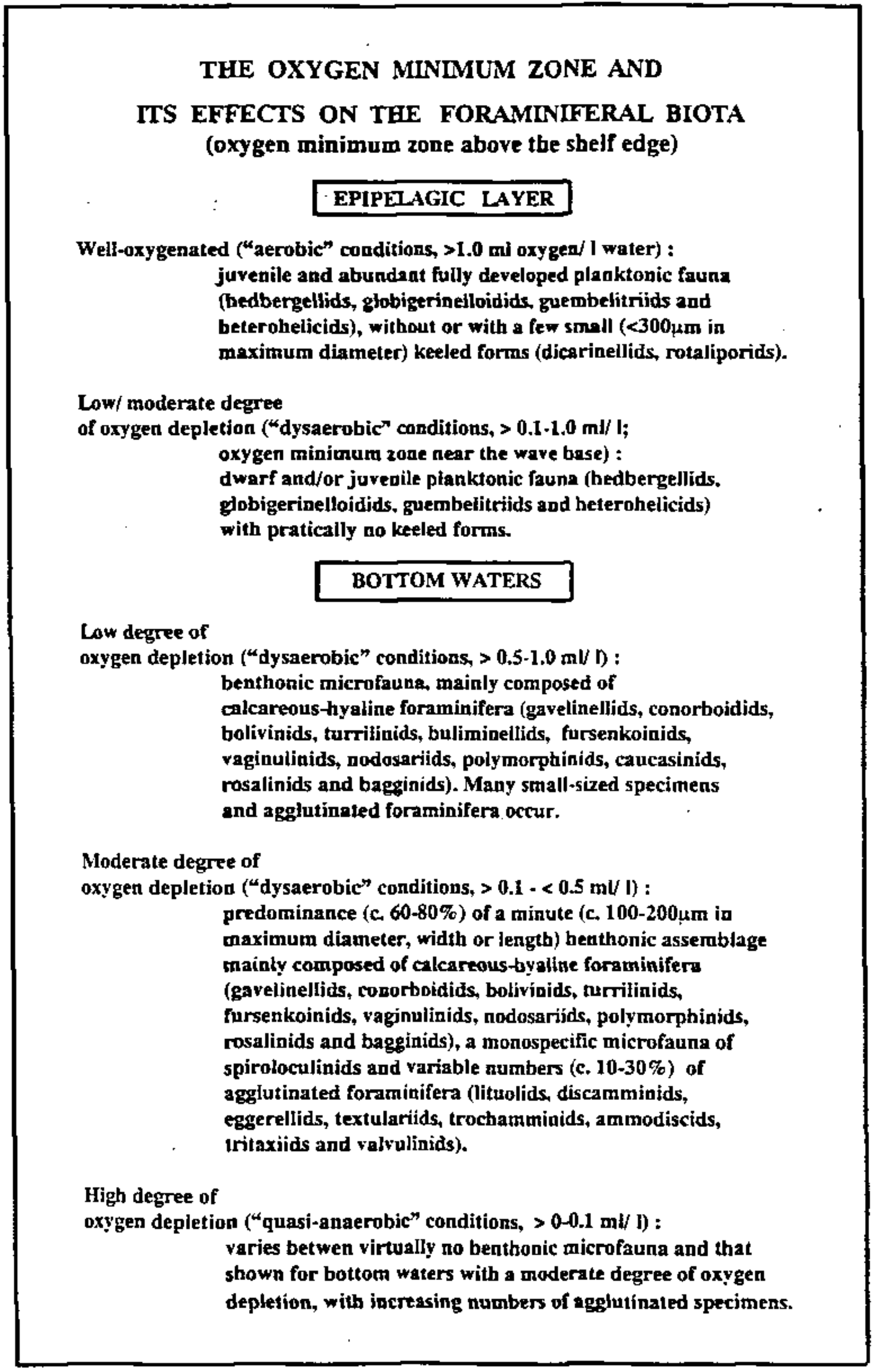
Waning hypoxic/anoxic conditions (dysaerobic to aerobic) are apparent towards the upper Albian succession of the Sergipe Basin. These are characterised by sediments with moderate to low TOC contents (around and lower than 1%) containing a slightly more diversified benthonic assemblage of calcareous foraminifera (represented mostly by gavelinellids, alabaminids, bagginids, conorboidids, epistominids, globorotalitids, patellinids, spirillinids, turrilinids, vaginulinids - CH-A, nodosariids, polymorphinids, turrilinids -

CH-B) with fewer agglutinated specimens (mostly eggerellids, bathysiphonids and verneuilinids) - (Figs 8.3-5).

5.5.2 - The Cenomanian to Turonian succession

Two maxima in oxygen depletion are apparent in the Cenomanian-Turonian succession: one in the lower Cenomanian and another in the uppermost Cenomanian-lowermost Turonian. The early Cenomanian event is exemplified by the section of well 1-CN-1-SE. The moderately organic-rich (TOC about 1.2-1.8% - HI 450-500) calcareous mudstones and shales contain a benthonic microfauna is composed by gavelinellids (*Gavelinella berthelini*-*Gav. plummerae*-*Gav. reussi* plexus, CH-A.1), globorotalitids (*Globorotalites* ex gr. *michelinianus*, CH-A.4), coiled vaginulinids [*Lenticulina* ex gr. *rotulata*, *Planularia complanata* (Reuss) - CH-A.6], nodosariids (*Dentalina communis* d'Orbigny, CH-B.3), cibicidids (*Cibicides* sp. A, CH-A.4) and buliminellids (*Quadratobuliminella* sp. A, CH-B.4). Rare eggerellids (*Marssonella trochus* var. *turris* - AG-A) also occur. This section is interpreted to have been deposited in a deep neritic environment with moderately dysaerobic bottom conditions and well oxygenated epipelagic water-masses. Further up in the lower Cenomanian sequence, represented in the section of well 1-CA-1-SE (Fig. 8.13), moderately to high organic-rich (TOC about 1-2.7% - HI 120-400) strata were deposited under dysaerobic/anaerobic bottom conditions in deep neritic to upper bathyal environments. No benthonic microfossils is recovered from the lower part, which contains only planktonic species [hedbergellids: *Hedbergella* (*H.*) ex gr. *delrioensis*, *Hedbergella* (*H.*) ex gr. *planispira* (Tappan); heterohelicids: *Heterohelix* ex gr. *globulosa* (Ehrenberg), *Het. moremani* (Cushman); and radiolarians]. The upper section yields an impoverished, low-diversity benthonic assemblage represented by rare gavelinellids (*Gavelinella berthelini* - *Gav. plummerae* - *Gav. reussi* plexus, CH-A.1) and nodosariids (*Nodosaria* ex gr. *obscura* Reuss, CH-B.3).

Latest Cenomanian-earliest Turonian low-oxygen tolerant foraminiferal assemblages were recovered from well-sections (e.g., well 1-CA-1-SE, Fig. 8.13) and from outcrops (uppermost Cenomanian: locality A-9; lowermost Turonian: localities A-2, A-22 and A-35). An abundant and moderately diversified planktonic microfauna was present throughout that time interval.



THE OXYGEN MINIMUM ZONE AND
ITS EFFECTS ON THE FORAMINIFERAL BIOTA
(oxygen minimum zone above the shelf edge)

EPIPELAGIC LAYER

Well-oxygenated ("aerobic" conditions, >1.0 ml oxygen/ l water) :
juvenile and abundant fully developed planktonic fauna (hedbergellids, globigerinelloidids, guembelitriids and heterohelicids), without or with a few small (<300μm in maximum diameter) keeled forms (dicarinellids, rotaliporids).

Low/ moderate degree of oxygen depletion ("dysaerobic" conditions, > 0.1-1.0 ml/ l; oxygen minimum zone near the wave base) :
dwarf and/or juvenile planktonic fauna (hedbergellids, globigerinelloidids, guembelitriids and heterohelicids) with pratically no keeled forms.

BOTTOM WATERS

Low degree of oxygen depletion ("dysaerobic" conditions, > 0.5-1.0 ml/ l) :
benthonic microfauna, mainly composed of calcareous-hyaline foraminifera (gavelinellids, conorboidids, bolivinids, turrilinids, buliminellids, fursenkoinids, vaginulinids, nodosariids, polymorphinids, caucasinids, rosalinids and bagginids). Many small-sized specimens and agglutinated foraminifera occur.

Moderate degree of oxygen depletion ("dysaerobic" conditions, > 0.1 - < 0.5 ml/ l) :
predominance (c. 60-80%) of a minute (c. 100-200μm in maximum diameter, width or length) benthonic assemblage mainly composed of calcareous-hyaline foraminifera (gavelinellids, conorboidids, bolivinids, turrilinids, fursenkoinids, vaginulinids, nodosariids, polymorphinids, rosalinids and bagginids), a monospecific microfauna of spiroloculinids and variable numbers (c. 10-30%) of agglutinated foraminifera (lituolids, discamminids, eggerellids, textulariids, trochamminids, ammodiscids, tritaxiids and valvulinids).

High degree of oxygen depletion ("quasi-anaerobic" conditions, > 0-0.1 ml/ l) :
varies betwen virtually no benthonic microfauna and that shown for bottom waters with a moderate degree of oxygen depletion, with increasing numbers of agglutinated specimens.

TABLE 5.3: Tentative correlation among the relative position of the oxygen minimum zone, the degree of oxygen depletion and their effect on the selection and abundance of foraminiferal assemblages (patterns observed in the uppermost Cenomanian-lowermost Turonian succession of the Sergipe Basin).

The planktonic foraminifera are mostly represented by hedbergellids [Hedbergella (H.) ex gr. delrioensis, Hedbergella (H.) ex gr. planispira, Hedbergella (H.) ex gr. simplex (Morrow), Hedbergella (W.) aprica (Loeblich & Tappan), Hedbergella (W.) archaeocretacea Pessagno, Hedbergella (W.) baltica Douglas & Rankin, Hedbergella (W.) brittonensis Loeblich & Tappan, Hedbergella (W.) paradubia Sigal], rare and small (about 295μm in maximum diameter) keeled morphotypes (rotaliporids: Rotalipora greenhornensis (Morrow) - uppermost Cenomanian]. Abundant and well diversified radiolarians (spumellarian and nassellarian forms) and diatoms also occur (see Chapter 7, Figs 7.1-2). The assemblages from hypoxic deep neritic to upper bathyal benthonic biotopes have a predominance (c. 40-60%) of gavelinellids [Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus, Lingulogavelinella(?) sp. cf. L. thalmanniformis (Plotnikova), Lingulogavelinella tormarpensis (Brotzen)], conorboidids [Conorboides ex gr. minutissima (Tappan)], rosalinids [Gavelinopsis (?) sp. A] and bagginids (Valvulineria sp. A) - CH-A.1-2, with variable numbers (c. 10-30%) of turrilinids [Praebulimina ex gr. nannina (Tappan), Neobulimina minima Tappan], bolivinids [Gabonita levis (de Klasz, Marie & Rérat), Gab. obesa (de Klasz, Marie & Rérat)], buliminellids (Buliminella sp. A), fursenkoinids [Cassidella ex gr. viscidus (Khan), Coryphostoma sp. B], caucasinids (Caucasina sp. A) - CH-B.4-5, polymorphinids [Globulina lacrima Reuss, Globulina prisca Reuss] - CH-B.1, spirillinids [Spirillina minima Schacko, Turrispirilina subconica Tappan] - CH-A.8, smooth nodosariids [Dentalina vistulae Pozaryska, Nodosaria ex gr. obscura Reuss] - CH-B.3, coiled vaginulinids [Lenticulina ex gr. rotulata, CH-A.6; (c. 5-10%)], together with a monofauna of spiroloculinids [Spiroloculina sp. A, CP-A; (about 5%)]. Agglutinated specimens (lituolids: Ammobaculites impexus Eicher, Ammomarginulina paterella Eicher; eggerellids: Marssonella kummi; textulariids: Textularia ex gr. subconica Franke; valvulinids: Tritaxilina(?) sp. A - AG-A; discamminids: Discammina sp. A and trochamminids: Trochammina sp. A - AG-B.1] also occur in variable numbers (c. 10-30%), in deeper (upper slope) siliciclastic environments of the uppermost Cenomanian. Minute calcareous-hyaline benthonic foraminifera (less than 200μm in maximum diameter, width or length) dominated (about 60-80%) during times of more intense and widespread oxygen depletion (long-term dysaerobic/quasi-anaerobic episodes; e.g., locality A-9, uppermost Cenomanian, Fig. 8.12) -

see Table 5.3. Highly oxygen-depleted bottom conditions are marked by the absence of benthonic microfauna (e.g., earliest Turonian section of well 1-CA-1-SE; see Fig. 8.13).

5.5.3 - Previous studies of benthonic foraminifera from mid-Cretaceous hypoxic/anoxic environments

Several studies have reported benthonic foraminiferal assemblages recovered from mid-Cretaceous hypoxic sediments in most oceanic and ensiatic basins. The following discussion presents a brief account of the more recent studies in order to evaluate the similarities in the distribution of low-oxygen tolerant benthonic foraminiferal assemblages.

5.5.3.(i) - northern South Atlantic

Through petrographic microbiofacies studies of finely laminated marls and shales from the upper part of the Macaé Formation in the Campos Basin, southeastern Brazil, Dias-Brito (1982) reported a benthonic assemblage, of uncertain Cenomanian age, composed of rare coiled vaginulinids and other undifferentiated calcareous-hyaline benthonics and textulariids, in an environment with hypoxic bottom conditions. In the Cenomanian to early Turonian(?) succession of the northern area of Campos Basin, Koutsoukos (1984) documented hypoxic marine deposits of marls and shales characterised by a scarce and low-diversity benthonic microfauna composed of bolivinids (*Bolivina*), turrilinids (*Neobulimina*), coiled vaginulinids (*Lenticulina*), polymorphinids (*Guttulina*), alabaminids (*Gyroidina*), anomalinids (*Anomalinoides*), and agglutinated specimens (eggerellids: *Marssonella*; haplophragmoidids: *Haplophragmoides*). From the latest Cenomanian-earliest Turonian deposits of the eastern area of Campos Basin, Azevedo *et al.* (1987) also gave account of the occurrence of coiled vaginulinids (*Lenticulina*), lagenids (*Lagena apiculata*), gavelinellids (*Gavelinella*), alabaminids (*Gyroidina*, *Gyroidinoides* aff. *praestans*), globorotalitids (*Globorotalites micheliniana*), pleurostomellids (*Pleurostomella*), and turrilinids, with a predominance of agglutinated foraminifera (haplophragmoidids: *Haplophragmoides*; trochamminids: *Trochammina*; lituolids: *Ammobaculites*; valvulinids: *Clavulina gabonica*; eggerellids: *Marssonella* trochus (d'Orbigny) var. oxycona (Reuss), and small-sized ammodiscids: Ammodiscus and Glomospira). A specialised monofauna of turrilinids [Neobulimina albertensis(?)] was also recorded from black shale deposits formed under quasi-anaerobic conditions (Azevedo et al., op. cit.).

Viviers (1986), in a study of the Cretaceous of Santos Basin, southeastern Brazil, reports from Cenomanian-middle Turonian deposits the almost complete absence of benthonic fauna. Organic-rich black shales (up to 3.5% of TOC), of middle neritic and upper bathyal environments, only yield rare coiled vaginulinids, turrilinids or small-sized agglutinated specimens (textulariids). From Turonian sediments drilled offshore the Pará and Maranhão basins, Brazilian equatorial continental margin, Beurlen & Regali (1987) reported sections with moderate dysaerobic conditions characterised by the paucity of benthonic assemblages (calcareous-hyaline and agglutinated foraminifera) and abundance of planktonic specimens.

