

**UTRECHT  
MICROPALAEONTOLOGICAL  
BULLETINS**

**J. HAGEMAN**

**BENTHIC FORAMINIFERAL ASSEMBLAGES FROM  
PLIO-PLEISTOCENE OPEN BAY TO LAGOONAL SEDIMENTS  
OF THE WESTERN PELOPONNESUS (GREECE)**

**20**

## UTRECHT MICROPALAEONTOLOGICAL BULLETINS

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BENTHIC FORAMINIFERAL ASSEMBLAGES FROM  
PLIO-PLEISTOCENE OPEN BAY TO LAGOONAL SEDIMENTS  
OF THE WESTERN PELOPONNESUS (GREECE)

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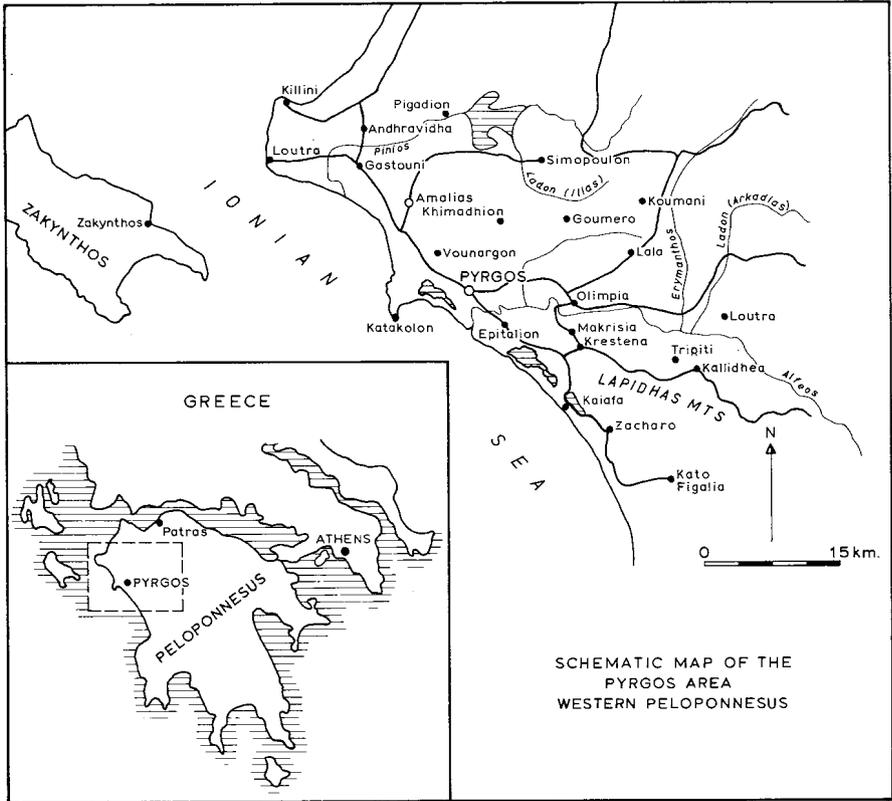


Fig. 1 Location of the Pyrgos area, western Peloponnesus.

## ABSTRACT

A quantitative investigation has been carried out on benthic foraminiferal faunas from Plio-Pleistocene, open bay to lagoonal deposits of the Vounargon Formation of the western Peloponnesus, and a reconstruction has been made of the paleogeographic history of this area.

After a period of denudation and deposition of lacustrine sediments in large areas of the Peloponnesus, a Late Pliocene transgression introduced an extensive shallow marine environment in the Pyrgos area, with numerous, probably East-West directed sand ridges. This depositional realm, which may have extended over large areas of the northern Peloponnesus, was probably connected with the open sea towards the North. To the South-East and South it was apparently bordered by a land mass, while a hypothetical ridge or shoal area, extending from the Gulf of Kyparissia towards Zakynthos may have formed the western boundary. The Gavrovo-Tripolitza flysch possibly was the main source for the material of the sand ridges. During the Pleistocene the area of maximum subsidence shifted to the northern part of the Pyrgos area, while large parts of the central Peloponnesus were uplifted. In this episode the orientation of the sand ridges changed from East-West to North-South.

Fifteen sections in the Vounargon Formation, which together are thought to present a characteristic picture of the open bay to lagoonal deposits, were studied in detail. A correlation could be established between the character of the benthic associations and environmental factors such as type of sediment, salinity, subaquatic vegetation and depth.

The relatively open marine basal parts of the Vounargon Formation appeared to contain a fauna of mud-dwellers with as its most important constituents *Brizalina*, *Bulimina* and *Cassidulina*. The faunas from environments associated with the sand ridges are generally characterized by high frequencies of species of *Nonion*, *Elphidium* and *Ammonia*. Sediments from environments with a strongly decreased salinity appeared to contain poor faunas made up almost entirely of *Ammonia beccarii tepida*.



## Chapter I

### INTRODUCTION

The Upper Cenozoic of the Pyrgos area in the western Peloponnesus (Greece) (fig. 1) is composed of shallow marine, lagoonal, lacustrine and fluviatile sediments. Five formations have been distinguished and mapped (Hageman, 1977). These are the sedimentary expression of a complicated history, which was mainly defined by differential, vertical movements. The distribution of the lithostratigraphic units and the position of the major faults are illustrated in the geological map (fig. 2). From the relation of the sediments in space and time, four successive episodes of the local Late Cenozoic history could be inferred; these are discussed in detail in the author's earlier paper. A short summary of this history will be presented in the following paragraphs. It should be noted that the results of the present study necessitate a revision of the 1977 interpretation (chapter VIII). To enable the reader to have easy access to the new data the following review is based on the 1977 version.

During the first time interval, Pliocene deposits of predominantly lacustrine origin accumulated in a flat area in the South. These sediments were included in the Platana Formation. The supposed paleogeographic configuration in the area during this interval is illustrated in figure 3.

Submergence associated with an increased supply of clastics resulted in the development of coastal bars and barriers and the installation of lagoonal systems during the Late Pliocene. In the sedimentary record this interval is reflected by the sands and silty clays of the Vounargon Formation (see fig. 4).

During the third episode, fluviatile and lacustrine deposits expanded over the earlier shallow marine-lagoonal sediments, owing to a more pronounced hinterland. The paleogeographic configuration and the distribution of the sediments of this regressive phase (the Olimpia and Erymanthos Formations in the South and the East) are illustrated in figure 5.