Petters (1983b) reported that during the mid-Cretaceous in the Benue Trough, Nigeria, there were deposited organic-rich (up to 7.4% of TOC) dark gray and black laminated shales of the Nkalagu Formation. Its sediments generally contain an exclusive planktonic foraminifera assemblage and, sometimes, dwarfed, low-diversity benthonic microfauna, which suggested deposition in a highly oxygen-depleted basin. Nyong & Ramanathan (1985) documented from the Calabar Flank, SE Nigeria, three episodes of oxygen-deficient bottom conditions during the late Albian, Cenomanian-Turonian and late Campanian. The foraminiferal assemblages recovered from the organic-rich sediments presented the following features: planktonic foraminifera in flood abundances (in some sections the only microfauna to be recovered); the benthonic foraminifera (when present) were generally represented by agglutinated specimens (lituolids: Ammobaculites; trochamminids: Trochammina; and spiroplectaminids: Spiroplectammina), with rare, rather poorly preserved, calcareous benthonic foraminifera including single species of bolivinids (Gabonita), coiled vaginulinids (Lenticulina) and gavelinellids (Gavelinella).

More recently Herbin et al. (1987), Jacquin & Graciansky (1988) and Magniez-Jannin & Jacquin (1988), through a study of several Cretaceous sites of the D.S.D.P. and O.D.P., documented the occurrence of two periods of black shale deposition in the northern South Atlantic, the first extending from the late Jurassic to the middle Albian, in part, and the second from the late Cenomanian to the early Santonian. The first hypoxic/anoxic episode is thought to have resulted from the confined, euxinic nature of diverse basinal settings, developed during the terminal phases of rifting and early sea-floor speading (Jacquin & Graciansky, op. cit.). The second period, with an oxygen depletion maximum in the early-middle Turonian, was characterised by a rhythmicity of carbonate levels (marls or white calcareous mudstones), rich in benthonic and planktonic microfauna and mudstones with residual organic matter, with rare benthonic foraminifera (essentialy agglutinated specimens), in middle bathyal to abyssal environments. This rhythmicity in the organic-carbon level and carbonate content was interpreted to result from cyclic fluctuations of the reducing bottom conditions due to cyclic variations in the depth of the mid-water oxygen-minimum zone (Jacquin & Graciansky, op. cit.).

5.5.3.(ii) - North Atlantic and Mediterranean Area

Hart & Bigg (1981) carried out a detailed investigation of the 'Black Band' level of carbonaceous mudstone from several localities in the chalk succession (Lincolnshire, U.K.). It was shown that the chalks are associated in some cases with a foraminifera microfauna dominated by planktonic species, with over 90% of the 250-500µm size fraction consisting of hedbergellids [*Hedbergella* (*Hedbergella*) and *H.* (*Whiteinella*)] with rare keeled species (*Rotalipora*, *Praeglobotruncana* and *Dicarinella*). In the 'Black Band' itself only a poor agglutinated microfauna assemblage of ammodiscids [*Ammodiscus cretaceus* (Reuss), *Glomospira corona* Cushman & Jarvis] and rzehakinids [*Psamminopelta bowsheri* Tappan] is recorded, indicating a drastic change to highly oxygen depleted bottom conditions. More recently, specimens of bolivinids (*Brizalina*), gavelinellids (*Gavelinella*) and ammodiscids (*Ammodiscus*) have been reported by Brasier & Young (oral communication, Boulder, Colorado, May 1988) to occur in the 'Black Band' sections of Humberside, northeast England. More recently, Jarvis *et al.* (1988) documented the effects of the Cenomanian-Turonian Oceanic Anoxic Event (OAE) in the Chalk Sea of NW Europe. All microfossil groups display uppermost Cenomanian abundance and diversity minima, closely corresponding to the a positive carbon stable-isotope peak. The low-oxygen tolerant microbenthos are mostly characterised by gavelinellids (*Gavelinella berthelini*, *Lingulogavelinella globosa*), smooth coiled vaginulinids (*Lenticulina* spp.) and textulariids (*Textularia chapmani*).

The Cenomanian-Turonian stratigraphic sequence of the Menoyo section, Alava, South Spain, was documented by Lamolda (1978). Although no geochemical or isotopic study has been carried out, in order to position and estimate the influence of the oxygen-minimum zone, the changes in the benthonic foraminiferal population follow a similar pattern to the regions further North (e.g., southern England) after the extinction of Rotalipora cushmani (Morrow), with the same morphotypes (Lamolda, personal communication, December 1987).

Reiss (1988) reported benthonic foraminifera assemblages and high-productivity palaeo-environments from Coniacian-Maastrichtian marine formations in Israel. The microfauna varied from highly diverse epi-/infaunal assemblages (mainly gavelinellids, in places apparently high-fertility related, large vaginulinids, nodosariids and occasionally more frequent Textulariidae, as well as some infaunal buliminaceans), in more aerated areas, to extremely low diversity, nearly exclusively infaunal, euryoxic (and detritus-bacteria feeding) buliminaceans (Praebulimina, Neobulimina) in dysaerobic to quasi-anaerobic environments.

From the Greenhorn Formation, Pueblo, Colorado, North America, Leckie (1985) reports from samples very close to the Cenomanian-Turonian boundary a low diversity and depauperate assemblage dominated by turrilinids (Neobulimina albertensis, with a minor component of Praebulimina fabilis) and gavelinellids (Gavelinella dakotensis; a synonym of the Gavelinella berthelini-Gav. plummerae-Gav. reussi plexus). Earliest Turonian samples yielded a recovery microfauna with increased diversity and, also present in the same assemblage as above, occur gavelinellids (Lingulogavelinella newtoni), bagginids (Valvulineria loetterlei), and turrilinids (Neobulimina canadensis-prolixa group). In the Cenomanian Mancos Shale, New Mexico and Arizona, Bernhard (1986) distinguished an assemblage dominated by gavelinellids (Gavelinella dakotensis), turrilinids (Neobulimina canadensis), nodosariids (Dentalina basisplanata), and uncoiled vaginulinids (Citharina kochii). Most taxa lack ornamentation.

In a study of the Cretaceous marine succession of Trinidad, Koutsoukos & Merrick (1986) recognised several specialised assemblages of foraminifera, radiolarians and microgastropods that thrived in widespread oxygen depleted sediments of Barremian, Aptian, Cenomanian and Turonian ages and, in sporadic horizons, from the late Santonian to Maastrichtian. Sediments of middle-late Cenomanian and Turonian ages yielded a low diversity benthonic foraminifera biota composed of coiled vaginulinids (Lenticulina), nodosariids (Dentalina, Nodosaria), and osangulariids (Osangularia) with rare agglutinated specimens (eggerellids: Marssonella trochus var. oxycona).

5.5.4 - Hypoxia and the Foraminiferal Response

The response of the benthonic foraminiferal assemblages to low-oxygen conditions is primarily dictated by two factors: (i) overall patterns of community trophic strategy; (ii) intensity, rate of change and duration of the event (e.g., Tables 5.2-4). Oxygen depleted water masses are usually a consequence of eutrophic epipelagic conditions (e.g., Rosenberg & Loo, 1988). High epipelagic productivity contributes to high levels of nutrient fall in the form of particulate organic material and induce oxygen deficiency on bottom waters. Deposited organic matter and bacteria are the primary trophic resources for the microbenthos thriving under such conditions. Therefore, specimens with morphological adaptations to a deposit feeding strategy are naturally favored. Furthermore, deposit feeders commonly inhabit microhabitats where oxygen levels are lower than at the sediment-water interface.

Most of the benthonic communities that thrived in these environmentally-stressed conditions had a predominantly "semi-epifaunal" (partially-buried and shallow burrowers in soft muddy substrates) or infaunal life position and were deposit feeders (grazing herbivores/detritivores or bacterial/detrital scavengers) - (see Fig. 5.11). This would certainly have accounted for their suitability to survive in low-oxygen (dysaerobic/quasi-anaerobic) environments, as these conditions are naturally found in the sediment as a result of the oxygen stratification of interstitial waters. As depth below the water-sediment interface increases, the firmness of the sediment (due to compaction and dewatering) increases and the oxygen content of interstitial waters drops drastically, and in virtually all sedimentary deposits there is a level that represents a redox boundary, below which the interstitial water is essentially devoid of free oxygen (Ekdale, 1985). This redox boundary results from oxygen depletion by organic decomposition within the sediment and lack of sufficient interstitial

SEDIMENTOLOGICAL, GEOCHEMICAL AND ISOTOPIC EVIDENCE

aerobic	dysaerobic to quasi-anaerobic
. variable biotic composition; function of changes in bathymetry and related parameters (substrate, temperate, nutrient supply, etc.)	. more consistent biotic composition; varies according to changes in oxygen content, calcium carbonate availability and bathymetry
. high diversity	. low diversity
. common intraspecific variations	. limited intraspecific variations
. variable morphotypes	. selected morphotypes
. low dominance	. high dominance
. high abundance	. variable abundance
. specimens of normal-sized tests dominate	. mixed test-sizes . specimens of minute test-sizes (c. 100-200µm in maximum diameter, width or length) dominate during dysaerobic/quasi-anaerobic conditions
. "r-" and "k-selected" specimens	. "r-selected" (opportunistic) specimens are the survivors and the first to colonise . "k-selected" (equilibrium) taxa appear in modest numbers, slowly occupying the few available niches
Trophic structure: complex (mixed groups of specialised feeding strategies)	Trophic structure: selected groups (omnivorous deposit feeders are favoured)
Substrate type: variable	Substrate type: fine-grained calcareous and siliceous muds

TABLE 5.4: General characteristic patterns of occurrence of benthonic foraminiferal assemblages in relation to oxic (aerobic) and hypoxic (dysaerobic to quasi-anaerobic) bottom conditions.

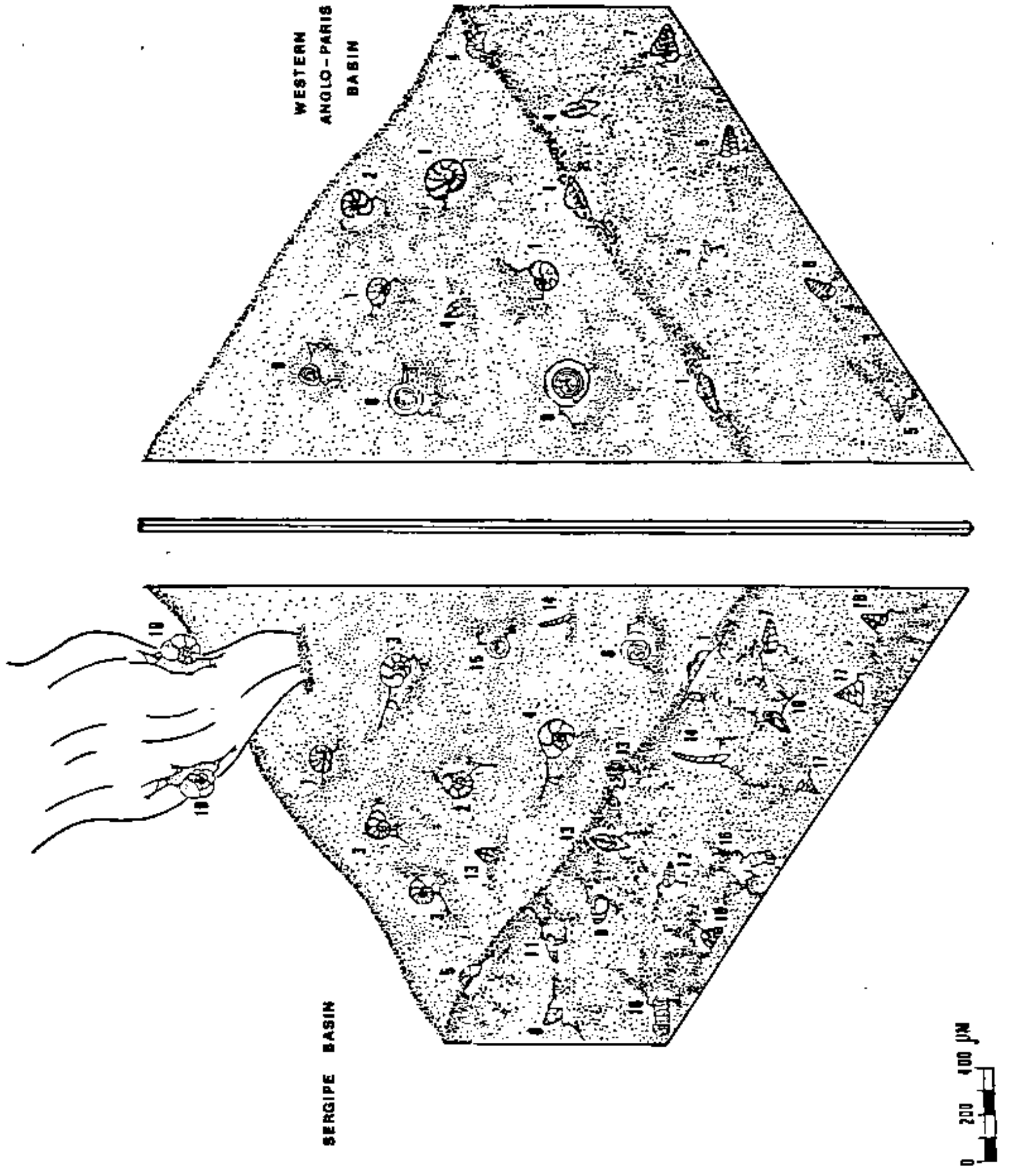


FIGURE 5.11: Idealised palaeo-environmental reconstructions of the sea bottom (deep neritic to upper bathyal environments) under oxygen depleted (dysaerobic) pelagic conditions in the Sergipe Basin and the western Anglo-Paris Basin (southern England), during the latest Cenomanian-earliest Turonian, depicting the characteristic foraminiferal taxa that were usually present. Dwelling habits are mostly conjectured.

circulation to renew the oxygen in the sediment from aerobic bottom waters. The water content of the sediments is also sharply reduced with depth in the sediment, which reflects increased grain packing and loss of pore water. However, in environments dominated and reworked by epi-/infaunal deposit feeders, the water and oxygen contents of the uppermost sediment layers are greatly increased.

Foraminiferal assemblages adapted to a predominantly infaunal or "semi-epifaunal" dwelling habit could, therefore, have a stronger tolerance to oxygen depleted conditions at the sediment-water interface. They would provide the assemblages for the initial recolonisation of all niches with the return to normal oxygen levels. Similar patterns have also been recorded with metazoan animals. Dysaerobic environments have a greater dominance by infauna and lower diversity than communities in well-oxygenated (aerobic) conditions (Byers, 1977).

The behavioural structure (inferred mode of life versus habitat) of the foraminiferal assemblages may also permit interpretation of community strategies in terms of adaptation rate and selection response to variable environmental conditions (i.e., "r-selectionn" vs. "K-selection"; cf. Pianka, 1970; Levinton, 1970; Ekdale, 1970). "Opportunistic" ("r-selected") taxa include those specimens that exhibit high reproductive rates (short ontogenetic cycle), high growth rates, broad environmental tolerances and generalised feeding strategies (Pianka, 1970; Levinton, 1970). Such opportunist specimens are usually the first settlers to attempt to colonise a habitat after a major environmental change (e.g., expansion of the oxygen minimum zone and intensification of oxygen depletion) or are the specimens that thrive in high-stress and/or low-resource (oligotrophic) environments (Ekdale, 1985). The r-selected foraminiferal assemblages have commonly low-diversity, high abundance and dominance of few taxa. On the other hand, "equilibrium" ("K-selected") species are those which are rather slow to colonise new environments but are adaptively superior in the long run to the more rapidly colonising opportunists (Pianka, 1970; Levinton, 1970). Relative to r-selected taxa, K-selected taxa generally exhibit lower reproductive and growth rates, and their environmental tolerances are much narrower. Equilibrium species usually are rather specialised feeders, which have adapted to occupy very specialised niches. They, typically, are individuals of high-diversity, persistent, climax communities. Although they cohabit and share available resources with many different taxa, individual species abundances and population densities generally are low. No single taxon dominates the assemblage (Ekdale, op. cit.).

The microfauna recovered from latest Cenomanian-earliest Turonian oxygen depleted (dysaerobic) outer shelf-upper bathyal environments are represented by low-diversity, epi-/infaunal deposit-feeding species, with limited intraspecific variation. The most common and abundant calcareous (in decreasing order of abundance: **CH-A.1>A.2>B.4>A.6>CP-A>CH-B.5>CH-B.1>A.8>B.3**) and agglutinated morphogroups **(AG-A>B.1)** represent the r-selected, "opportunistic", stress-tolerant taxa that would be the pioneers to rapidly colonise newly available niches (see Tables 5.3-4).

Bernhard (1986) observed that modern organic-rich clays of small Antarctic hypoxic/anoxic basins have very high water contents and are floculent, producing indistinct sediment-water interfaces, and suggested (Bernhard, op. cit., p. 213) that "while small foraminifera of low density may interact successfully in this soupy low-oxygen zone, other larger, denser foraminifera could easily sink through it into the underlying anoxic sediments". Plano/concavo-convex, low trochospiral, broad and flattened morphologies in general would provide more surface area per unit volume than more inflated morphotypes, a feature which would decrease the rate of sinking into soft, floculent, muddy substrates and/or increase oxygen uptake (Bernhard, op. cit.). The occurrence in mid-Cretaceous low-oxygen deposits of low-diversity assemblages with the predominance of plano/spiro-convex and low trochospiral, epifaunal deposit-feeding calcareous-hyaline morphotypes, with variable numbers of tapered elongate, flattened-elongate infaunal deposit-feeders and lenticular, epifaunal/shallow infaunal taxa (e.g., Table 5.3, Fig. 5.11), would be, basically, the response to individual dwelling habits and community feeding strategies. Basic patterns in community trophic structures would, therefore, primarily dictate the composition of the biota after a major environmental turnover (Table 5.4).

Test size may also have had an indirect relationship with such oxygen depressed conditions. Bernhard (1986) reported foraminiferal assemblages with predominantly minute (c. 65-105μm in maximum diameter or length) calcareous-hyaline specimens from Albian (D.S.D.P. Site 465A) and Cenomanian (Mancos Shale, New Mexico and Arizona) dysaerobic/quasi-anaerobic sediments. Several layers from the Cenomanian-Turonian of

Sergipe also yield benthonic foraminiferal asssemblages dominated (about 60–80%, to over 90%) by minute (c. 100–200μm in maximum diameter, width or length) calcareous-hyaline morphotypes (e.g., locality A-9, uppermost Cenomanian - Fig. 8.12; see also Tables 5.3–4). This "dwarfism" could be either the result of enhanced reproductive rate (restricted ontogenesis) and early gametogenesis under optimal environmental conditions (nutrient availability, less competition - Bradshaw, 1957, 1961; Murray, 1963 - and scarce/absent predation by mud-eating macrobenthos - e.g., Phleger & Soutar, 1973; Douglas & Heitman, 1978; as suggested by the high foraminiferal abundance), or could reflect adverse (stunted growth), stressed environmental conditions (Lalicker, 1948b; Murray, op. cit.). However, the evidence from extant assemblages suggests that the first possibility is the most probable one (e.g., Bradshaw, 1961). Harman (1964) reported the presence of abundant foraminiferal assemblages from laminated sediments formed in water of oxygen content less than 0.1ml O_2/l within the slope and basin plain of the Santa Barbara Basin, California. Several dwarfed forms were observed to occur within the low-oxygen zone of the basin, "all of these species characterized by thin, fragile, test walls" (Harman, op. cit., p. 87) with no surface ornamentation. Phleger & Soutar (op. cit., p. 113) observed that "small size of specimens is a characteristic of large standingstocks of benthic foraminifera in areas of high production" and suggested that "this small size may be due to rapid reproduction under "optimum" conditions characterized by abundance of food". Foraminifera of minute tests have a lower oxygen consumption for metabolism than larger ones (Bradshaw, 1961), an important physiological prerequisite for survival under oxygen depleted environments, and a probable competitive advantage for these protozoas thriving under such conditions (Phleger & Soutar, op. cit.). Brasier (1982, p. 2) has also observed two general size-related trends in foraminiferal tests: "r-selection under unstable conditions, which favours small size as a consequence of high reproduction rates and precocious maturation; k-selection under predictable conditions, which favours large size as a consequence of low reproduction rates and delayed maturation". Therefore, the abundant assemblages of minute benthonic foraminifera from low-oxygen environments most likely represent r-selected individuals that reached maturation during earlier ontogenetic stages, in ideal conditions of plenty nutrient supply with less competition and predation.

The agglutinated assemblages appear not to be depressed by low-oxygen conditions but, on the contrary, occur mostly with normal sized tests and in proportionally higher numbers (c. 20–100% of the total benthonic assemblage in upper Aptian–lower Albian, and c. 10–30% in the uppermost Cenomanian–lowermost Turonian) with decreasing oxygen levels (Figs 8.3–5, 8.12, Table 5.3). It has been previously demonstrated that agglutinated foraminiferal assemblages are abundant in areas of poor circulation with low oxygen, high CO_2, low pH and a slightly negative redox-potential (Eh) at the sea floor (e.g., Butt, 1980; Wood, 1981; Miller et al., 1982; Gradstein et al., 1983; Berggren, 1984; Jones & Charnock, 1985; Jones, 1986; Hughes, 1988), which would, therefore, account for this distribution pattern.

5.6 - FORAMINIFERAL PALAEOCOMMUNITIES

Basically twelve distinctive benthonic foraminiferal palaeocommunities occur in the Cretaceous shelf and slope deposits of the basin and are summarised in Table 5.5. These have been recognised empirically from the distribution patterns (through time and space) of the assemblages. The palaeocommunities are characterised by the relative dominance of the major foraminiferal groups (i.e., gross relative percentage in the total assemblage greater than average) and related to variations in inferred trophic structures and substrate niche patterns (see Table 5.5). They are shown to intergrade in distribution, the extent of that depending upon the overall environmental conditions (Fig. 5.12).

5.6.1 - Trophic Groups and Substrates

Many authors (such as Peterson, 1911, 1913; Craig & Jones, 1966; Thorsen, 1966; Johnson, 1971; and, more recently, Buzas et al., 1989) have shown how in the present-day marine environment the distribution of the epifaunal and infaunal biota is primarily influenced by the nature of the substrate. Palaeocommunities dominated by epifaunal deposit feeders ("C1-C3, D, E") characterise soft, fine-grained calcareous muddy substrates - Tables 5.1, 5.5, Figs 5.1-2, 5.12. Soft siliceous muddy bottoms, of outer shelf-upper bathyal environments, were probably extensively reworked by the infaunal bacterial/detrital scavengers (B1). Deposit feeders (e.g., Palaeocommunities A2, B1-B2, C2-C3) are usually abundant where the food

FORAMINIFERAL PALAEOCOMMUNITIES AND TROPHIC STRATEGIES	ASSOCIATIONS		TIME-INTERVAL	PELAGIC CONDITIONS		DISTRIBUTION OF BIOTOPES	BIOTIC RESPONSE	
				Oxygen level	Nutrient level		Diversity	Selection
Infaunal deposit-feeding agglutinated foraminifera (AG-A), with minor assemblages of epifaunal deposit feeders (AG-B.1)	A 1	Lituolidae-Haplophragmiidae	late Aptian-earliest Albian	aerobic / dysaerobic	mesotrophic / eutrophic	paralic	oligotaxic	" K "
	A 2	Eggerellidae-Verneuilinidae-Textulariidae-Siproplectamminidae	late Aptian-middle Albian, latest Cenomanian	dysaerobic / quasi-anaerobic		middle/outer shelf to upper slope		" r "
Infaunal deposit-feeding calcareous-hyaline foraminifera (CH-B), with variable subordinate amounts of infaunal agglutinated (AG-A) and epifaunal calcareous-hyaline passive herbivores (browsers) and deposit feeders (CH-A)	B 1	Bolivinacea-Turrilinacea-Buliminacea	Campanian-Maastrichtian	aerobic	mesotrophic / oligotrophic	outer shelf to upper slope	polytaxic	" K "
			earliest Turonian	aerobic/ dysaerobic	mesotrophic / eutrophic		oligotaxic	" r "
	B 2	Polymorphinidae-Vaginulinidae-Nodosariidae	late Aptian-middle Albian			shelf	oligotaxic / polytaxic	" K "
Epifaunal deposit-feeding calcareous-hyaline foraminifera (CH-A), with less frequent assemblages of infaunal calcareous-hyaline (CH-B) and agglutinated (AG-A), and increasing numbers of epifaunal/shallow infaunal agglutinated (AG-B) deposit feeders in deeper environments	C 1	Epistomariidae-Osangulariidae-Alabaminidae	Campanian-Maastrichtian	aerobic	mesotrophic/ oligotrophic	upper slope	polytaxic	
	C 2	Gavelinellidae	Cenomanian-Coniacian	aerobic/ dysaerobic	mesotrophic / eutrophic	middle/ outer shelf - upper slope	oligotaxic	" r "
			late Aptian-Albian			inner/ middle shelf		" r " / " K "
	C 3	Alabaminidae-Vaginulinidae				outer shelf / upper slope		
Epifaunal/shallow infaunal deposit-feeding calcareous-hyaline foraminifera (CH-A.3, CH-B.3), with fewer infaunal agglutinated (AG-A) and calcareous-hyaline (CH-B) foraminifera	D	Gavelinellidae-Chilostomellidae-Quadrimorphinidae	Santonian -Maastrichtian	aerobic/ dysaerobic	oligotrophic	upper/ middle slope	oligotaxic/ polytaxic	" K "
Epifaunal/shallow infaunal deposit-feeding agglutinated foraminifera (AG-B.2-4), with fewer numbers of epifaunal/shallow infaunal calcareous-hyaline (CH-A.3,A.6,CH-B) and infaunal agglutinated deposit feeders (AG-A), and rare agglutinated suspension feeders (AG-C)	E1	Haplophragmoididae-Ammosphaeroidinidae-Verneuilinidae-Hormosinidae-Lituolidae	Santonian-Maastrichtian	aerobic / dysaerobic	oligotrophic	upper/ middle slope	oligotaxic	
	E2	Ammosphaeroidinidae-Verneuilinidae-Spiroplectamminidae	Albian	dysaerobic/ quasi-anaerobic	mesotrophic/ eutrophic	outer shelf/ upper slope		"r" / "K"
Suspension-feeding agglutinated foraminifera (AG-C) with less frequent epifaunal/shallow infaunal agglutinated deposit feeders (AG-B.2-4)	F	Bathysiphonidae-Hippocrepinidae-Ammodiscidae-Ammosphaeroidinidae-	Santonian-Maastrichtian	dysaerobic / quasi-anaerobic	oligotrophic	middle/ lower slope		"K"
			late Aptian-Albian		mesotrophic / eutrophic	upper slope		"r" / "K"
Mixed calcareous-hyaline foraminiferal assemblages with complex trophic structures (= mixed groups), high diversity and no dominance	G	Gavelinellidae-Bolivinacea-Turrilinacea-Buliminacea	Campanian-Maastrichtian	aerobic	oligotrophic	outer shelf / upper slope	polytaxic	"K"

TABLE 5.5: Benthonic foraminiferal palaeocommunities, trophic structures and biotic response (the latter conceptually adapted after Fischer & Arthur, 1977; Pianka, 1970; Hallock, 1987).

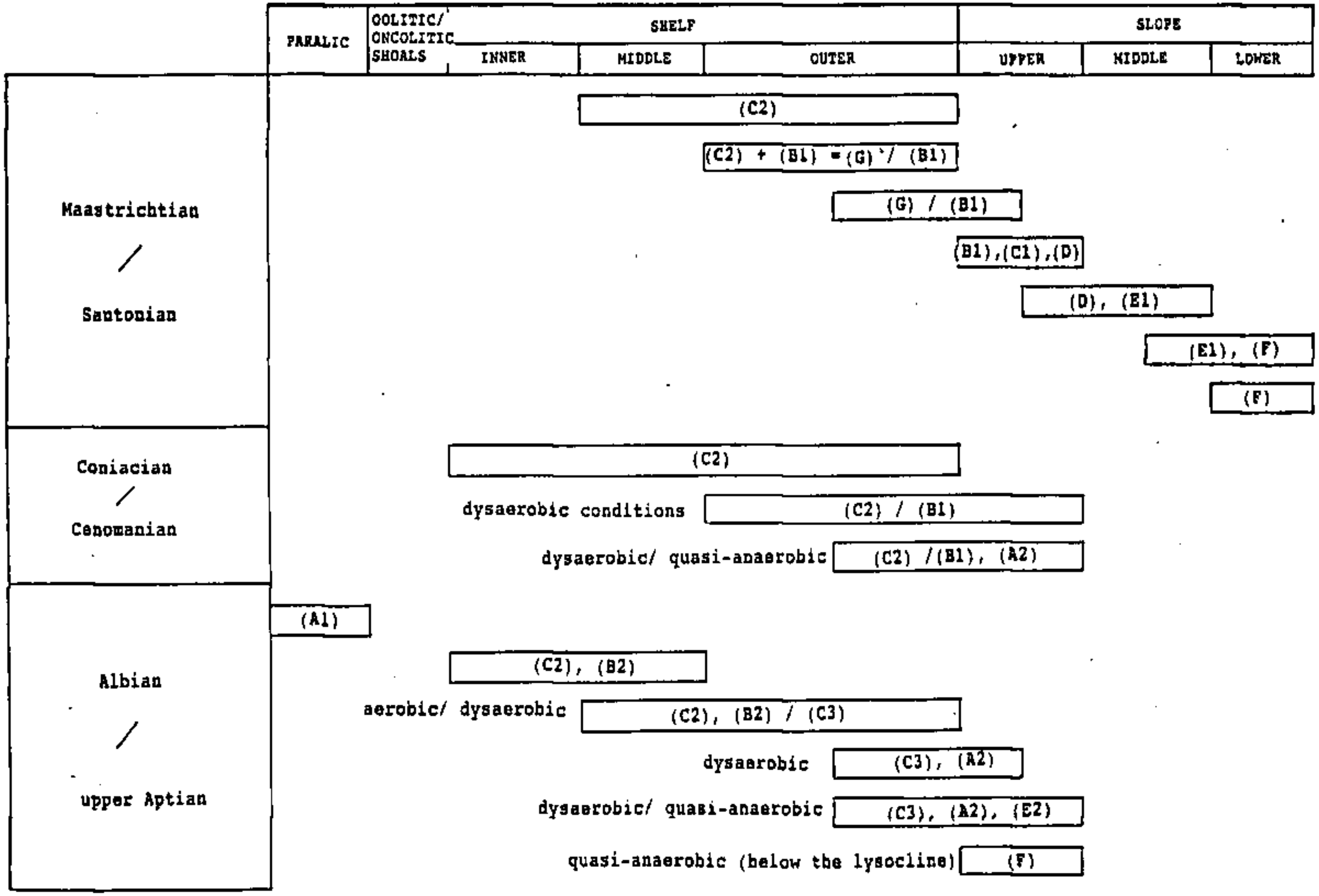


FIGURE 5.12: Distribution patterns of benthonic foraminiferal palaeocommunities (see Table 5.4) in Cretaceous shelf and slope environments of Sergipe.

supply is relatively constant and regular (cf. Scott, 1978), a common feature during the mid-Cretaceous hypoxic/anoxic episodes and deposition of organic rich shales/marls and calcareous mudstones (section 5.5, and Chapter 8, sections 8.2.4, 8.3.1). Palaeocommunities dominated by epifaunal suspension feeders ("F"; such as in 'flysch-like' bathyal deposits of the Albian and Santonian-Maastrichtian deposits of Sergipe), thrived in firm fine-grained sandy or siliceous muddy substrates containing an inadequate food supply (e.g., Rhoads & Young, 1970). These organisms (feeding mainly upon suspended and resuspended organic detritus, and also probably capable of directly utilizing dissolved organic material) were usually dominant in oligotrophic environments, such as below the photic zone, where epibenthonic bacteria and detritus may be the chief trophic resources (cf. Lipps, 1983) - Fig. 5.1.