The northern part of the investigated area, which was thought to be an emerged block during the Pliocene, had probably already started to subside during this regressive phase. After a transgression of short duration this part of the realm was transformed into shallow marine and lagoonal environments during the Early Pleistocene. To the East the sediments corresponding to these environments interfinger with fluviatile and lacustrine deposits. Be-

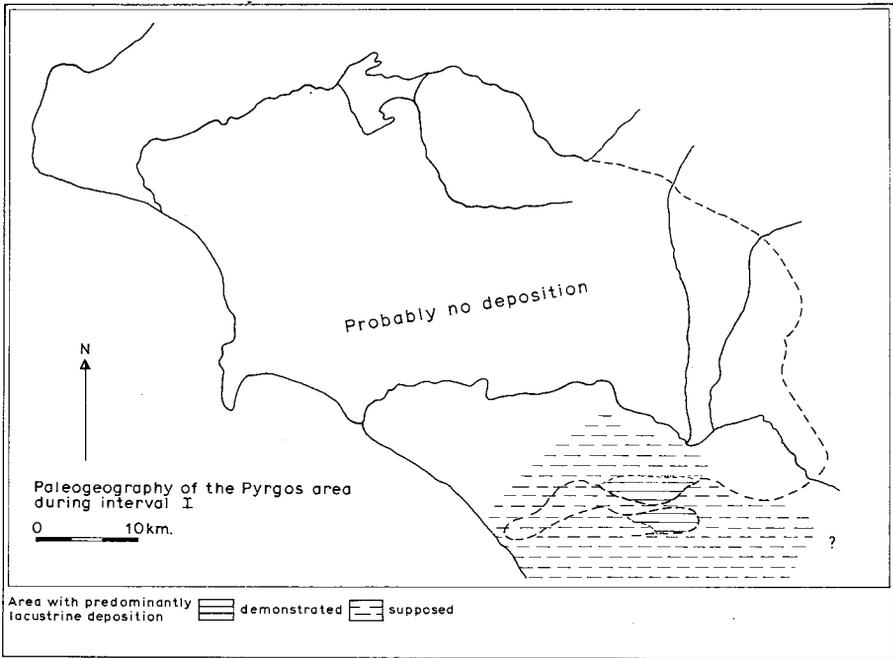


Fig. 3 Paleogeographic configuration of the Pyrgos area during the first interval of the sedimentary history (interpretation 1977).

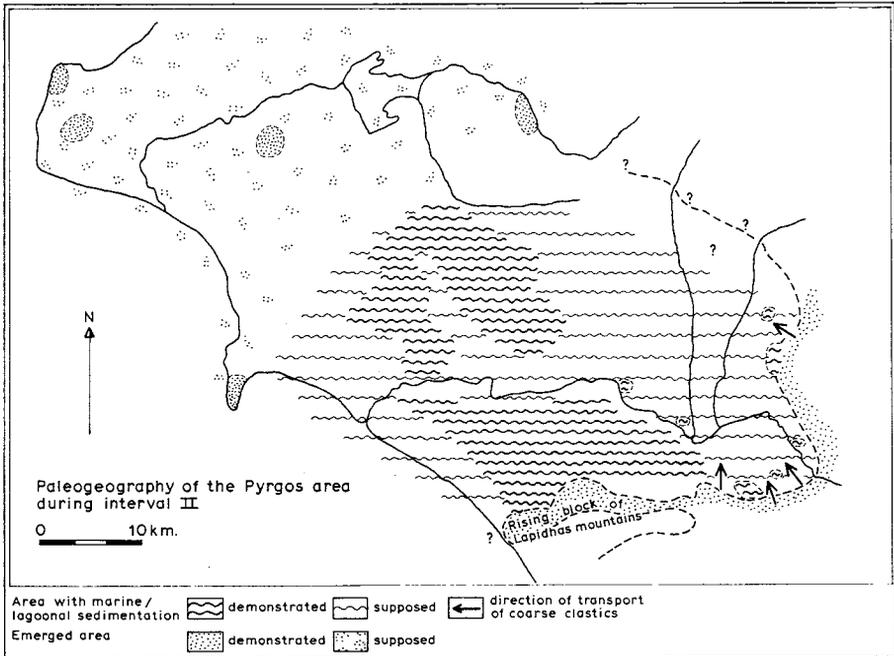


Fig. 4 Paleogeographic configuration of the Pyrgos area during the second interval of the sedimentary history (interpretation 1977).

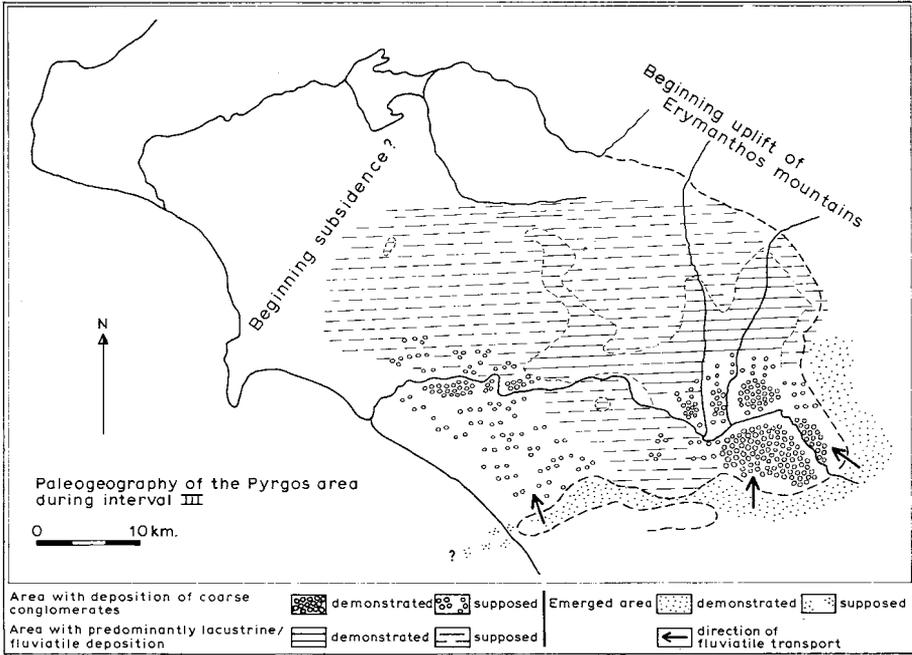


Fig. 5 Paleogeographic configuration of the Pyrgos area during the third interval of the sedimentary history (interpretation 1977).

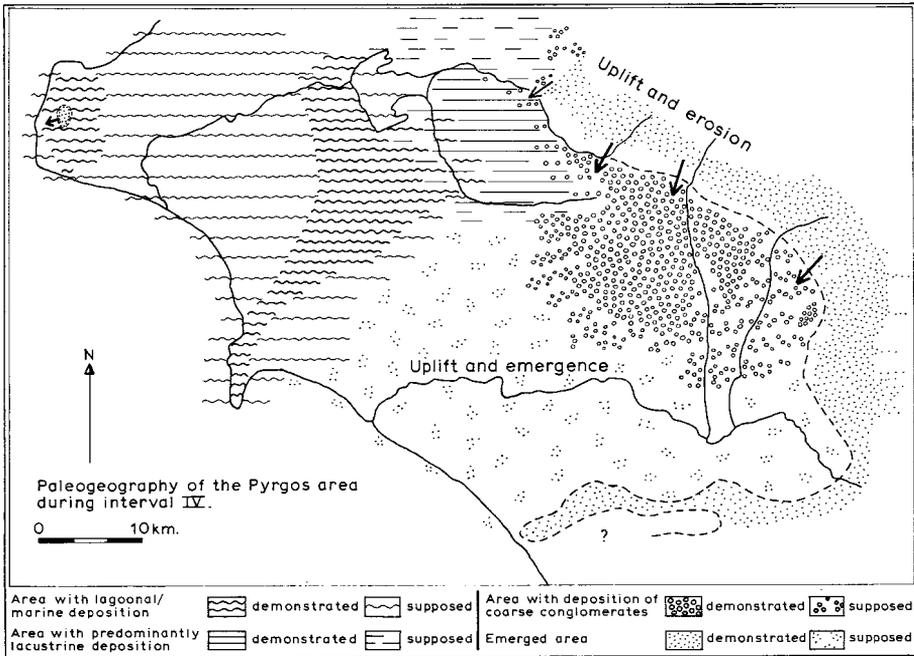


Fig. 6 Paleogeographic configuration of the Pyrgos area during the fourth interval of the sedimentary history (interpretation 1977).

cause of the lithological similarity the marine and lagoonal sediments of this fourth episode have also been included in the Vounargon Formation; the non-marine clastics in the East are placed in the Balmi Formation. The paleogeographic configuration is given in figure 6.