Rhoads & Young (1970) proposed a relationship between trophic-group distribution and structure of the sediment-water interface. Silt-clay facies, densely populated with deposit feeders, had a reworked granular structure of the surface layers of the sediment due to intense feeding activities. This produced a loose uncompacted surface (unstable substrate), unsuitable for colonisation by suspension feeders. Sandy facies, low in organic content, had a low density of deposit feeders, with increased abundance of suspension-feeders. The bottom lacked a reworked granular surface. Scott (1976) correlated the trophic structure complexity of benthonic communities with environmental stability in regard to energy resource. He showed that the proportions of species of different feeding habits (= mixed trophic groups) increased as environmental energy decreased (= more stable environment). Upper-middle bathyal biotopes with high diversity and abundance of deposit feeders (Palaeocommunities E1 and E2) are commonly accompanied by low diversity and smaller numbers of suspension feeders, and vice-versa (e.g., Palaeocommunity F) - (trophic group segregation according to variable substrate stability; cf. Rhoads & Young, 1970, p. 151) - see Tables 5.1, 5.5, Figs 5.1-2, 5.12. Palaeocommunities of mixed trophic groups ("G"; as in the fine laminated shales of the Campanian-Maastrichtian outer shelf-upper slope deposits of Sergipe) would indicate relative physical stability of the substrate (cf. Rhoads & Young, 1970) and a wide spectrum of utilisable nutrient resources (nutrient heterogeneity spectrum) on and in the sediment.

5.6.2 - Palaeocommunity Distribution Patterns and Trophic Structures

The composition and distribution patterns of benthonic foraminiferal palaeocommunities (abundance and diversity of the foraminiferal biotopes) seems to be primarily related to community strategies of exploitation of the trophic resources in the microhabitats (available levels and nutrient heterogeneity spectrum, i.e., the trophic resource continuum; May & MacArthur, 1972; Hallock, 1987). Substrate niche patterns (type and stability - cf. Rhoads & Young, 1970; Sokolova, 1972; Kauffman & Scott, 1976; Scott, 1976, 1978; Buzas et al., 1989; see section 5.6.1), dissolved oxygen concentrations and available levels of calcium carbonate for test calcification (i.e., gradients in the redox potential and the carbonate equilibrium at sediment/water interface) are also generally attributed to be amongst the most important parameters deciding the distribution of benthonic foraminifera (e.g., Murray, 1973; Haig, 1979; Bernhard, 1986; Gooday, 1986; and references therein). Environmental thresholds, in relation to water-mass conditions and bathymetric niches, can be then inferred and predicted to the distribution of the major trophic groups and foraminiferal paleocommunities (see Figs 5.2, 5.12).

Throughout the Cretaceous deposits of the Sergipe Basin the composition of the foraminiferal morphogroups, the relative abundance and diversity patterns show a clear trend in a seaward direction away from nearshore (e.g., Figs 5.2-6, 5.12). The development of extensive paralic (tidal flats and lagoonal environments) and shallow neritic conditions during the later Aptian-earliest Albian, at the beginning of the marine sedimentation in Sergipe, created broad shallow platforms having abnormally high salinity patterns, warmer temperatures and high concentrations of calcium carbonate (Chapters 6 and 8). The characteristic benthonic foraminiferal microfauna to have flourished in that setting is represented by small-sized gavelinellids, polymorphinids, nodosariids, vaginulinids, ichthyolariids, eggerellids, textulariids, spiroplectamminids and rare hauerinids (Palaeocommunities B2 and C2). The agglutinated foraminiferal microfauna characteristic of late Aptian-earliest Albian paralic (lagoonal) environments, is well distinguished in having an abundance of infaunal deposit feeders (bacterial/detrital scavengers) with minor numbers of epifaunal herbivorous/detritivorous foraminifera (Palaeocommunity A1).

Although no algal remains were found, this pattern could suggest that the community was associated with standing stocks of macrophytic benthonic algae and/or epibenthonic diatoms. The herbivorous/detritivorous cyclamminids (Buccicrenata) probably fed directly on the algae, while the infaunal elements ingested detrital organic matter (e.g., small pieces of sea-weeds, dead diatoms) and bacteria. The relative low diversity of microfossils in paralic (lagoonal) environments is almost certainly due to the severe environmental stresses normally found in such settings, which probably accounted for a strict selection of few adapted taxa (K-selected during long-term stabler conditions). Similar modern environments are characterised by sharp fluctuations in salinities and water temperatures, as well as by frequent and large disturbances of the sedimentary substrate (e.g., locality A-32, Angico Member - lagoonal facies with influence of storm waves; Fig. 8.1, Photo 8.3). Seaward of the marginal environments, the calcareous muds of the middle and outer shelf were occupied by Palaeocommunities C2, B2 and C3 (Fig. 5.12). Many of their microfaunal constituents have been shown in the previous sections to have adaptations for life on relatively stable, soft muddy substrata. It is remarkable the abundance of epi-/infaunal active deposit feeders. Assemblages dominated by suspension feeders (Palaeocommunity F), with smaller amounts of deposit feeders, were commonly recorded in association with turbiditic deposits in late Aptian-Albian outer shelf to upper slope settings (e.g., Fig. 8.8).

Dysaerobic to quasi-anaerobic conditions prevailed at intermittent periods during the mid-Cretaceous in Sergipe. For instance, the microfauna recovered from the latest Cenomanian-earliest Turonian oxygen-depleted outer neritic-upper bathyal environments (see discussion above, sections 5.5.2 and 5.5.4) is represented by low-diversity r-selected, "opportunistic", epi-/infaunal deposit-feeding taxa, with limited intraspecific variation (Palaeocommunities C2, B1, A2; Table 5.5, Fig. 5.12). On the other hand, the Santonian-Maastrichtian outer shelf-upper bathyal siliciclastic sediments of Sergipe yield abundant and highly diversified K-selected, "equilibrium", foraminiferal assemblages (Palaeocommunities C2, G, B1, C1, D; Table 5.5, Fig. 5.12). Aerobic conditions were present in the water column (Mello et al., 1989). The evidence suggests a well developed photic zone and probable extensive oligotrophic conditions at epipelagic layers near the shelf edge. Nutrient deficient waters are more stable and clearer than richer waters, have longer and more complex food chains, and, therefore, permit higher degrees of specialisation (Hallock, 1987). The variable benthonic foraminiferal palaeocommunities indicate, however, a steady food supply from variable sources. The major nutrient resources for such biotopes would be originated from epibenthonic algae and packaged organic detritus (e.g., Fig. 5.1). The latter arrives in the sea floor mostly in the form of aggregates (faecal pellets), in the guts of migrating plankton and micronekton, and as occasional carcasses of large organisms (cf. Angel, 1988). Fresh phytodetritus aggregtes have also been shown to horst abundant, low-diversity extant foraminiferal assemblages in the deep-sea floor (Gooday, 1988). Relatively high primary organic productivity in oligotrophic environments is mantainned by photosynthetizers (e.g., coccolithophorids) specialised in concentrate the scarce nutrient resources in the water column (cf. Morris, 1980; Hallock, op. cit.). It seems, therefore, that widespread epipelagic oligotrophic conditions, in outer neritic and oceanic settings, may result in a heigh spectrum of nutrient heterogeneity in the sea-floor and increase the variety of utilisable habitat types. These conditions could have induced the development of polytaxic benthonic palaeocommunities with complex trophic structures (mixed groups) in the Santonian-Maastrichtian [see Table 5.5, and Figs 5.12-13(B)].

5.6.3 - Global mid-Cretaceous Distribution Patterns and Trophic Structures

Three major benthonic associations have been recognised by Haig (1979) in the global distribution of mid-Cretaceous foraminifera:
(i) Ammobaculites Association : low diversity association characterised by abundant siliceous agglutinated foraminifera with very small and unornamented calcareous-hyaline specimens (widely distributed within shallow, land-locked, hyposaline, epicontinental seas, which were apparently situated at palaeolatitudes than 30^{o} North and South, and corresponded with cool-temperate ocean currents); Marssonella Association : characterised by calcareous agglutinated foraminifera associated with a diverse assemblage of calcareous-hyaline specimens (apparently restricted to low palaeolatitudes open continental shelves, corresponded with warm ocean currents within the tropical marine belt at low palaeolatitudes); and

Recurvoides Association : characterised by siliceous agglutinated species with usually absence of calcareous-hyaline foraminifera (mainly recognised from very deep water palaeo-environments in geosynclinal troughs and open oceans). The Ammobaculites Association was also recognised to have developed locally in very shallow, brackish lagoons within the tropical belt (as is the case with the "Lituolidae-Haplophragmiidae Association" - Palaeocommunity A1, Table 5.5 - from the late Aptian and earliest Albian paralic biotopes from Sergipe). Haig (op. cit., p. 36) suggested that "the factor influencing these distributions seems to have been availability of calcium carbonate for organic precipitation". These associations could also be associated with palaeocommunity differentiation in the exploitation of chief nutrient resouces. Shallow, epicontinental seas, at high palaeolatitudes, with non-carbonate terrigenous sedimentation, have the major input of foraminiferal food resources in the form of deposited detrital organic matter and bacteria, therefore favouring the development of assemblages with adaptation to an epi-/infaunal deposit-feeding strategy (omnivores and bacterial/ detrital scavengers) - (Ammobaculites Association). The same applies to the deeper areas of the ocean - (Recurvoides Association). Open continental shelves, at low latitudes, with carbonate-rich sedimentation beneath the photic zone, have the epibenthonic algae (diatoms and sea-weeds) and deposited organic detritus as the major food supply, and therefore favour the development of passive epifaunal herbivores (encrusting browsers) and grazing deposit feeders, with variable assemblages of infaunal deposit feeders (the latter especially developing in pelagic carbonate environments) - (Marssonella Association).

5.7 - DIVERSITY PATTERNS AND ENVIRONMENTAL GRADIENTS

Foraminiferal diversity patterns are a direct response to palaeoceanographic conditions and can reflect long-term cumulative changes produced by seasonal cycles in sea-level, sediment type, redox conditions and rates of food supply. A significant increase in diversity is more likely to result from an increase in the variety of habitat types. More niches would be created (higher biogeographic differentiation) leading to an increase in taxonomic diversity with exploitation of new habitats (Schopf, 1980). Diversity patterns are, therefore, particularly sensitive recorders of variations in the "trophic resource continuum", i.e., to the conceivable entire range of available resouce levels at a specific time and depositional setting (cf. May & MacArthur, 1972; Hancock, 1987) - see Table 5.6(A-B).

Cumulative percentage diagrams, total diversity histograms and palaeobathymetric contour curves are presented in Fig. 5.13(A-E) for the upper Aptian-Maastrichtian succession of the Sergipe Basin. Standing diversity patterns of the planktonic and benthonic species are based on the total number of species collectively [Fig. 5.13(B)] and the total number of species in certain selected groups [number of species per genus, Suborder Globigerinina; number of species per family-group, for the benthonic foraminifera - Fig. 5.13(A,C-D)].

The total diversity histogram for the benthonic foraminifera [Fig. 5.13(B)] shows a certain regular, cyclic pattern of diversification. A somewhat similar response is also noted when the patterns of diversification for each major individual Suborder is considered [Fig. 5.13(A,C-D)]. The number of species progressively decline from the early Albian to the early Cenomanian, through a series of small diversification "blooms" which are then terminated by a reduction of species via extinction events and/or environmental turnovers. During Cenomanian-early Coniacian times the species diversity was much lower, as well as in number of specimens, and the assemblages were mostly dominated by epifaunal deposit feeding, calcareous-hyaline foraminifera - (Palaeocommunity C2). A peak in diversity occurs during the latest Cenomanian-earliest Turonian, which is also reflected in the planktonic biota [foraminifera, radiolarians and diatoms - Fig. 5.13(B), Chapter 7, Fig. 7.1]. It is important to note that the hypoxic/anoxic episodes at the Aptian-Albian and Cenomanian-Turonian boundaries most probably caused the extinctions of many taxa. However, as the low-oxygen conditions waned, newly evolved or imigrant species spread rapidly, within the limits of their environmental tolerance, occupying the niches left vacant following the extinctions. The appearances of these new species keep unchanged the total number of taxa during the early Albian and early Turonian, suggesting, therefore, full exploitation of niches [see Fig. 5.13(B)].

<table>
<tr><td rowspan="3">PALAEOCEANOGRAPHIC CONDITIONS</td><td colspan="2">RISING SEA LEVEL
(decreased/ interrupted continental runoff)</td><td colspan="3">LONG-TERM HIGH STAND OF SEA LEVEL</td></tr>
<tr><td>well-mixed water masses</td><td colspan="2">stratified water masses (sluggish circulation)</td><td colspan="2">well-mixed water masses</td></tr>
<tr><td>aerobic conditons</td><td colspan="2">dysaerobic/anaerobic conditions (expanded O.M.Z.)</td><td colspan="2">aerobic conditions</td></tr>
<tr><td rowspan="4">TROPHIC STRUCTURE</td><td>T.R.C. expansion</td><td colspan="2">T.R.C. contraction</td><td colspan="2">expanded T.R.C.</td></tr>
<tr><td>increasing spectrum of nutrient heterogeneity</td><td colspan="2">low spectrum of nutrient heterogeneity</td><td colspan="2">high spectrum of nutrient heterogeneity</td></tr>
<tr><td>development of oligotrophic conditions in outer neritic and oceanic settings</td><td colspan="2">widespread eutrophic conditions</td><td colspan="2">widespread oligotrophic conditions in outer neritic and oceanic settings, away from nutrient sources</td></tr>
<tr><td>selected trophic groups dominate</td><td colspan="2">selected trophic groups</td><td colspan="2">mixed trophic groups</td></tr>
<tr><td rowspan="3">BIOTIC RESPONSE</td><td>"r-selected" biotas dominate over "K-selected" taxa</td><td colspan="2">"r-selected" biotas</td><td colspan="2">"K-selected" biotas conolize the available niches and dominate over "r-selected" ones</td></tr>
<tr><td>oligotaxic</td><td colspan="2">oligotaxic</td><td colspan="2">polytaxic</td></tr>
<tr><td>specific and generic radiation (colonization of new available niches)</td><td colspan="2">extinction of specialised (oligotopic) taxa</td><td colspan="2">specific and intraspecific diversification (ecophenotypic specialisation to full exploitation of available niches)</td></tr>
<tr><td>TIME-INTERVAL</td><td>(late Coniacian to early Campanian)</td><td>(late Aptian to earliest Albian, earliest Cenomanian, latest Cenomanian)</td><td colspan="2">(early to middle Albian, early to middle Turonian)</td><td>(middle to late Albian, late Campanian to Maastrichtian)</td></tr>
</table>

TABLE 5.6(A): Idealised scheme showing the probable interaction among changing palaeoceanographic conditions, the trophic resource continuum, overall selection response and rates of biotic diversity (conceptually adapted after Fischer & Arthur, 1977; Pianka, 1970; Hallock, 1987).