Finally the sea withdrew from the larger part of the Pyrgos area and sedimentation became restricted to the deposition of marine terraces and lagoonal sediments in today's coastal area, and to the accumulation of fluviatile terraces. Right up to the present day differential vertical movements have played an important role in shaping the relief of the area.

In this paper a detailed account will be given of the benthic foraminiferal faunas and the lithology of the shallow marine to lagoonal successions of the Upper Pliocene and Lower Pleistocene Vounargon Formation and an attempt will be made to present a paleoenvironmental analysis, based on the quantitative investigation of the benthic foraminiferal assemblages encountered.

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## Chapter II

### THE VOUNARGON FORMATION

The Vounargon Formation consists of repeated alternations of silty clays and sands, most of which are thought to reflect deposition in marginal marine environments. The formation overlies preneogene rocks, but at some places in the South it covers the lacustrine deposits of the Platana Formation. In the southern and central areas the Vounargon Formation is overlain by the lacustrine and fluvatile deposits of the Olimpia and Erymanthos Formations. In the North-East the Vounargon Formation is overlain by the mainly lacustrine Balmi Formation, although parts of both formations seem to be contemporaneous. On the Katakolon peninsula a caprock of marine limestone terrace deposits is found on top of Vounargon deposits with unconformable contact.

The maximum exposed thickness of the Vounargon Formation is about 500 metres, but approximately 1000 metres were recorded from wells drilled near Sosti (Hageman, 1977) and South of Karatoula (Von Loczy, unpubl. rep., 1951?), and probably more than 1700 metres in a boring near Katakolon (Mitzopoulos, 1940).

The Vounargon successions show considerable differences with respect to the thickness of the individual lithological units and to the macrofossil content.

In the central and southern parts of the Pyrgos area individual silt/sand bodies may attain a thickness of up to 40 metres; such strata may be traceable over more than 5 kilometres. The sands are often rich in sedimentary features such as small- and large-scale cross-bedding and horizontal lamination. The uppermost parts of the individual sands may show cementation; in such cases they often show numerous closely-packed molluscs or casts thereof, predominantly of *Cardium*.

The finer-grained intervals in the central and southern areas have a maximum thickness of 25 metres. In general, they consist of silty clays, which may contain intercalations of thin lignite seams and of limestones which originated in brackish (or even fresh) water. The macrofossil content of the clays is highly variable. Within one unit, layers with a rich and diversified marine mollusc assemblage may alternate with intervals, which are barren or contain a fauna of low diversity.

The clays, silts and sands are often arranged in thick, upwards-coarsening

sequences of up to 60 metres; up to six superposed sequences have been observed in the high ridges in the central part of the area.

In the South, the basal part of the formation consists of greyish-blue, marly and silty, partly laminated clays with a rich macrofauna, which includes genera such as *Arca*, *Aporrhais*, *Cardium*, *Dentalium*, *Murex*, *Pecten*, *Serpula*, *Turritella* and *Venus*. The pelecypods are often found with both valves attached. In the surroundings of Grillos and Tripiti these deposits attain a thickness of 40 metres. They are found on top of the lacustrine deposits of the Platana Formation and are overlain by thick successions of alternating clayey and silty/sandy beds. In the south-eastern and eastern parts of the area basal clayey Vounargon sediments locally overlie preneogene rocks.

Calcareous nannofossil associations derived from these basal strata of the Vounargon Formation belong to the *Discoaster surculus* Zone, which indicates that the open marine influence started during the Late Pliocene.

Along the eastern margin of the present distributional area of the Upper Neogene between Kallidhea and Okhthia (fig. 2), the Vounargon Formation has a thickness of only some 150 metres. It shows successions, characterized by relatively limited thickness of the individual lithological units (generally less than 10 metres), by a high number of indurated interbeds of calcareous sandstone and by some intercalations of often ill-sorted, breccious conglomerates. These data were thought to suggest that the recent, eastern boundary of the distributional area of the Vounargon Formation is close to the position of the basin margin during deposition.

Also in the southwestern part of the area, in the vicinity of the Lapidhas Mountains, the sand and clay units are generally not so thick as in the central area, while the number of indurated levels, which are thought to correspond to periods of non-deposition, is relatively high. Conglomeratic and breccious intercalations are absent, however, and rich malacofaunas have been found. It is thought that the Lapidhas Mountains acted as a, possibly submerged, relative high in the South during the deposition of this part of the Vounargon Formation.

Contacts are exposed between the Vounargon Formation and the overlying Olimpia and Erymanthos Formations at several places in the central and southern parts of the area. The transition invariably occurs over a short interval. Close to the contact, the uppermost part of the Vounargon Formation may contain coarse, conglomeratic intercalations in the sandbodies. These coarse interbeds witness to a rather sudden supply of coarse terrigenous material.

On the Katakolon peninsula, West of Pyrgos, 50 metres of greyish, partly

laminated, fossiliferous clays probably constitute the basal part of the Vounargon Formation. A rich and diversified macrofauna is present with *Aporrhais*, *Arca*, *Cardium*, *Dentalium*, *Murex*, *Nassarius*, *Natica*, *Pecten*, *Venus*, *Serpula*, corals and bryozoa. These fossiliferous clays closely resemble those found near the base of the formation in the South and in the East, but they contain a nannoplankton flora characteristic for the Early Pleistocene (*Pseudoemiliana lacunosa* Zone). The same age was inferred (Hageman, 1977) for the calcareous nannoplankton assemblages from the Vounargon deposits in the Killini peninsula and in the sediments from the deepest part of a drilling near Sosti, North of Amalias (see fig. 1).

The successions of the Vounargon Formation in the North (approximately North of the line Katakolon – Ag. Trias) differ from those in the central and southern parts of the area in that they have less thick individual clay and sand units, which do not exceed 15 and 7 metres respectively, and have a macrofauna of reduced marine affinity; *Cardium*, *Limnocardium*, *Cerithium*, *Melania* and *Ostrea* are the predominating forms. The most diversified macrofaunas are often found in the sands, whereas the clays are either barren or contain brackish faunas with a high number of specimens and a low species diversity.

The stratigraphic position of the northern deposits of the Vounargon Formation relative to those described from the central area can be unravelled along the road Pyrgos – Oinoi. Here, Vounargon deposits of the “northern type” are found on top of 50 metres of coarse, fluviatile conglomerates, which are probably an offshoot of the Olimpia Formation. These conglomerates, which are found in the uppermost part of the clay and silt/sand successions, are similar to those described from the central area.

In the surroundings of the barrage-lake of the Pinios river the supposedly lagoonal successions of the Vounargon Formation show a lateral transition in an eastward direction to lacustrine deposits of the Balmi Formation.

The Vounargon sediments of the Killini peninsula resemble those from the northern area. They are found along and on top of preneogene rocks. Locally they contain ill-sorted, breccious-conglomeratic interbeds, which reflect periodical influxes of coarse material. A basal, clayey interval with a diverse, open marine malacofauna was not found in this region, but some clayey intercalations appeared to contain a calcareous nannoplankton flora which could be assigned to the Early Pleistocene *Pseudoemiliana lacunosa* Zone.