	LOWERING SEA LEVEL (increased continetal runoff)	LONG-TERM LOW STAND OF SEA LEVEL (steady continental runoff)
PALAEOCEANOGRAPHIC CONDITIONS	well-mixed water masses	stratified water-masses (loss of oceanic circulation)
	aerobic/dysaerobic conditions (increased primary productivity)	dysaerobic/anaerobic conditons (high primary productivity)
TROPHIC STRUCTURE	T.R.C. contraction	T.R.C. contracted
	decreasing spectrum of nutrient heterogeneity	low spectrum of nutrient heterogeneity
	increasing mesotrophic/eutrophic conditions	widespread eutrophic conditions
	specialised trophic groups are eliminated	selected trophic groups
BIOTIC RESPONSE	"r-selected" biotas dominate over "k-selected" taxa	"r-selected" biotas
	oligotaxic	
	extinction of specialised (oligotopic) taxa	
TIME-INTERVAL	(latest Albian, early Cenomanian, middle-late Turonian)	(early to middle Cenomanian, middle-late Turonian to early Coniacian)

TABLE 5.6(B): Idealised scheme showing the probable interaction among changing palaeoceanographic conditions, the trophic resource continuum, overall selection response and rates of biotic diversity (conceptually adapted after Fischer & Arthur, 1977; Pianka, 1970; Hallock, 1987).

FIGURE 5.13 (A-E): Cumulative percentage diagrams (number of species per genus, Suborder Globigerinina; number of species per family-group, for the benthonic foraminifera) and total diversity histograms for the upper Aptian to Maastrichtian of the Sergipe Basin.

(A) Planktonic foraminifera cumulative percentage plot. Suborder Globigerinina: 1=Archaeoglobigerina, 2=Biticinella, 3=Contusotruncana, 4=Dicarinella, 5=Gansserina, 6=Globigerinelloides, 7=Globotruncana, 8=Globotruncanella, 9=Globotruncanita, 10=Family Globuligerinidae, 11=Guembelitria, 12=Hedbergella (Favusella), 13=Hedbergella (Hedbergella), 14=Hedbergella (Whiteinella), 15=Family Heterohelicidae, 16=Marginotruncana, 17=Praeglobotruncana, 18=Rotalipora, 19=Rugoglobigerina, 20=Ticinella.

(B) Histograms of the total numbers of species of planktonic and benthonic foraminifera plotted against time. The shaded areas refer to new appearances, while the blank parts indicate those species continuing from the previous time-interval. (A = Suborder Textulariina; shaded and blank areas to the right = Suborders Miliolina, Spirillinina, Involutinina, Lagenina, Robertinina and Rotaliina).

(C) Calcareous benthonic foraminifera cumulative percentage plot. Suborder Miliolina: 1=Family Hauerinidae, 2=Spiroloculinidae; Suborder Spirillinina: 3=Patellinidae, 4=Spirillinidae; Suborder Involutinina: 5=Involutinidae; Suborder Lagenina: 6=Ichthyolariidae, 7=Lagenidae, 8=Nodosariidae, 9=Polymorphinidae, 10=Vaginulinidae; Suborder Robertinina: 11=Conorboididae, 12=Epistominidae; Suborder Rotaliina: 13=Alabaminidae, 14=Anomalinidae, 15=Bagginidae, 16=Bolivinidae, 17=Buliminellidae, 18=Chilostomellidae, 19=Cibicididae, 20=Cymbaloporidae, 21=Epistomariidae, 22=Eponididae, 23=Fusenkoinidae, 24=Gavelinellidae, 25=Globorotalitidae, 26=Lacosteinidae, 27=Nonionidae, 28=Osangulariidae, 29=Pleurostomellidae, 30=Quadrimorphinidae, 31=Reussellidae, 32=Rosalinidae, 33=Siphogenerinoididae, 34=Stilostomellidae, 35= Turrilinidae.

(D) Agglutinated foraminifera cumulative percentage plot. Suborder Textulariina: 1=Family Ammodiscidae, 2=Ammosphaeroidinidae, 3=Aschemocellidae, 4=Ataxophragmiidae, 5=Bathysiphonidae, 6=Cyclamminidae, 7=Discamminidae, 8=Eggerellidae, 9=Haplophragmiidae, 10=Haplophragmoididae, 11=Hippocrepinidae, 12=Hormosinidae, 13=Lituolidae, 14=Lituotubidae, 15=Nezzazatidae, 16=Orbitolinidae, 17=Psammosphaeridae, 18=Pseudogaudryinidae, 19=Rhabdamminidae, 20=Rzehakinidae, 21=Saccamminidae, 22=Spiroplectamminidae, 23=Textulariidae, 24=Trochamminidae, 25=Verneuilinidae.

(E) Palaeobathymetric contour curves inferred for the upper Aptian-Maastrichtian succession of the Sergipe Basin (based on the palaeoenvironmental data and palaeogeographic reconstructions of the studied sections - see Chapter 8). Dashed areas refer to the timing and positioning of the maximum hypoxic/anoxic episodes (see section 5.5). The left limit in the figure corresponds to the present-day NW onshore border of the basin (e.g., area of the Riachuelo and Itaporanga highs), whereas the right side corresponds to the SE limit of the studied offshore area (e.g., area of wells 1-SES-3 and 1-SES-24).

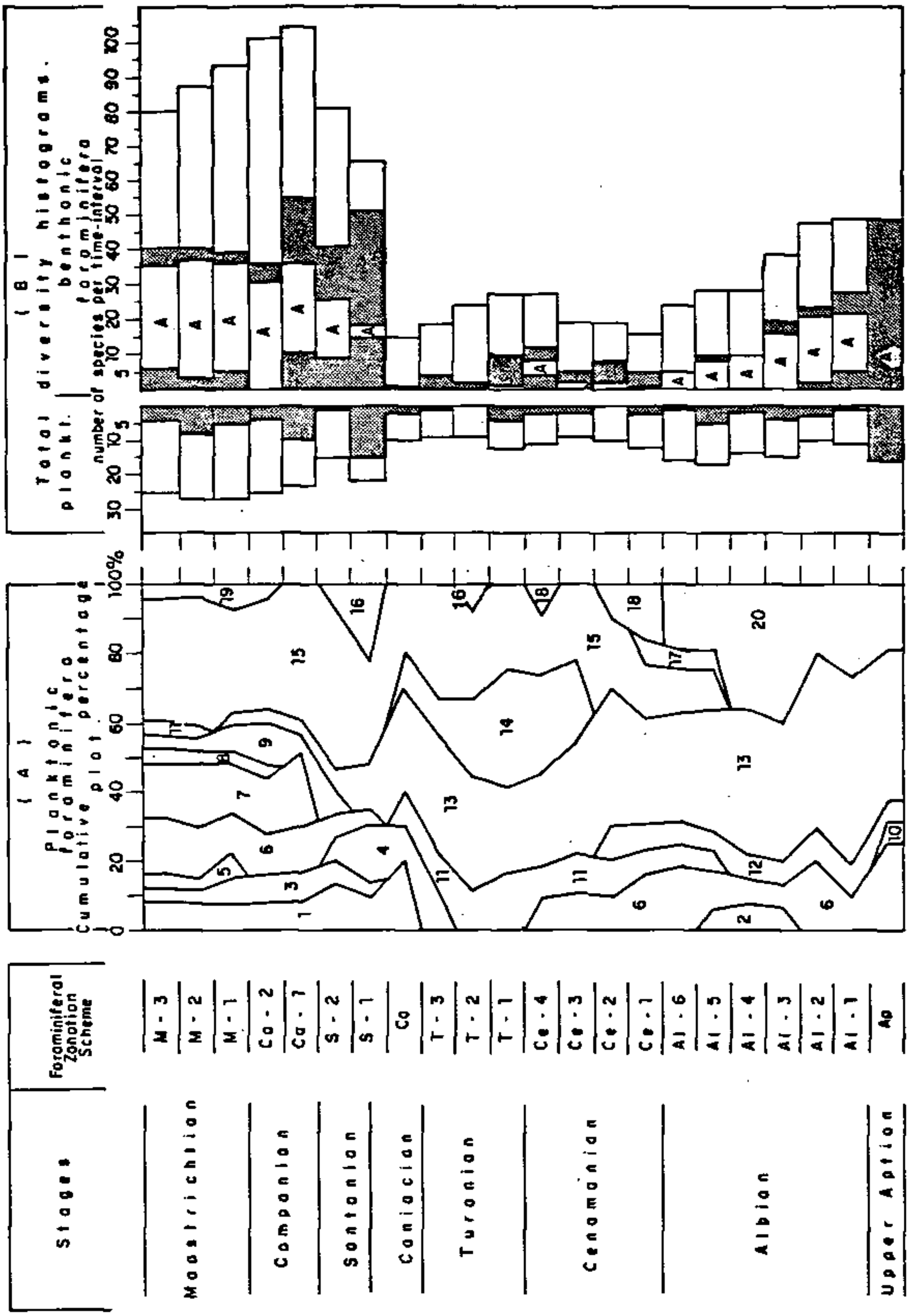


FIGURE 5.13(A-B): Planktonic foraminifera cumulative percentage plot (A) and total diversity histograms (B).

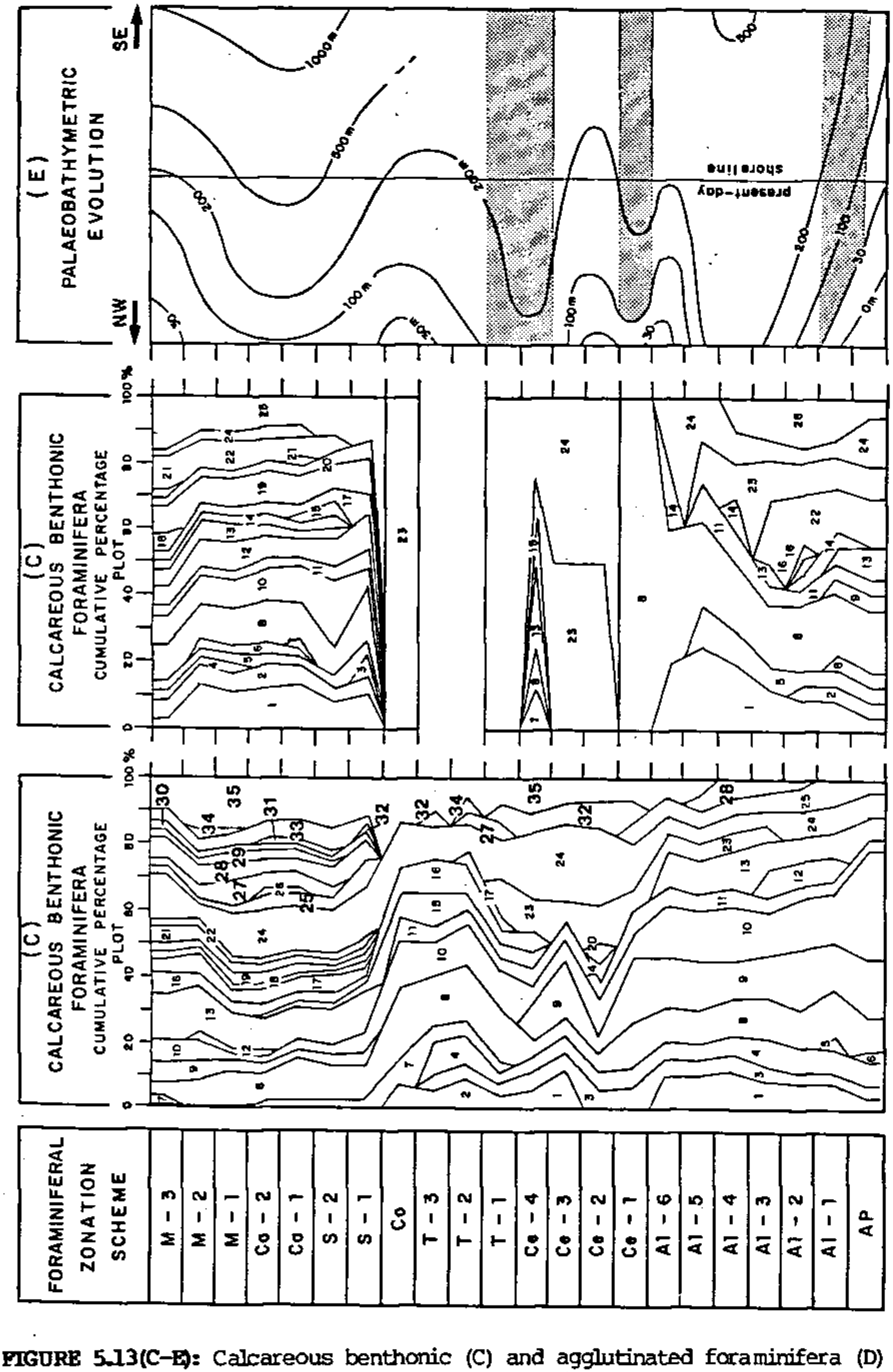


FIGURE 5.13(C-E): Calcareous benthonic (C) and agglutinated foraminifera (D) cumulative percentage plots and palaeobathymetric evolution (E).

There is a sharp increase in diversity during late Coniacian-Santonian to Maastrichtian times, with a maximum in the early Campanian [palaeobathymetric maximum of the basin - see Fig. 5.13(E) and Chapter 8, section 8.4]. The late Coniacian-Santonian to Maastrichtian represents a time-interval of relatively stable environmental conditions (e.g. well mixed and overall well-oxygenated water masses). Outer shelf and upper slope foraminiferal biotopes have rich assemblages with a very high generic and specific diversity, and a complex trophic structure (Palaeocommunities C2/ G/ B1). Occasional levels in outer shelf and upper slope environments have predominance of infaunal deposit-feeding calcareous-hyaline taxa (Palaeocommunity B1) - Table 5.5, Fig. 5.12, see also section 5.6.2. Long-term high-stands of sea-level during the late Cretaceous, coupled with widespread aerobic pelagic conditions, contributed to create niches and promote evolutionary diversification, with the development of polytaxic biotas.

5.7.1 - Palaeocommunities and Stratigraphic Cycles

Episodic or periodic changes in the proportion of seasonal componentes accumulated in the sediments (e.g., organic detritus) produce cyclic laminated bedding within a stratigraphic unit. However, this seasonal lamination is not usually recognised due to bioturbation, which destroys almost all the evidence in both the lacustrine and marine environments (Anderson, 1986). On the other hand, during episodes of oxygen-depleted bottom waters, where bioturbation by macrobenthos is mostly absent, the sediments are almost always finely laminated. Major changes in seasonality (climatic forcing), and related oceanographic events, generate cyclic bedding patterns at a larger scale, extending into the Milankovitch range of cycles, which can be easily recognisable in the geologic record (e.g., Bottjer et al., 1986; Schwarzacher, 1987). The so-called "Milankovitch cycles" in the sedimentary record are attributed to the influence of "Earth's periodic orbital variations and consequent changes in the ammount and in the latitudinal and seasonal distribution of solar energy at the earth's surface" (Arthur & Garrison, 1986, p. 370), through their influence on global climate and depositional processes. Seasonality basically controls epipelagic primary productivity, the influx of land-derived organic detritus and the rate of supply of dissolved and packaged organic matter for the deep ocean.

Mid-Cretaceous pelagic carbonate sediments from the Sergipe Basin exhibit very thin/thin rhythmic interbedding of calcareous mudstones/marls and thick-bedded wackstones/packstones in outcrops (upper Aptian-Albian: Photos 8.2-3, 8.8; Cenomanian-Turonian: Photos 8.12, 8.15-17, 8.19-7.26) and well-sections (e.g., Figs 6.2, 8.2-5, 8.13-14). These bedding rhythms may be ultimately related to orbitally induced rhytmic climatic variations. For instance, high-resolution stratigraphic analyses of upper Aptian cored sections (e.g., wells 7-CP-252-SE, Fig. 6.2, and 1-CPB-1R, Fig. 8.2) demonstrated the cyclic nature of palaeo-environmental changes and carbonate productivity of that early marine episode in the northern South Atlantic (see also Chapter 6). In the studied section of well 7-CP-252-SE (Fig. 6.2) 12 rhythmic beds of shales-marls/carlcareous mudstones can be differentiated. The interbedding rhytms are most likely to be the expression of long-term cumulative changes produced by seasonal variations (such as periodic alternation of humid and arid climate episodes) in carbonate productivity, terrigenous influx and local sea-level in the stratigraphic record. Moreover, the evidence also suggests that the variations in the thickness of the carbonate-rich cycles (proportionally reflected in estimates of planktonic foraminiferal abundances) are the result of changes in surface-water productivity of calcareous organisms (e.g., calcareous nannoplankton and foraminifera), rather than an effect of dissolution or diagenesis. This model of productivity cycles matches the pattern of the "climatic precession index" of Berger (1978), in which the basic 19 to 23kyr cycle of the axial precession is modulated by the 100kyr cycle of orbital eccentricity (Bottjer et al., 1986). According to this model, the individual pair of rhythmic beds may average 21kyr, so that the total marine stratigraphic section shown in Fig. 6.2 could represent approximately 120kyr, assuming continuous sedimentation, which would suggest an average accumulation rate of about 26cm/kyr for the paralic (tidal flats)/inner-middle neritic deposits of the upper Aptian.

CHAPTER 6

ECOPHENOTYPIC AND ONTOGENETIC POLYMORPHISM OF PLANKTONIC FORAMINIFERAL COMMUNITIES DURING THE MID-CRETACEOUS

6.1 - INTRODUCTION

One of the most intriguing groups of Cretaceous planktonic foraminifera is the **favusellids**. Individuals of this morphogroup have a highly variable globigerine chamber shape and arrangement, and a characteristic surface ornamentation of fine-to-coarse ridges forming a honeycomb-like pattern. First described by Carsey (1926) as Globigerina washitensis, from the Del Rio Clay of Texas, U.S.A., they were later assigned to a new genus, Favusella, by Michael (1972). Based on the number of chambers per whorl, spire height, inflation rate and relative coarseness of the honeycomb-like ornamentation, Michael named several new species: Fav. hiltermanni (Loeblich and Tappan, 1961), Fav. nitida, Fav. orbiculata, Fav. pessagnoi, Fav. quadrata, Fav. scitula, and Fav. wenoensis. Longoria & Gamper (1977) added Fav. confusa, Fav. hedbergellaeformis, Fav. papagayosensis, Fav. planata, and Fav. voloshinae.

Grigelis & Gorbatchik (1980), in a revision of the taxonomy of Jurassic and Early Cretaceous globigerine-like foraminifera, presented a modified and emended description of the family Favusellidae, proposed by Longoria (1974), and included in this family the genera Globuligerina Bignot and Guyader and Conoglobigerina Morozova. Grigelis & Gorbatchik (1980) also assigned to the genus Favusella, the species Fav. tardita (Antonova), first recognised in the Upper Barremian-Lower Aptian deposits of Azerbaidzhan, northwestern Caucasus by Antonova et al. (1964).

The distribution of favusellids shows a remarkably consistent occurrence in shallow-water carbonate environments, where there is usually great abundance and wide variability in test shape. In order to assess the relationships between test morphology and environment, rich favusellid assemblages, recovered from mid-Cretaceous sections in Sergipe, were studied.

The terminology of ontogenetic stages used herein follows the definitions of Loeblich & Tappan (1964). Therefore, we have adopted the term **neanic** for specimens considered to represent a youthful stage in ontogeny. Neanic specimens are 100-250μm in diameter and display considerable variation in chamber arrangement, number of chambers per whorl, coarseness of test ornamentation and position of aperture. **Ephebic** (adult stage) specimens are 250-350μm in diameter. **Gerontic** specimens are 350-500μm in diameter.

6.2 - DISTRIBUTION OF FAVUSELLIDS

6.2.1 - Stratigraphic Distribution and Variability in Test Morphology

Specimens assigned to Favusella have an extensive global distribution (Fig. 6.1). They have been recorded in the upper Barremian-lower Aptian deposits of the northwestern Caucasus (Antonova et al., 1964), Atlantic ocean near the coast of Morocco (Roesler et al., 1978; Grigelis & Gorbatchik, 1980); and in upper Aptian-Albian to lower-middle Cenomanian deposits of the Brazilian continental margin (Petri, 1962; Schaller, 1969; Noguti & Santos, 1972; Beurlen, 1982; Dias-Brito, 1982, 1987; Koutsoukos, 1982, 1984, 1987; Viviers, 1982, 1985, 1986, 1987; Dias-Brito & Azevedo, 1986; Azevedo et al., 1987 a,b; Koutsoukos & Dias-Brito, 1987; Viviers & Beurlen, 1987; Viviers & Regali, 1987), Caribbean Basin (Trinidad: Bolli, 1959), Central and North America (Mexico: Longoria, 1974; Longoria & Gamper, 1977; Cuba: Ayala, 1962; Blake Plateau, north of the Bahama Islands: Loeblich & Tappan, 1961; Texas, Oklahoma and Minnesota: Loeblich & Tappan, 1961; Pessagno, 1967; Michael, 1972; California: Dailey, 1973), western and northwestern African coast (Walvis Ridge: Caron, 1978; Gabon: de Klasz & Gageonnet, 1965; Ghana: Khan, 1970; Senegal: Castelain, 1965; Morocco: Viterbo, 1965; Wiedmann et al., 1978; Butt, 1982; near the Canary Islands: Butt, 1978; Rosler et al., 1978; Algeria: Sigal, 1952), North-West Europe (southern England: Hart, 1970, 1973, 1983; Carter & Hart, 1977; Harris, 1982; Hart et al., 1981, 1989; Germany: Risch, 1971; northern France: Sigal, 1965; Price 1976, 1977 a,b; southern Spain: Hermes, 1969), North Africa (Libya: Barr, 1968, 1972); East Europe (Polish western Carpathians: Salaj & Samuel, 1966; Crimea, USSR: Grigelis & Gorbachik, 1980; Northwestern Anatolia, West of Ankara, Turkey: Demir Altiner, personal communication, Tubingen, September 1989); Middle East (Negev Desert, Israel: Arkin & Hamaoui, 1967), eastern African coast, Indian coast (Tanzania: Bate & Bayliss, 1969; Madagascar: Sigal, 1966; Somalia: Prestat, 1970), and in the northwestern Pacific ocean (Japan: Takayanagi, 1960; Takayanagi & Iwamoto, 1962).

In Jurassic and Lower Cretaceous sections the favusellids have small tests, subspherical chambers, trochoid, irregularly trochoid or high

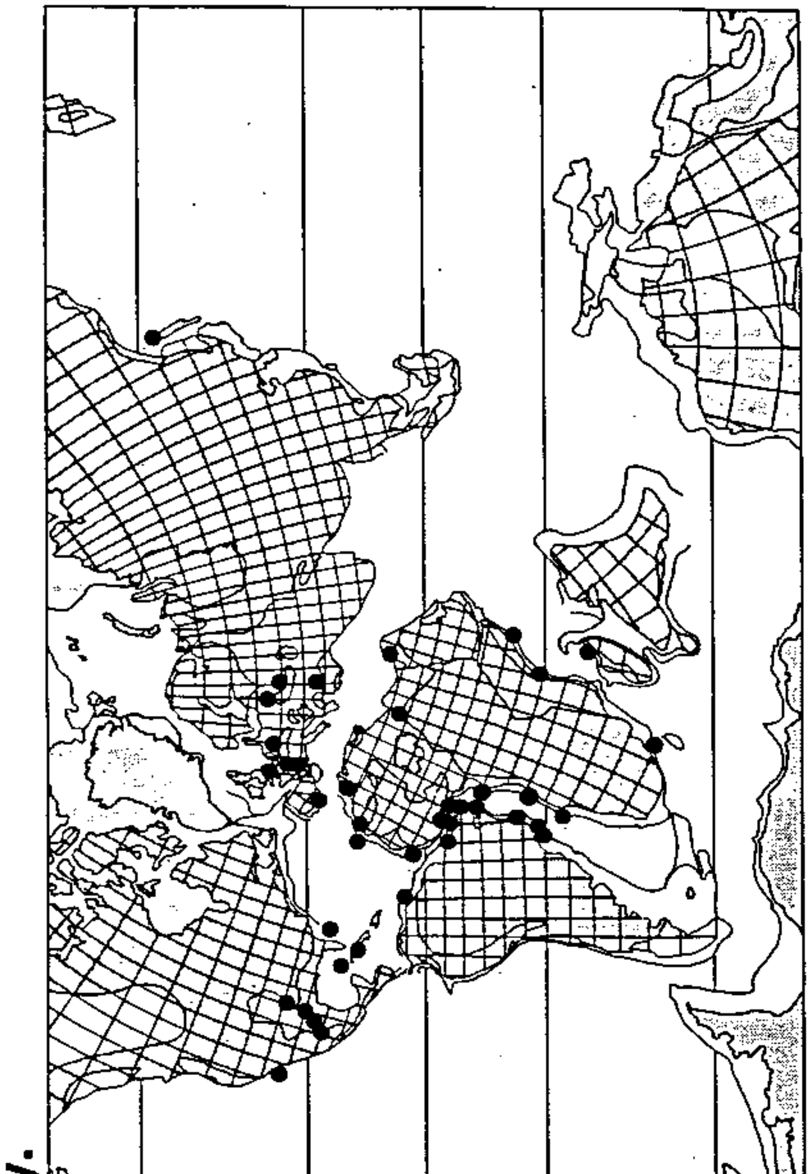


FIGURE 6.1 : Known paleogeographic distribution of **Hedbergella (Favusella) washitensis** (Carsey) assemblages in mid-Cretaceous strata. Plotted on a mid-Cretaceous (100 m.y.) palaeogeographic map (after Barron *et al.*, 1981).

trochospiral form, a tubercular or reticulate test surface and an umbilical aperture (Grigelis & Gorbatchik, 1980). Later Early Cretaceous and Cenomanian favusellids show an increased test size, greater variability in chamber arrangement, and coarser surface ornamentation. Grigelis & Gorbatchik (1980) also observed that the test surface of Barremian-Aptian favusellids is covered by a network of irregular, frequently elongated quadrangular ridges, whereas regular polygonal ridges (honeycombs) are present on Albian-Cenomanian specimens.

6.2.2 - Evidence of Palaeo-environmental Control

The dispersal of favusellids during Middle and Late Jurassic time took place mainly along the northern margin of the Tethys and in the epicontinental basins of Europe (Grigelis & Gorbatchik, 1980). These authors (p.188-189) also reported that "on the territory of the southern part of the USSR favusellids have been found in comparatively shallow-water Berriasian and Valanginian deposits (Crimea, Azerbaidzhan) and only as single specimens in deeper-water deposits of the upper Albian and Cenomanian (Crimea)".

Michael (1972), Longoria (1974) and Grigelis & Gorbatchik (1980) observed that the favusellids are commonly found in neritic environments and have not been recorded in bathyal or abyssal deposits. The latter authors interpreted the morphologic features of the favusellids as environmental adaptations, whereas Michael (1972, p. 213) considered that their distribution "is influenced by a particular environmental parameter such as salinity" and that "its peculiar ornamentation may be a reflection of such environmental influence". Hart and others (1981) stated that the peculiar stratigraphic distribution of the favusellids in the U.K. probably indicates a pronounced ecological control. Favusellids were also recorded by Dias-Brito (1982) from shallow neritic calcareous mudstone deposits, of tropical waters with hypersaline bottom conditions, of the lower Macaé Formation (early to middle Albian) of the Campos Basin, southeastern Brazil.

Assemblages of hedbergellids characterized by heavy ornamentation (pustulae and costulae) arranged in variable patterns were described by Saint-Marc (1973) from middle Cenomanian deposits of Lebanon, which accumulated in a warm-water neritic environment. Caron (1978) reported a rich population of Hedbergella "à costellae" from the Albian neritic deposits of the Walvis Ridge and Angola Basin, and noted a pronounced environmental influence on the appearance of the costulate ornamentation. Leckie (1984, p. 598) described a similar assemblage from the upper Albian and lowermost Cenomanian of Morocco, remarking on its "significant biostratigraphic, and perhaps environmental, value". In a recent review of the palaeo-ecology of mid-Cretaceous planktonic foraminifera, Leckie (1987) tentatively included the ornamented Hedbergella species [Hedb. washitensis (Carsey) and Hedb. libyca Barr] in his epicontinental sea faunal group (<100m water depth), also stressing that these species are particularly characteristic of warm, shallow-water environments, such as marginal seas or carbonate platforms.

6.3 - FAVUSELLIDS FROM THE SERGIPE-ALAGOAS BASIN

Oil-well sections (some cored throughout) and extensive outcrops in the Sergipe Basin provide a marine sedimentary record spanning the late Aptian to Maastrichtian. The abundance of favusellids in the mid-Cretaceous strata, the refined stratigraphical control (localities dated by ammonites and foraminifera - Chapter 4) and detailed palaeo-environmental reconstructions (Chapters 5 and 8), altogether provide an excellent setting for research into this planktonic group.

The upper Aptian succession (Fig. 6.2) is a record of the first true marine sedimentation in the northern proto-South Atlantic. The character of this event in Sergipe, from non-marine (hypersaline lacustrine - Mello, 1988, data for the Sergipe Basin) to marine (carbonate-dominated) deposition, is marked by a depositional hiatus and an abrupt change in the microfauna. The Aptian non-marine sediments yielded only carbonized wood fragments, fish debris, rare microgastropods and rare ostracods. The first marine microfaunal elements appear in the late Aptian strata as abundant, but low-diversity microbivalves and microgastropods in finely laminated calcareous mudstones and shales. This suggests the development of extensive paralic conditions (tidal flats) in this area of Sergipe (Aracaju High). The microgastropod assemblages most likely flourished in the lower limit of the intertidal zone, where the salinity level is closer to normal, browzing on blue-green algal mats (e.g., James, 1983). Less than two meters above this level occurs a "bloom" of favusellids, of varied sizes and morphology, along