## Chapter III

### PURPOSE OF THE INVESTIGATION

#### INTRODUCTION

It had become clear from the lithostratigraphic fieldwork (Hageman, 1977) that the Vounargon Formation consists of deposits formed in a large variety of depositional environments, from entirely open marine to variously restricted ones. In view of the encountered macrofaunas and today's lakes behind the coastline near Pyrgos it is reasonable to assume that during the deposition of the Vounargon Formation, lagoons and freshwater lakes occurred as well. A preliminary review of the microfaunas confirmed that the expected variation of environments really is represented.

The purpose of the present investigation was to check and establish the sedimentary history and suite of paleogeographic reconstructions by means of microfaunal analyses.

Twelve sections from different areas and composed of different types of succession of the Vounargon Formation were selected for more detailed microfaunal analysis. Two sections show the relatively open marine Upper Pliocene clays above the base of the formation in the South, a third represents the open marine deposits at the base of the Pleistocene part of the Vounargon Formation. A fourth section shows the transition from open bay to shallow, more sandy deposits which show some degree of isolation from the open sea. Five sections are situated in the southern and central parts of the area with its thick silty clay to sand sequences, while another one is from the area with relatively thin clay and sand alternations and numerous cemented levels adjacent to the Lapidhas Mountains. Finally, two sections represent the sequences which are thought to overlie the deposits of the Early Pleistocene transgression on the Katakolon peninsula and in the North.

In addition some data will be presented on the faunas from the Sosti drilling and from the section on the Killini peninsula.

It should be emphasized that there is no lithostratigraphic correlation between any two of these sections. For several of them we have a fair idea about their position relative to the base or the top of the formation, but the field data are insufficient to follow individual layers from one section to another.

## METHOD OF INVESTIGATION

The lithological outline and stratigraphical position of each section will be described, special reference being made to sedimentological aspects and the macrofossil content. For the micropaleontological investigation, samples were taken in such a way that they can be regarded as being representative for the faunal composition of the successive lithological units in each section.

In order to obtain comparable observations, all samples were submitted to the same procedure. First, the samples were saturated with water. In order to get an insight into the density of benthic foraminifera in the sediments (number of benthic foraminifera per unit volume of sediment), the total volume of wet sediment was measured; then the samples were washed and the residues coarser than  $125 \mu$  were dried. The number of splits ( $n$ ) of the total residue of a sample necessary to obtain a countable number of benthic specimens and the total number of specimens in the final split ( $a$ ) were determined. The function  $2^n \cdot a$  gives an estimate of the total number of benthic foraminifera present in the residue. For a statistical error analysis of the method see Zachariasse and M. M. Drooger (in Zachariasse et al., 1978). Finally the number of specimens of the size fraction larger than  $125 \mu$  per 1 cc wet sediment was calculated. It should be stressed that the treatment with carbon tetrachloride (see below) certainly gives too low results for these densities.

Unfortunately, a great number of our samples proved to be very poor in foraminifera, which made it necessary to treat the washed residues with carbon tetrachloride ("floating method"), to speed up the operations to arrive at a sufficiently high number of specimens for a further quantitative analysis. This was done for all samples. After treatment with carbon tetrachloride each residue was separated into smaller portions by means of an "Otto sample splitter" and finally 300 benthic foraminiferal specimens (when available) were determined to species level and counted. In addition, the number of planktonic foraminifera seen while counting these 300 benthics was recorded.

Treatment of the washed residue with carbon tetrachloride may have a distorting effect on the faunal composition. This gravity settling method implies that species with many well-preserved specimens may be over-represented in the counts, while those with many "heavy" or ill-preserved specimens, such as arenaceous specimens and sediment-filled individuals, may show up in percentages distinctly lower than their "real" relative frequencies. Consequently, we have to handle the quantitative data with

caution and not much significance can be attached to smaller fluctuations in the numbers of single species from successive samples. In addition, one has to be careful because of the various errors inherent in the counting method itself (Zachariasse et al., 1978).

Most of the samples from sandy sediments appeared to contain a considerable number of radiolarians. These specimens appeared to have a Paleogene age (W. R. Riedel, pers. comm.), and consequently must have been reworked.

#### FREQUENCY DIAGRAMS AND DISTRIBUTION CHARTS

For all samples of a section the numbers of specimens of each taxon encountered are given in the distribution charts, shown in tables I–XIV, along with the number of planktonic foraminifera, the benthos density (number of benthic foraminifera per 1 cc sediment) and the calculated  $\alpha$ -index (Fisher et al., 1943), used as an estimate of faunal diversity.

In the frequency diagrams (figs. 7–20) taxa taken together are those that are either closely related, or that have an analogous external morphology, probably due to their similar way of life. Sixteen groups of taxa were distinguished:

1. *Ammonia beccarii*-group (consisting of *A. beccarii* var. *beccarii*, *A. beccarii* var. *inflata* and *A. beccarii* var. *tepida*),

2. *Ammonia perlucida*,

3. *Elphidium* species,

4. *Nonion boueanum*,

5. *Cancris auricula*,

6. *Reussella spinulosa*,

7. *Fursenkoina schreibersiana*,

8. Species with a plano-convex test, the shape probably being connected with their "attached" mode of life. These are mainly *Asterigerina* species, *Asterigerinata mamilla*, *Cibicides lobatulus* vars. 1 and 2, *Hanzawaia rhodiensis*, *Planorbulina mediterraneensis*, *Rosalina bradyi* and *R. globularis*. Also species generally occurring in low relative frequencies, such as *Discorbinella bertheloti*, *Gavelinopsis praegeri*, *Neoconorbina milletti* and *Patellina corrugata* were incorporated in this group.

9. Miliolids,

10. Arenaceous species,

11. *Valvulineria complanata*,

12. Species with a calcareous, perforate wall, a trochoid chamber arrangement and a biconvex test (*Cibicides burdigalensis*, *C. dutemplei*, *C. ungeria-*

*nus* and *Oridorsalis stellatus*),

13. Species of *Bulimina*, *Globobulimina*, *Stainforthia*, *Trifarina* and *Uvigerina* (the *Bulimina*-group),

14. Species of *Bolivina*, *Brizalina*, *Coryphostoma* and *Loxostoma* (the *Brizalina*-group),

15. Species of *Cassidulina* and *Globocassidulina* (the *Cassidulina*-group),

16. Finally all species not belonging to one of these 15 categories were grouped together as "miscellaneous".

Whenever a group reaches a frequency of 5% or more in one sample of a section, all data of more than 3% have been entered in the drawing. For the first fifteen groups none of the percentage values below 3% could be recorded separately in the diagrams. The total of such low values per sample has been added to the miscellaneous category (16).

#### METHOD OF INTERPRETATION

The majority of the foraminiferal species found in the deposits of the Vounargon Formation are also known from recent environments. Therefore it seems plausible that the depositional environments might be reconstructed by simply comparing our faunas with recent assemblages. In fact, however, little is known about the ecological conditions which today control the preferential environment of a species. Most persons working on the ecology of benthic foraminifera agree that the factors determining the biotope of a species are numerous (temperature, salinity, light intensity and quantity, nutrient supply, water chemistry, hydrodynamic energy, hydrostatic pressure, biological competition, etc.) and that the effect of each of these factors separately is difficult to determine. It is often assumed that depth is the main factor, which influences all the others. If the data from the literature on the distribution of recent foraminifera are compared with each other, it is evident that local conditions play a major role in the distribution patterns. Moreover, it should be realized that the ecological niche of some species may have changed in the course of time.

It should also be realized that by comparing fossil assemblages with recent populations one usually compares thanatocoenoses with biocoenoses. While a biocoenose gives a time-restricted picture of a certain environment, a fossil assemblage reflects the ecological history at one place over a longer period of time. As already stated by Von Daniels (1970), the composition and the diversity of a benthic foraminiferal population may vary considerably during one year. And in our samples thousands of years may be represented.

Last but not least, it should be emphasized that the considerable taxonomic confusion that exists with regard to several groups of species (especially shallow water elements, like *Elphidium* and Miliolidae) restricts the applicability of many of the data from the literature concerning the recent distribution of foraminifera.

The direct comparison of our faunas with recent assemblages therefore can give only a rough estimate of their paleoenvironment. Another approach seems possible, however. If the succession of our faunas in all the sections is compared with the sedimentary changes, another approximation of the biotopes of these faunas may be made. As a consequence we tried to base our primary paleoenvironmental analysis as much as possible on such a line of reasoning. A first step in the reconstruction of the paleoenvironments is the interpretation of the stratigraphical and sedimentological data. From the frequency distribution of single taxa or groups of taxa along the stratigraphic column and their relation to the observed lithological changes, additional information can be gathered.

From a comparison of the data and interpretation of all 12 sections we shall attempt to draw some general paleoecological conclusions.

In a separate chapter we shall compare our biotope conclusions concerning the various associations with published environmental data on similar recent associations.

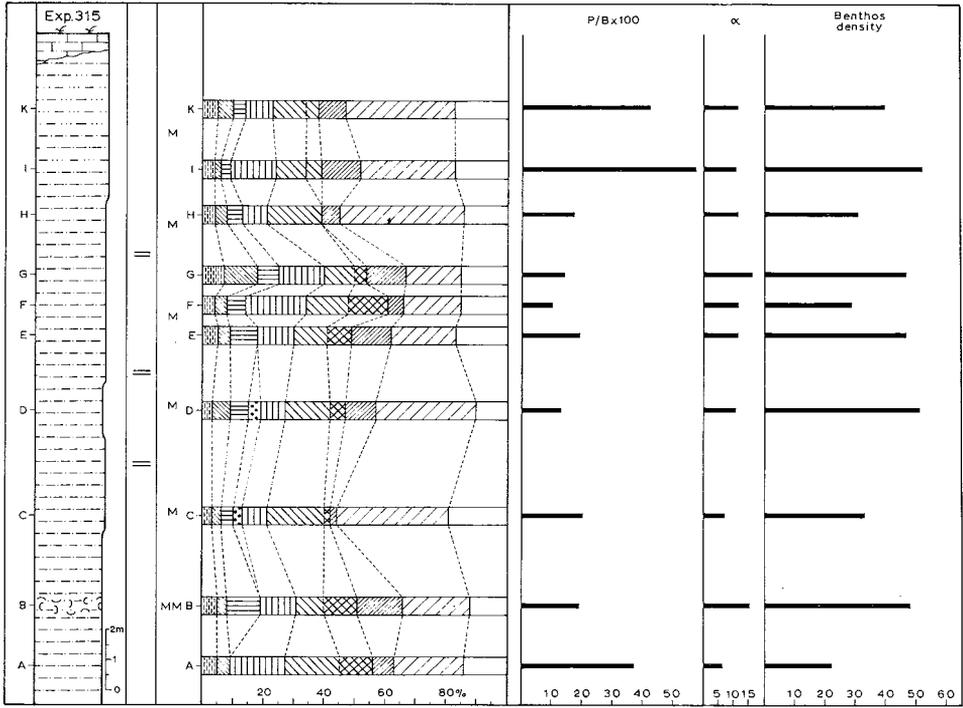


Fig. 7 Lithostratigraphic column and frequency diagram of benthic species at Katakolon, exp. 315.

STRATIGRAPHIC COLUMNS	FREQUENCY DIAGRAMS	SEDIMENTOLOGICAL SYMBOLS	
Fine Sand	<i>Globobulimina</i>	Parallel lamination	
Coarse Sand	"Brizalina"	Small scale cross lamination	
Clay	<i>Uvigerina</i> "Bulimina"	Large scale low angle cross lamination	
Silty Clay	Biconvex trochoid spp.	Slumping	
Silt	<i>Valvulineria complanata</i>	Scour and fill structure	
Limestone	Agglutinants	Indurated level	
Gypsum	Miliolids	Bioturbation	
Lignite	Plano-convex spp.	<b>PALEONTOLOGICAL ABBREVIATIONS</b>	
Conglomerate	<i>Fursenkoina schreibersiana</i>	C <i>Cardium</i> single(C) scattered few double(cc) abundant	
Breccia	<i>Reussella spinulosa</i>	G Gastropods	
Mollusc Shells	<i>Cancris auricula</i>	M Molluscs	
	<i>Nonion boueanum</i>	O Oysters	
	<i>Elphidium</i>	P Pelecypods	
	<i>Ammonia perlucida</i>	Pl Plant remains	
	<i>A. beccarii tepida</i>	V <i>Venus</i>	
	<i>A. beccarii beccarii</i>		
	<i>A. beccarii inflata</i>		
		<b>LEGEND</b>	

## Chapter IV

### THE "OPEN MARINE" SUCCESSIONS

Open marine clays and silty clays were deposited in the southern part of the area during the beginning of the second, Late Pliocene episode of the Late Cenozoic history of the Pyrgos area. It was assumed that the clays accumulated in a semi-enclosed embayment (see fig. 4). After a relatively short period, the rapid increase in the terrigenous-clastic supply is thought to have caused the development of bars and barrier systems and the transformation of the open bay into various lagoonal environments.

Fundamentally the same processes defined the sedimentation in the North during the fourth interval of the sedimentary history, when an initially open marine phase was rapidly succeeded by a return to "lagoonal" conditions.

In the sedimentary record the most open marine period in the South is reflected by the Upper Pliocene clays and silty clays exposed in the surroundings of Grecka, Tripiti, Alifiri and near Okhthia (see fig. 1). Sections Grecka (exps. 300 and 305) are representative for these types of sediment. Section Katakolon (exp. 315) is the best section for studying the faunal associations of the marine clays deposited during the early part of the fourth, Pleistocene episode.

The lithological columns of the three sections are given in figures 7, 8 and 9, which also present graphically the relative frequencies of the groups of benthic foraminifera, the P-B ratio (given as the number of planktonic specimens per 100 counted benthic elements), the calculated values of the  $\alpha$ -index and the benthos density.

In all three sections the sediments are mainly silty clays and clays, generally of a greyish-blue colour. In sections Grecka 305 and Katakolon there is a slight upward increase in the silt content. Molluscs are abundant in all three sections; as a rule they are randomly distributed. *Arca*, *Cardium*, *Ostrea*, *Pecten*, *Venus*, *Aporrhais*, *Melania*, *Murex*, *Turritella*, *Vermetus* and *Dentalium* predominate. There is a negative correlation between the grain-size and the number of molluscs. The upward overall increase in the silt content in sections Grecka 305 and Katakolon goes together with a decrease in the number of molluscs.