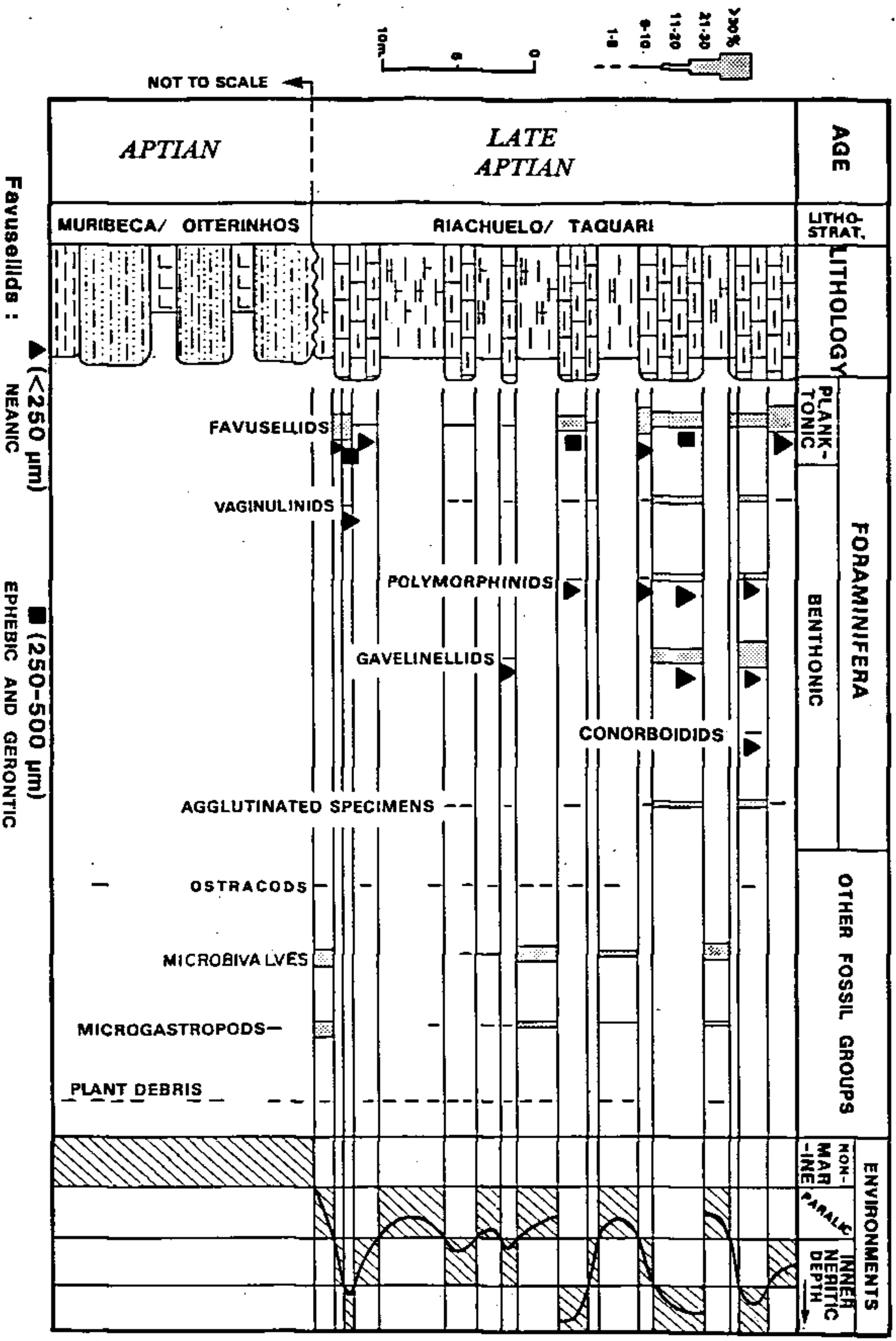


FIGURE 6.2 : Distribution and relative abundance of major foraminiferal taxonomic groups and associated microfossils in **well 7-CP-252-SE** and evolution of depositional environments.

with rare small nodosariids [Dentalina raristriata (Chapman), Pseudonodosaria ex gr. humilis (Roemer)] and ichthyolariids [Lingulonodosaria nodosaria (Reuss)]. They represent the earliest foraminiferal population to colonise and thrive in the newly available marine niches at the western margin of the proto-South Atlantic ocean basin. The episodic restoration of the paralic conditions (indicated by occasional levels with frequent specimens of microbivalves and microgastropods and no foraminifera or echinoids) higher in the sequence, clearly points out the cyclic nature of local sea-level changes of this early marine episode.

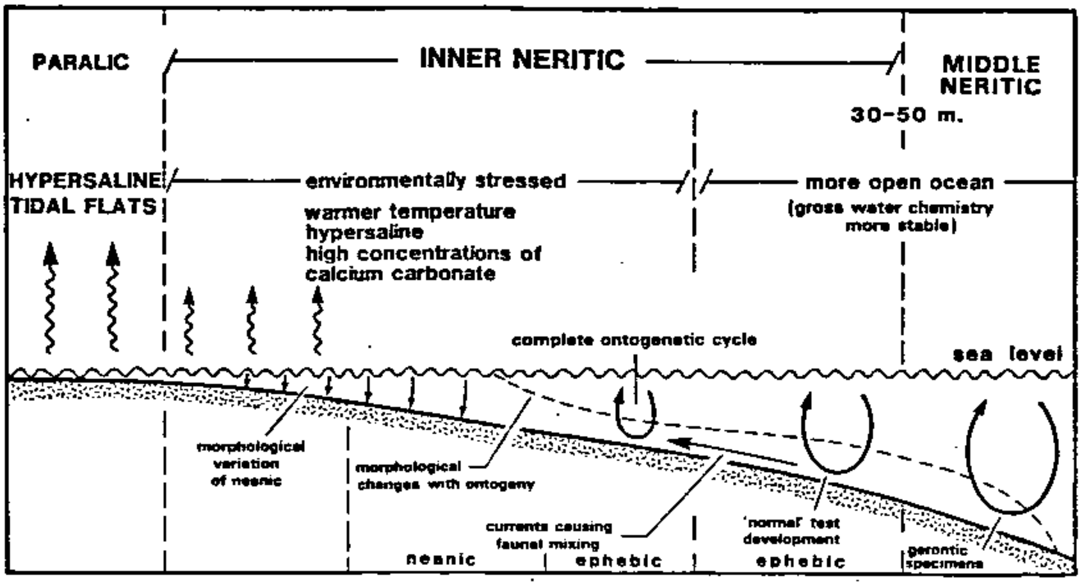
Tappan & Loeblich (1973, p. 232) stated that "ecosystems of all types may be roughly divided into those that are physically controlled, stress dominated, or 'immature', and those of greater 'maturity', representing stability of physical conditions". The authors observed that the planktonic communities of immature or stress-controlled ecosystems are characterized by low diversity, variable gross productivity and small-sized species with highly variable morphology. These same microfaunal patterns were also observed in the marginal marine deposits of the late Aptian in Sergipe, which accumulated in a stress-dominated ('immature') paleo-ecosystem with highly unstable abiotic properties (such as temperature, salinity, nutrient supply, oxygen concentration, bathymetry, etc.) - (Fig. 6.2, see also Chapter 5, section 5.5.1).

Abundant assemblages of favusellids, dominated by small specimens (100-250μm; Pl. 6.1, Figs 1-6), are usually found in the nearshore inner neritic palaeo-environments. Variable numbers of young ephebic specimens (250-300μm; Pl. 6.1, Figs 7-9) also occur at these locations, probably due to their transport toward shore by shallow coastal currents, causing faunal mixing of nearshore and deeper inner neritic favusellid assemblages.

In more open marine waters (inner to middle neritic), where a thicker pelagic niche is available, the favusellid population is dominated by larger specimens (300-500μm; ephebic and gerontic forms with 2.5-3.5 whorls). The favusellids are less abundant and have less morphologic variability (generally represented by morphotypes described as Favusella washitensis - see Pl. 6.1, Figs 10-15). The associated benthonic foraminifera are representative of the inner-middle shelf **Marssonella Association** of Haig (1979). This is characterised here by the presence of calcareous agglutinated foraminifera [Ammobaculites reophacoides Bartenstein, Marssonella kummi Zedler, Marss. ozawai Cushman, Marss. trochus (d'Orbigny) oxycona (Reuss), Marss. trochus turris (d'Orbigny), Quasispiroplectammina ex gr. alexanderi (Lalicker), Quasispir. ex gr. goodlandana (Lalicker), Quasispir. linki (Petri) and Textularia minuta Berthelin], together with a diverse assemblage of rotaliine types, mainly composed of polymorphinids [Eoguttulina anderyi Petri, Globulina lacrima Reuss, Glob. prisca Reuss, Guttulina sp. A, Pyrulina cylindroides (Roemer), Ramulina fusiformis Khan], nodosariaceans [Astacolus sp. cf. A. scitula (Bertehelin), Astacolus sp. A, Dentalina communis d'Orbigny, Dent. raristriata, Lenticulina ex gr. subangulata (Reuss), Marginulina ex gr. aequivoca Reuss, Pseudonodosaria ex gr. humilis, Vaginulina ex gr. debilis (Berthelin), Vag. ex gr. kochii Roemer], ichthyolariids [Lingulonodosaria nodosaria (Reuss)], gavelinellids (Lingulogavelinella ciryi Malapris-Bizouard) and conorboidids [Conorboides ex gr. minutissima (Tappan)]. Rare miliolaceans [Quinqueloculina(?) sp. A] also occur - (Figs 6.2-3).

The presence of frequent small favusellid specimens in nearshore biotopes could be explained by three possible situations: 1) a limited pelagic habitat with optimal environmental conditions (e.g., good nutrient supply), which, because of high gross productivity and strong competition in a restricted vertical space, have led to short ontogenesis (Pl. 6.1, Figs 1-3) of the planktonic population, with specimens reaching maturity more quickly and reproducing at smaller sizes (Bradshaw, 1957, 1961; Murray, 1963); 2) dwarfism due to adverse environmental conditions (e.g., shortage of nutrients; Murray, 1963), or; 3) the mass concentration, in a nearshore environment, of a planktonic community which died before complete ontogenesis was accomplished, therefore resulting in mainly specimens with early stages of test growth and surface calcification.

After considering the total number of chambers per whorl of these small favusellids it is concluded that most of them represent populations of neanic and young ephebic specimens with, generally, 1-2 whorls (see Pl. 6.1, Figs 1, 4-6, and Pl. 6.2, Figs 1-4). Larger mature individuals have tests of 2.5-3.5 whorls; earlier chambers are somewhat masked by succeeding ones and overgrowths of the test ornamentation (Pl. 6.2, Figs 5-6). Consequently, the first and third possible situations (cited above) seem more likely to have influenced the distribution pattern of the favusellids, but the third probably played the most important role.



PLANKTONIC FORAMINIFERA

% of FAVUSELLIDS	100%	99-90%	89-60%	59-30%	29-10%
% of NEANIC	70-50%		49-10%	9-0%	
AVERAGE TEST DIAMETER	100-250 µm		250-350 µm		350-500µm
% of other HEDBERGELLIDS		0-10% (☆)	11-40% (☆)	41-70% (☆)	60-50%
% of TICINELLIDS		0%	0%	0-10% (☆)	11-40%
% of GLOBIGERINELLOIDIDS		0%	0%	0-5% (☆)	0-5%

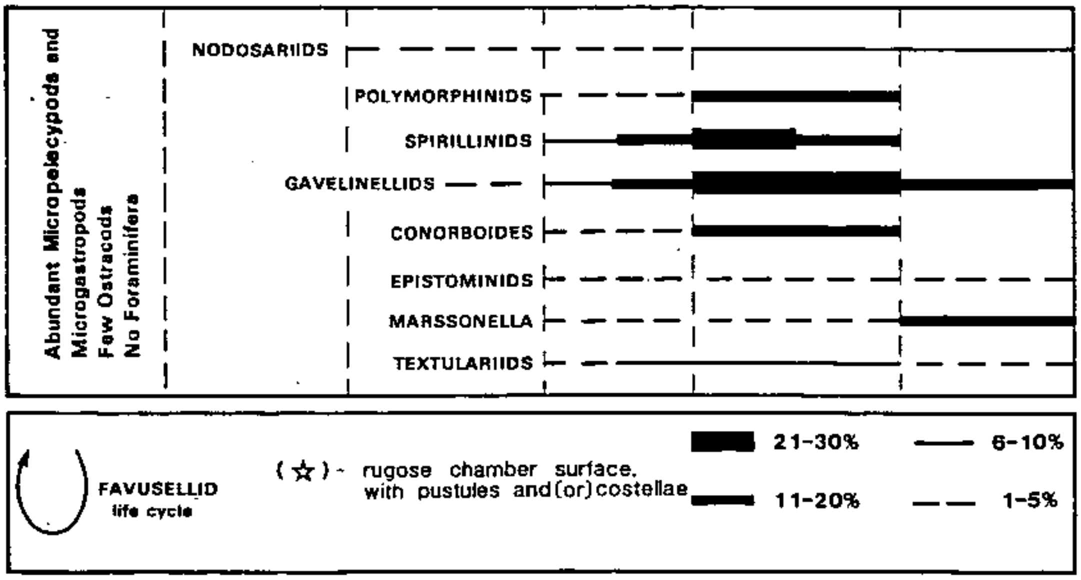


FIGURE 6.3 : Schematic paleoenvironmental model showing the idealised distribution of microfossils in a mid-Cretaceous shallow shelf setting (using composite data from the upper Aptian to middle Albian succession of the Sergipe Basin). The microfaunal proportions are based on relative abundance estimations of sample size-fractions larger than 63μm.

It is inferred that the calcification process in the development of the surficial tubercles and polygonal ridges was progressive and that the amount and complexity of calcification was related to the time available for complete maturation of the specimen. The discovery of several small specimens (mostly pre-adult, around 100 to 250µm) showing incipient tuberculate ornamentation (Pl. 6.1, Figs 1-6; Pl. 6.2, Figs 7-8) is further support for this interpretation. Larger (250-300µm and larger) well-preserved specimens show more uniform and coarser tuberculate or reticulate ornamentation (Pl. 6.1, Figs 10-15; Pl. 6.2, Figs. 9-14). However, test size does not always have a direct relationship to coarseness of surface ornamentation. Most of the specimens between 250 and 350µm size show the best developed tuberculate or reticulate ornamentation, whereas several larger specimens have only localized areas with ornamentation. This is perhaps due to post-mortem abrasion during transport by bottom currents in more open marine settings, which were the typical habitats of gerontic forms (Fig. 6.3).

Apparently, when the 250-300µm diameter size was reached, the favusellids decreased their diameter growth and started to add new chambers spirally, in a variable pattern; this resulted in tests with low to high trochospires in later mature stages (see Pl. 6.1, Figs 10-15). Less morphological variation was observed after this growth stage, which is considered to represent the start of the adult phase in normal ontogenetic development.

In comparing the successive growth stages of some extant planktonic foraminiferal assemblages at species and supraspecific levels, Brummer et al. (1986) recognised that major taxonomic characters (such as chamber arrangement, wall texture, development of a keel and apertural position) change during the ontogeny of certain species. Bé & Hemleben (1970) through a study of successive growth stages of a living planktonic foraminifer, Globigerinoides sacculifer (Brady), found little morphological resemblance between neanic specimens and those of adult and gerontic growth stages (see Pl. 6.1, Figs 1-15; Pl. 6.2, Figs 7-14), and concluded (p. 231) that "in view of its changing nature, the foraminiferal test's surface texture or topography is of secondary taxonomic importance". The authors also observed an abnormally shaped last chamber (like the ultimate chamber found in mature favusellid individuals - see Pl. 6.1, Figs 10-15) that occurred mostly in larger specimens, but also occasionally in smaller individuals as well. They interpreted this chamber as a morphological character that would have caused the termination of further test growth, whatever the age of the organism.

Higher in the stratigraphic sequence the favusellid assemblages sharply decline in number being progressively replaced by numerous other planktonic foraminifera with rugose/pustulose (pustules and/or costellae) chamber surface. For instance, rugose/pustulose specimens of Hedbergella ex gr. delrioensis (Carsey), Hedb. ex gr. simplex (Morrow), Ticinella raynaudi Sigal (last occurrence in the uppermost Albian) and Praeglobotruncana delrioensis (Plummer) are abundant in the uppermost Albian and lowermost Cenomanian strata [Chapter 4, section 4.2.1.(i); Chapter 5, section 5.4.4; and Chapter 8, section 8.2.3]. Similar assemblages were described by Saint-Marc (1973) from middle Cenomanian deposits of Lebanon (Hedbergella costellata Saint-Marc, a probable synonym of Hedb. ex gr. delrioensis); from the Albian neritic deposits of the Walvis Ridge and Angola Basin (Caron, 1978); from the upper Albian and lower Cenomanian of Morocco (Sliter, 1980; Leckie, 1984); and from the Coniacian of the southern Pyrenees (Fondecave, 1975). These rugose foraminiferal assemblages are in turn replaced by abundant specimens of non-ornamented Hedbergella and Ticinella in deeper environments (Fig. 6.3). Favusellids do occur, however, in occasional "blooms" of large specimens (later ephebic and gerontic forms), probably linked to periods of sea-level lowering and/or to displacement of unconsolidated shallow-water deposits by turbidity currents. A discontinuity in the favusellid record is present between the end of the Albian and the early part of the Cenomanian, when they reappear, for the last time, in reduced numbers.

6.4 - DISCUSSION

6.4.1 - Phylogenetic Relationships

No short-range stratigraphic significance can be attributed to the favusellids. They occur, with variable morphologic diversity, from the late Barremian-early Aptian (Azerbaidzhan, northwestern Caucasus: Antonova et al., 1964; Morocco coast, Atlantic ocean: Grigelis & Gorbatchik, 1980) to the early-middle Cenomanian.