Planktonic foraminifera are relatively frequent in Katakolon and fairly rare in the Grecka sections. Index species allowing a biostratigraphic assignment of the sections to any particular part of the zonal systems were not

found. In the Grecka sections *Globigerina apertura*, *Globigerinoides elongatus* and *G. ruber* are the most numerous taxa. They are accompanied by less frequent *Globorotalia crassaformis*, *Globigerina acostaensis*, *G. bulloides*, *G. falconensis*, *G. pseudobesa*, *G. quinqueloba*, *Globigerinoides extremus*, *G. obliquus*, *G. trilobus* and *Globigerinella* sp. In Katakolon the most frequent species are *Globigerina bulloides*, *Globorotalia inflata*, *Globigerinoides ruber*, *G. trilobus* and *Orbulina universa*.

Both the Katakolon and Grecka sections appeared to contain rich nannoplankton associations, which could be used for biostratigraphic purposes. The presence of *Discoaster surculus*, *D. pentaradiatus* and *D. brouweri* at Grecka suggests that these sediments belong to the *Discoaster surculus* Zone, which is indicative of the Upper Pliocene. The associations of Katakolon contain *Pseudoemiliana lacunosa* and *Gephyrocapsa caribbeanica*; this association is characteristic for the Lower Pleistocene *Pseudoemiliana lacunosa* Zone.

### Benthic foraminifera

Throughout the section Katakolon (fig. 7, table 1) the diversity of the benthic foraminiferal assemblages is relatively high ( $\alpha$  is in most samples larger than 10); the various groups of taxa distinguished are present in fairly constant relative frequencies throughout the section. The larger part of the assemblages is made up of representatives of the groups of biconvex *Cibicides*, *Bulimina-Uvigerina*, *Brizalina* and *Cassidulina*; less frequent are arenaceous forms, miliolids and plano-convex species. The P-B values ( $= P/B \times 100$ ) vary between 10 and 58.

In the Grecka sections (figs. 8 and 9, tables II and III) the groups of *Bulimina*, *Brizalina* and *Cassidulina* are the major faunal constituents. Together they invariably make up 70 to 90% of the total association, but

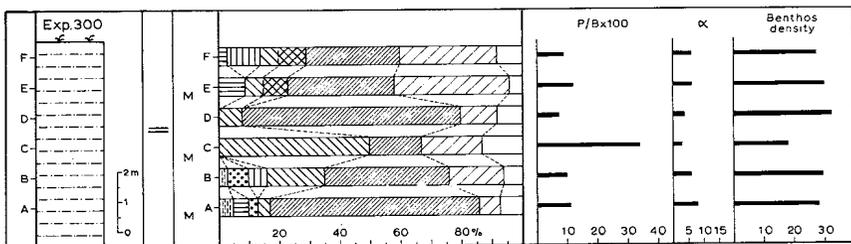


Fig. 8 Lithostratigraphic column and frequency diagram of benthic species at Grecka, exp. 300. For the legend see fig. 7 or the last page.

fluctuations in their relative frequencies are greater than at Katakolon. For example, *Cassidulina* is recorded with frequencies varying between 0 and 60%. The benthic foraminiferal diversity factor is constantly less than 10, the P-B values vary between 2 and 34.

Although the three groups prevailing in the Grecka sections are well represented in Katakolon, it should be noted that the predominant species in the *Bulimina* and *Brizalina* groups are different (*Bulimina elongata subulata* versus *B. marginata*, and *Brizalina aenariensis* and *B. spathulata* versus *B. dilatata*). In contrast with section Katakolon *Uvigerina* becomes an important faunal constituent only in the upper two samples of section Grecka 300; in the other samples it is either absent or present in low numbers only. Some other species are more regularly present in fair numbers in Katakolon: *Gyroidinoides delicatus*, *Melonis barleeanus* and *Sphaeroidina bulloides*.

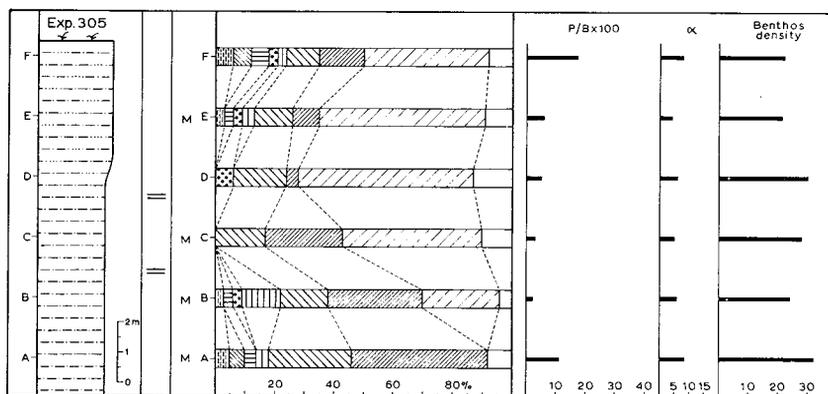


Fig. 9 Lithostratigraphic column and frequency diagram of benthic species at Grecka, exp. 305. For the legend see fig. 7 or the last page.

### Interpretation

In section Katakolon the diverse character of the benthic foraminiferal assemblages and the high number of mud-dwelling organisms, such as representatives of *Bulimina*, *Brizalina*, *Cassidulina* and *Uvigerina* (Murray, 1973), point to an open marine environment with mainly clayey sedimentation. The low frequency of the group of plano-convex, probably epiphytic forms suggests that plant growth was unimportant. The relatively low numbers of planktonic foraminifera suggest that the depositional environment was rather shallow.

The interpretation of the Grecka assemblages is somewhat more difficult. According to the field-stratigraphic studies and the ensuing reconstruction of the sedimentary history and paleogeographic configuration (Hageman, 1977), it may be assumed that the clays of sections Grecka were deposited in a relatively wide, open embayment (fig. 4). An attempt will be made to interpret the observed faunal composition and fluctuations in terms of such a paleogeographic configuration.

In the Grecka sections the high numbers of mud-dwelling specimens of the groups of *Bulimina*, *Brizalina* and *Cassidulina* also point to an environment with predominantly clayey sedimentation. The minor importance or near-absence of taxa with a tolerance for salinity fluctuations, such as *Ammonia*, *Elphidium* and *Nonion*, and the rather diverse character of the calcareous nannoplankton and planktonic foraminiferal assemblages indicate that the salinity must have been normal and that the connection with open marine waters must have been good. However, the low benthos diversity and the very high fluctuations in the percentage composition of the three main mud-dwelling groups suggest that the Grecka clays did not accumulate in a marine environment that remained constantly the same. The fluctuations in the relative numbers of the *Bulimina*, *Brizalina* and *Cassidulina* groups cannot be explained in terms of squeezing effects (Zachariasse et al., 1978), because their total remains more or less the same. Taxa not belonging to this mud-dwellers group apparently cannot have influenced the strongly fluctuating pattern either, because they never constitute more than about 25% of the total faunas.

It is evident that the Pliocene environment near Grecka and the Pleistocene conditions at Katakolon were not exactly the same, although no differences can be demonstrated in the depth, substrate and salinity. The greater P/B ratio, the more diverse benthic assemblage and the ununderstood difference in species predominance in *Bulimina* and *Brizalina* suggest that Katakolon was more accessible to the open marine influence than Grecka. The Pliocene position of Grecka may well have been in the interior of an open bay whereas Katakolon was situated closer to the open Mediterranean. Differences in nutrient supply and composition may have caused the less diverse and more strongly fluctuating character of the mud-dwelling components in the Grecka sections, but this observation adds little or nothing to our knowledge.

## Chapter V

### THE TRANSITION FROM "OPEN MARINE" TO "RESTRICTED MARINE"

North of the Lapidhas Mountains the transition from marine clays to "lagoonal" successions is accompanied by rather a sudden increase in the relative quantity of silt and the appearance of thick sand units. The overlying sediments are clearly of more or less restricted character because the open marine mud-dwellers association does not recur. The transition can be seen at several places, but only at a few localities can it be sampled in detail. This is for instance the case in section Kallidhea in the south-easternmost part of the area (see fig. 2).

Section Kallidhea (exp. 301, fig. 10, table IV) is about two km from the village, along a track leading from the cemetery in a north-eastern direction. The section consists of about 57 metres of silty clays, silts and sands, most of which are arranged in three sequences with upwards-coarsening trends. The deposits are overlain by fluvatile conglomerates of the Olimpia Formation.

The basal 25 metres of section Kallidhea show a gradual vertical transition from grey, silty clays to yellowish silts and sands. The silty clays in the lower 15 metres are homogeneous in structure. Especially in the basal three metres they contain a rich and diverse mollusc association, which is reminiscent of that of the Grecka sections.

The silty clays succeeding this mollusc-bearing interval alternate with sandy strata. These beds are generally bounded by distinct bedding planes and display locally an internal horizontal lamination. There is an increase in an upward direction of both the thickness (from 10 to 60 cm) and the average grain size in these sandy beds.

The bulk of the sediments in the upper 10 metres of the lower 25 m clay-sand sequence consists of sands, which are rich in sedimentary structures such as horizontal lamination and small-scale and large-scale cross-lamination. Especially in the upper part of this sandbody parallel lamination with a slight dip prevails in North-West/South-East outcrops, with the inclination of the laminae to the North-West. In North-East/South-West exposures the lamination is mainly horizontal. These sedimentary features in the upwards-coarsening sequence provide evidence of the growth of the sandbody in a NW direction. The top of the sequence shows a cemented level with numer-

ous casts of molluscs (mainly *Cardium*). This is overlain by 2 metres of sands, which again have a cemented top.

The next sequence (sampling interval 301 M-Q) shows 6 metres of silty clays, overlain by 5 metres of fine sands. The silty clays contain angular mollusc fragments and show some thin intercalations of sandy strata. The interval between the clays and the overlying sand body is marked by 30 cm of bioclastic limestone, composed of closely packed *Cardium* specimens. The contact between the limestone and the overlying sands is sharp. The sands are homogeneous and show another indurated level at the top.

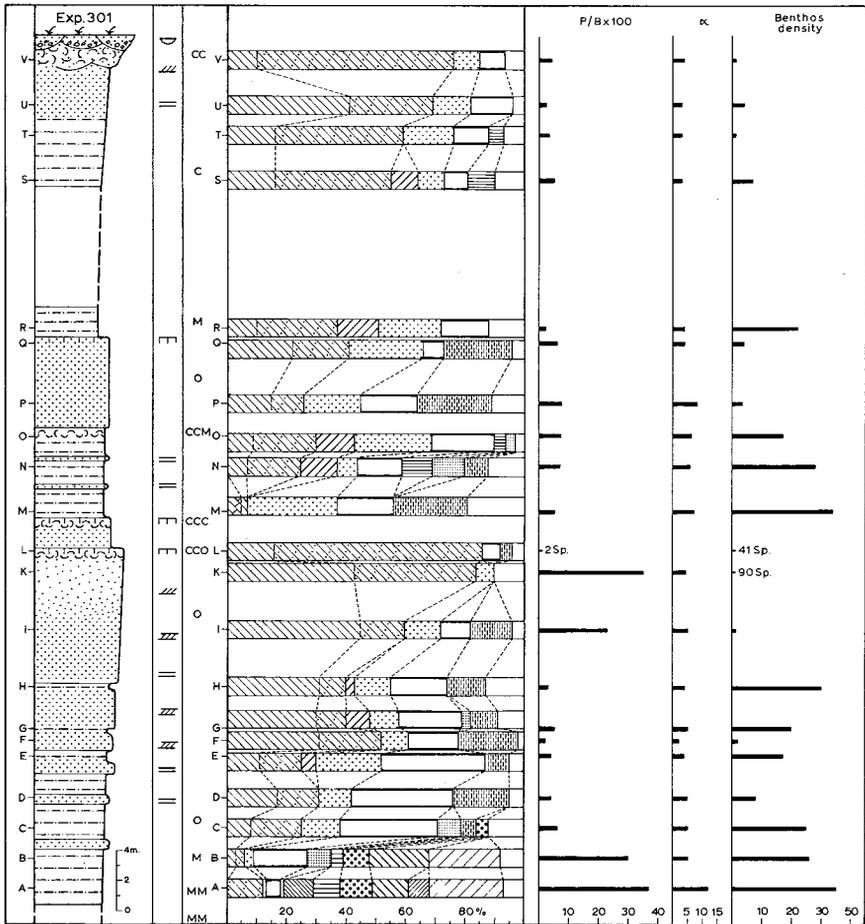


Fig. 10 Lithostratigraphic column and frequency diagram of benthic species at Kallidhea, exp. 301. For the legend see fig. 7 or the last page.

Although interrupted by a non-exposed interval of 8 metres, the uppermost 20 metres of section Kallidhea seem to consist of another upwards-coarsening sequence of silty clays and sands (sampling interval 301 R-V). These sediments are homogeneous in structure; upwards the sands change gradually, but over a short interval, into a bioclastic limestone, mainly consisting of *Cardium*. The top of the sequence is made up of coarse sands and fine conglomerates, arranged in lens-shaped bodies.

In a northern direction these sediments appear to be succeeded by at least 150 metres of mainly fluvial deposits of the Olimpia and Erymanthos Formations.

### Benthic foraminifera

The faunal composition of the basal silty clays (samples 301 A and B) resembles that of the Grecka sections. The differences are in the relatively higher values of the P-B ratio, the relatively low number of *Brizalina* group specimens and the presence of *Ammonia beccarii tepida*, *Nonion boueanum*, *Fursenkoina schreibersiana*, *Reussella spinulosa* and *Valvulineria complanata* in appreciable numbers.

The faunal composition of the sediments above this interval is distinctly different. *Ammonia*, *Elphidium*, *Nonion* and plano-convex forms become the most important groups, while the larger part of the species present in the basal silty clay rapidly decreases in number or disappears altogether.

In all three major sequences the *Ammonia beccarii*-group shows a distinct upward increase in frequency. In the lowermost sequence this increase is mainly caused by the increase in the number of *Ammonia beccarii beccarii*. *A. beccarii tepida* remains present in rather constant frequencies, except in the sediments near the top of the sequence. In the poor fauna of the uppermost sample 301 L, 28 of the 41 benthic specimens belong to this variety. In the upwards-coarsening sequence in the middle part of the section *A. beccarii beccarii* and *A. beccarii tepida* both increase in relative numbers, while in the uppermost sequence the less striking increase of the otherwise predominant *A. beccarii*-group is caused mainly by an increase in the number of *A. beccarii tepida*.

The next important faunal constituents, *Elphidium* and *Nonion boueanum*, are present in all sediments, without showing a clear trend, though *N. boueanum* reaches its highest frequencies in the middle part of the lowermost sequence. *Ammonia perlucida* and *Fursenkoina schreibersiana* are relatively most frequent in some samples of the silty clays. *Reussella spinulosa* is met with especially in the middle and upper parts of the section,

although it is occasionally present in low quantities (less than 5%) in the lowest sequence as well.

The plano-convex species reach their highest frequencies in the lower and middle sequences; they are almost entirely absent in the uppermost sequence.