Masters (1977) considered all the favusellid species as junior synonyms applied to intraspecific variants of the single species Globigerina washitensis Carsey. The same usage was followed later by Caron (1985), although retaining the generic designation of Favusella and a phylogenetic lineage from Globuligerina (cf. proposition of Grigelis & Gorbatchik, 1980; see below). According to Masters (1977), forms similar to any of these favusellid species are found associated with "typical" Globigerina washitensis over its entire stratigraphic range. As he clearly pointed out (p. 479), "some of the specimens illustrated by Michael (1972, Pl. 5, Figs. 4-9) show indisputable evidence of post-burial deformation. The resulting flattening and associated features were used by him as species-level characteristics". However, Masters' use of the genus Globigerina for all hedbergellids and favusellids is an excessively broad concept with which I cannot agree. Globigerina and Hedbergella differ, basically, by characteristic test features of wall structure and porosity. Specimens of hedbergellids (including favusellids) have a microgranular hyaline outer wall structure, whereas Globigerina may have outer walls with a radial hyaline (prismatic) outer layer and a microgranular hyaline inner layer, or may be entirely microgranular hyaline in structure (Pessagno, 1967, 1969; Pessagno & Miyano, 1968). Furthermore, in the center of each surficial polygon of Globigerina there is a single, large pore, whereas in hedbergellids numerous smaller pores are dispersed all around the test or within each individual reticulate cell (and between tubercles of a favusellid specimen; see Pl. 6.2, Figs 8, 14); fewer pores are also scattered on the edges of the cell-ridges and tubercles.

From the observation of figured topotype specimens of Conoglobigerina Morozova and Globuligerina Bignot & Guyader, from Middle-Upper Jurassic and Lower Cretaceous sections (in Grigelis & Gorbatchik, 1980, Pl. 1, Figs 1-7), a close morphological similarity is noticeable between these early favusellids and later small-sized specimens of Favusella (e.g., Conoglobigerina: test surface ornamentation in the form of rounded or elongated tubercles, some forming short ridges; Globuligerina: trochoid or irregularly trochoid test, surface ornamentation of tubercles and reticulate system of irregular quadrangular cells). A phylogenetic sequence of Conoglobigerina-Globuligerina-Favusella was proposed by Grigelis &

Gorbatchik (1980). However, the evidence presented herein suggests a more intimate taxonomic affinity between these species, which can only be assessed after further investigation of holotypes and topotype material of Jurassic and Early Cretaceous favusellids.

6.4.2 - Palaeo-environments and Functional Morphology

The available evidence clearly indicates that environment strongly controlled the distribution of the favusellid morphotypes. After examining several thousands of favusellid specimens from various localities and well-sections of the mid-Cretaceous succession of the Sergipe Basin it is concluded that these forms should be considered as ontogenetic polymorphs and ecophenotypic variations of a single hedbergellid (favusellid) taxon. The typical cancellate ornamentation that characterises the subgenus Favusella (see taxonomy, Chapter 3) could result from a response to a water mass with warmer temperatures, hypersalinity (cf. Mello, 1988; data for the Sergipe Basin) and high concentrations of calcium carbonate, as commonly found in shallow-marine carbonate environments (Murray, 1973; Lees, 1975; Pigott, 1982). The high evaporation rates associated with warm, shallow-marine conditions tend to increase the calcium carbonate concentration in the sea water and, consequently, its availability for organic calcification (Murray, 1973, p. 229). The random tuberculate/reticulate surface ornamentation of the mature favusellids may well be a response to a variably high calcium carbonate background level.

In comparison with the current knowledge of extant planktonic foraminiferal life cycles (Lipps, 1970; Bé, 1977; Caron, 1983a) we conjecture that the favusellid gametogenesis took place in relatively open waters (inner-middle neritic) during the adult and gerontic stages. Reproduction of other hedbergellids most likely occurred in middle to outer neritic waters (deeper than 30-50m). Following gametogenesis the growing juveniles would have ascended to surface waters (e.g., Caron & Homewood, 1983). Water movements could then result in this young, near-surface dwelling population being washed into shallower carbonate-saturate marginal environments, where the planktonic foraminiferal population is remarkably rich and composed of nearly 100% of neanic and young ephebic favusellids (Fig. 6.3). This could have led the foraminiferal protoplasm to an overabsorption of calcium ions during early ontogenetic stages. The calcium store is deposited on the test progressively, during test growth or, perhaps, prior to gametogenesis, as observed on some extant foraminifera (C. Hemleben, oral communication, Tubingen, February 1986). This precipitation results in thicker walls, coarser surface ornamentation, and more robust tests (trochoid shape). The juveniles that have not been washed shoreward and succeeded in growing in deeper water, less saturated in calcium carbonate, would evolve into other rugose (with pustules and/or costellae) and non-rugose hedbergellids. Ephebic and gerontic favusellids, thriving in progressively deeper water with ontogenesis, occupied, in few numbers, the same niches (inner-middle to outer neritic) of other deep offshore planktonic taxa, as they can be found associated with variable proportions of rugose and non-rugose hedbergellids, ticinellids and globigerinelloidids (Fig. 6.3).

It is also possible that there is a relationship between test morphology and water energy conditions (coarse and thick ornamentation contributing to test protection in very agitated shallow waters). In the Sergipe sections most of these favusellid populations thrived in low-energy conditions (inner neritic deposits of calcareous mudstones and marls), but they are also known to occur in high-energy environments (e.g., oolitic/oncolitic-bioclastic packstones/grainstones) of the lower-middle Albian deposits of the Campos Basin (Koutsoukos, 1987) and the Cumuruxatiba-Jequitinhonha Basin (Koutsoukos & Dias-Brito, 1987), both in SE and NE Brazil. Despite the fact that the function of surface ornamentation in foraminiferal tests is not precisely known, it has been conjectured that the build-up of surface ornamentation in a planktonic foraminifer living in a habitat with relatively high-density bottom-waters (warm waters, hypersaline, with high concentrations of calcium carbonate), would cause it to sink more easily in the water column in order to reach a preferred density level (Caron & Homewood, 1983, p. 455). Depending upon how coarse the calcification was (generally higher in larger mature specimens), this could have enabled a particular community to thrive in a pelagic niche near the sea-bottom, somewhat insulated and protected from the very warm surface waters, which would result in a mature stage with a quasibenthonic life habit and distribution pattern. The hypothesis of a benthonic phase during the life cycle of the early favusellids has also been suggested by Caron (1983b) in order to explain their origin from benthonic foraminiferal ancestors in Jurassic times and their subsequent restricted palaeo-environmental distribution.

Gorbachik & Kuznetsova (1986) observed that Globuligerina oxfordiana (Lower Oxfordian), Conoglobigerina meganomica (Callovian) and Favusella washitensis (Late Albian) all possess walls which were primarily aragonite. This unparalleled test mineralogy within the Suborder Globigerinina has been used by Banner & Desai (1988, p. 144-146) to support the separation of these genera into a distinct superfamily, the Favusellacea. However, this evidence should be considered with greater care, from a palaeo-ecological point of view, in order to unveil the true causes behind such unique test mineralogical composition. Aragonite is an othorhombic unstable form of $CaCO_3$ and is formed at higher temperatures than calcite. It may be the original form in which $CaCO_3$ is deposited, inverting in the course of time to the more stable calcite (cf. Whitten & Brooks, 1974). The environment par-excellence inhabited by the favusellids has been shallow, warm, hypersaline, carbonate-saturated marginal seas or carbonate platforms. The primary stage in the biomineralization process of planktonic foraminiferal communities thriving in these biotopes would follow, ultimately, basic mineralogical rules and cannot be simply related to a genetic background. Therefore, the $CaCO_3$ store to be secreted in the form of either ortorhombic or hexagonal crystals is most likely to have been dictated by the overall environmental conditions. In shallow, warm, carbonate-saturated waters, the more stable $CaCO_3$ form to be formed would be aragonite rather than calcite.

PLATE 6.1

Hedbergella **(Favusella)** **washitensis** (Carsey) showing progressive morphological change (in chamber arrangement, test surface ornamentation and apertural position) with ontogenetic development.

All illustrations are scanning electron photomicrographs.
Scale bars = 100um.

1–6: Neanic specimens. All umbilical views. Low trochospire formed by 1-1.5 whorls; generally 3–5 chambers in last whorl, increasing gradually in size; last chamber considerably larger, comprising $^1/_3$-$^1/_2$ of total diameter of test; primary aperture umbilical. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, (1–2, 5) core 1: 466.00m; (3–4) core 1: 466.20m; (6) core 1: 466.50m.

Evidence suggests a dichotomous course in ontogenetic development of favusellid population. Less common alternative pathway is indicated by horizontal white arrows. Here, the very early neanic form in (1) would have envolved to the small (stunted growth ?), still immature specimen in (3), morphologically similar to (5) and (6). In the most common alternative pathway, the test gradually increases, envolving progressively from specimen in **1** to **4**, and thereafter to subsequent stages.

7–8: Intermediate lobate specimens (young ephebic stage). Umbilical views. Low trochospire, formed by 2 whorls; generally 4 chambers in last whorl, gradually increasing in size as added; primary aperture umbilical to extraumbilical. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, (7) core 1: 466.00m; (8) core 1: 466.70m.

9: Quadrate intermediate specimen (young ephebic stage). Umbilical view. Low trochospire, formed by 2-2.5 whorls; usually 4.5–5 chambers in the last whorl, gradually increasing in size as added; primary aperture umbilical to slightly extraumbilical. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 1: 466.20m.

10-15: Large spiro-convex mature specimens (late ephebic stage). (10, 12, 14) Umbilical views; (11, 13, 15) peripheral views. Low to high trochospire, formed by 2.5-3.5 whorls; generally 5-6 chambers in last whorl, increasing gradually in size as added; ultimate chamber smaller, bare or smoother ornamentation, produced toward umbilicus and partially covering it; primary aperture umbilical-extraumbilical. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 4: 496.55m.

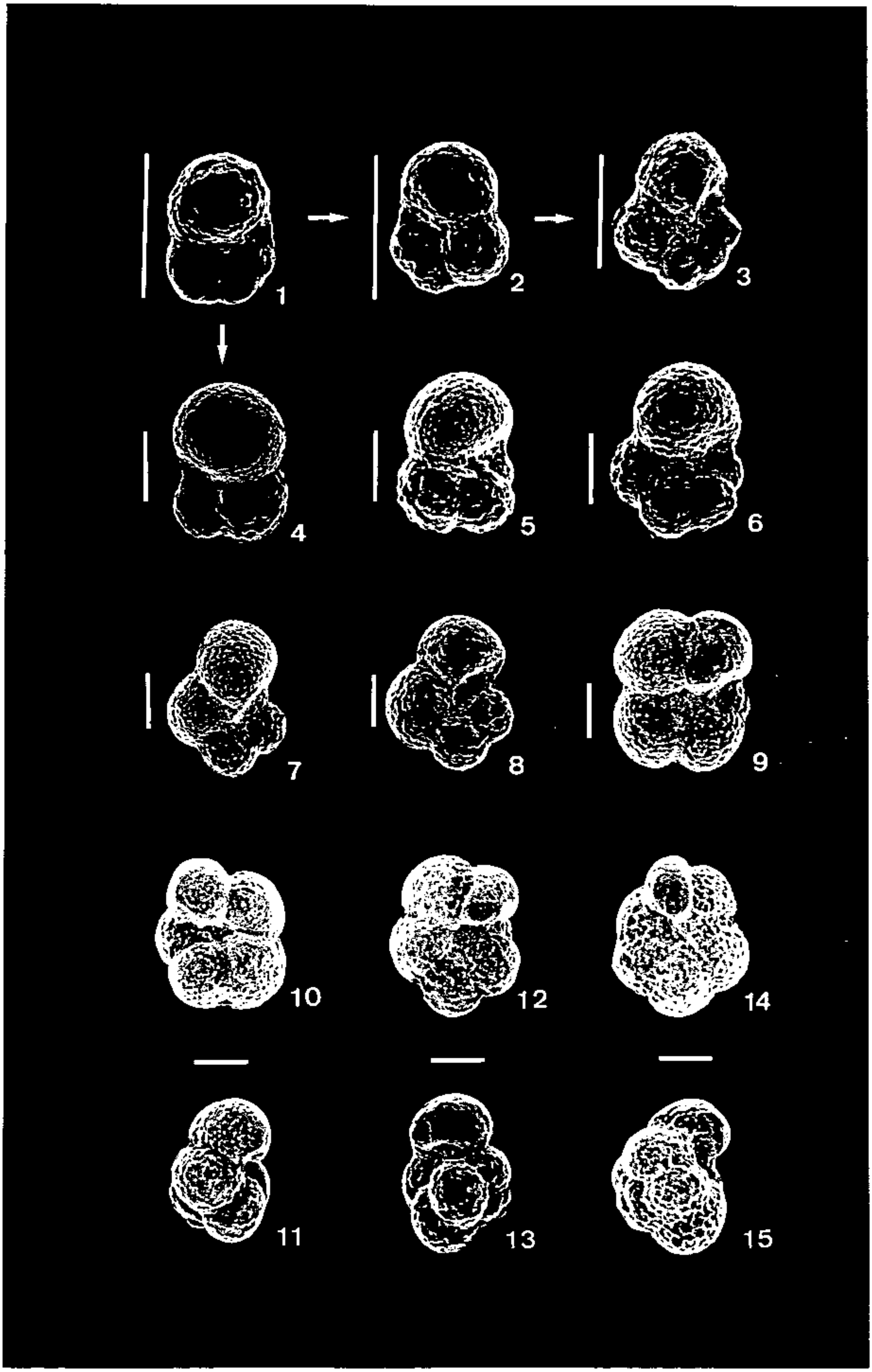

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PLATE 6.2

Hedbergella (Favusella) washitensis (Carsey)

All illustrations are scanning electron photomicrographs of spiral views and scale bars = 100μm, unless otherwise indicated.

1–4: Neanic to young ephebic (intermediate) specimens. Tests show 1.5–2 volutions of spherical chambers, becoming progressively more lobate as added. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, (1) core 1: 466.00m, (2-4) core 1: 466.70m.

5–6: Mature specimens (late ephebic stage). Tests contain 2.5–3.5 volutions of moderately spherical chambers; earlier whorls somewhat masked by succeeding ones and overgroths of test ornamentation. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 4: 496.55m.

7–8: Neanic specimen. (7) Spiral view; (8) detail of penultimate chamber showing the incipient tuberculate ornamentation; note also minute pores scattered on surface; scale bar = 10μm. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 1: 466.00m.

9–10: Young ephebic specimen. (9) Umbilical view; (10) detail of ultimate chamber showing test surface covered by rounded and elongate tubercles, several forming short ridges. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 1: 466.00m.

11–14: Ephebic specimens. (11) Umbilical view; (12) detail of second chamber of last whorl showing well developed reticulate system of coarse ridges forming irregular polygonal cells (honeycomb pattern); (13) spiral view; (14) detail of penultimate chamber; note numerous minute pores dispersed within each individual reticulate cell; pores also scattered on edges of cell-ridges. Riachuelo Formation, Taquari Member, Well 7-CP-252-SE, core 4: 496.55m.


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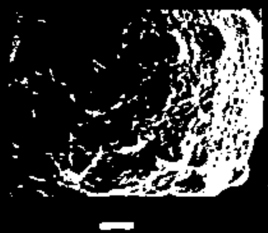
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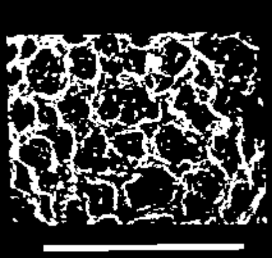
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