Finally the presence of thecamoebians in sample 301 N should be mentioned.

### Interpretation

The upwards-coarsening trend in the major sequences of section Kallidhea are thought to reflect the repeated approach or expansion of sand bodies because of shallowing in environments with otherwise prevailing clayey sedimentation. The final phase of the section is clearly regressive, as is indicated by the presence of the fluvio-lacustrine Olimpia Formation on top. With these factors in mind, we can try to interpret the observed faunal compositions and fluctuations.

The faunal composition of the lowermost silty clays resembles that of the Grecka sections: *Cassidulina* and *Bulimina* are relatively the most frequent groups. It may be postulated that the lowermost samples of section Kallidhea are still representative for the muddy open bay environment in the south-eastern part of the area before the clear development of sand bodies. The diverse character of the benthic foraminiferal fauna and the relatively high P-B values indicate that the conditions during deposition of the basal part (301 A, B) of section Kallidhea were less mud-controlled and more open than those inferred for the Grecka clays. The presence in the assemblages of *Ammonia*, *Nonion boueanum* and *Fursenkoina schreiberiana*, which are taxa reaching high frequencies in the higher parts of the section, may indicate that a coastal area with some fresh water supply was closer in Kallidhea than in Grecka.

The horizontally laminated sandy intercalations appearing higher in the silty clays of the lowermost upwards-coarsening sequence indicate an intermittent supply of sands, probably during periods of high energy. Similar recent and fossil sediments have been described in the literature (e.g. Reineck and Singh, 1972) and interpreted as "storm-layers", which originate during occasional, "high energy" events, during which material from shallow areas is eroded and transported to environments normally characterized by tranquil conditions. The upwards-coarsening of these deposits in the silty clays of the lowermost sequence suggests a decreasing distance between the depositional environment and the source area of the sands. The presence

of a thick sand body with horizontal and cross-stratifications in the upper part of the sequence suggests that this process was accompanied by a shallowing of the environment which allowed the area of sand supply to encroach upon the Kallidhea spot. This process culminated in a period of non-deposition and possibly emersion, as can be concluded from the indurated nature of the top part of this sand.

The shallowing of the environment during the deposition of the basal part of the lowermost sequence of section Kallidhea (sampling interval 301 A-C) is reflected in the foraminiferal faunas by a conspicuous decrease in the P-B ratio and by the replacement of the *Bulimina/Cassidulina* association by another, consisting mainly of *Ammonia*, *Elphidium*, *Nonion boueanum* and plano-convex species. The increasing sand supply higher up was accompanied by an increase in *Ammonia beccarii beccarii* and a decrease in the relative numbers of *Nonion boueanum*. In contrast *A. beccarii tepida*, *Elphidium* and plano-convex species remain present in more or less constant frequencies.

The very shallow conditions with considerable salinity fluctuations which prevailed in the environment in which the uppermost sands were formed (301 K-L) are reflected by the extreme dominance of the *Ammonia beccarii*-group, especially its variety *tepida*, and the extremely low benthos density of the sediment.

No micropaleontological data (no samples) are available from the next two metres of sand. Lithologically, they suggest a repetition of the top part of the underlying sequence.

The silty clays of the middle sequence overlying these sands point to a return to tranquil, marine sedimentation conditions. The upward increase in the relative numbers of *Ammonia beccarii*-group and *Ammonia perlucida* in the silty clays, and the absence or extremely low numbers of Buliminidae, *Valvulineria* and *Cassidulina* may point to deteriorated connections with the open sea, which possibly caused a decrease in the salinity. Fresh-water input is also indicated by the occurrence of thecamoebians in sample 301 N. In these waters which are assumed to have been hyposaline especially *Ammonia perlucida* and to a lesser extent *Reussella spinulosa* appear to reach relatively high frequencies. The same holds true for *Fursenkoina schreibersiana*. If the assumption of slight salinity fluctuations is correct, we must assume a preference for relatively normal marine salinities for the group of plano-convex species, because of their upward decrease in frequency in the silty clays of this part of the section. The *Cardium* limestone at the top of the silty clays (301 O) demonstrates another period of non-deposition or even emersion following littoral conditions.

The relatively high numbers of plano-convex forms in the sands above the *Cardium* bed (sample 301 P and Q) suggest a renewed increase in more normal-marine influence. Because of the sharp contact between the limestone and the sands, it seems likely that this return to more normal-marine conditions occurred rather abruptly, for instance in connection with a sudden submergence and a renewed sand supply. In the sand body the upward increase in frequency of the *Ammonia beccarii*-group and *Elphidium* may be considered as being the reflection of the next phase of the shallowing of the environment, which culminated again in non-deposition and possibly emergence, as is suggested by the cemented level at the top of the sand. The middle part of the section between 301 L and 301 R evidently does not correspond to a single upwards-coarsening sequence. Actually three sedimentation phases end in a non-deposition phase at sea level, if we can explain the *Cardium*-beds and indurated tops as such.

In spite of the non-exposed interval of 8 metres, it seems likely that the sediments of the upper part of section Kallidhea are arranged in one upwards-coarsening sequence. The presence of a low diversity, *Ammonia*-dominated fauna in the basal silty clays of this sequence indicates that the final phase of deposition in the south-eastern area started with the installation of a tranquil, restricted marine, probably lagoonal environment. The upwards-coarsening character of the sequence, and the presence of conglomeratic channel-fill deposits in the upper part of the sand point to a filling phase with increasing hydrodynamic energy, followed by the progradation of a fluvial system of the Olimpia Formation over the previous lagoonal environment. The high frequencies of *Ammonia beccarii tepida* and *A. perlucida* in the assemblages of the silty clays are an indication that a fresh-water supply played a role during the early phase of deposition of this third major sequence.

Summarizing the data from section Kallidhea we can conclude that the major factors determining the composition of the foraminiferal associations were the hydrodynamic energy, the grain-size of the substrate and the salinity of the water. Especially during deposition of the basal part of the section a somewhat greater depth may have played a role as well.

The transition from the muddy environment of the open bay to the sandy, more near-shore conditions is expressed in the fossil record in the lowermost part of the section (sampling interval 301 A-C) by a rather sudden decrease in the P-B ratio and in the frequencies of Buliminidae, *Cassidulina*, agglutinated species, miliolids and *Valvulineria complanata*, and the appearance of assemblages consisting of *Ammonia*, *Elphidium*, *Nonion boueanum*,

*Fursenkoina schreibersiana* and plano-convex species. Amongst the group of "normal marine mud-dwellers" *Valvulineria complanata* seems to be a form with a slightly greater tolerance for the changing conditions.

The increase in the grain-size of the sediment in the thicker individual sequences is generally accompanied by a relative increase in the *Ammonia beccarii*-group. In the lower sands this increase is caused by an increase in *A. beccarii beccarii*, in the uppermost sands, which probably were deposited in a very shallow, more restricted environment, the poor faunas are often largely made up of *A. beccarii tepida*.

The very high P-B values shown by some of the assemblages from the sands (samples 301 I and K) are thought to be due to the very low numbers of benthic foraminifera in these sediments. The increase in the *A. beccarii*-group in all three sequences points to a repeated increase in ecological stress, probably in greater salinity fluctuations as a consequence of a relatively greater fresh-water supply. The upwards-increasing importance of *Ammonia beccarii tepida* both in the individual sequences and in the entire succession thus would indicate that this form has the greatest tolerance for the deviating conditions of hyposalinity.

Both *Ammonia perlucida* and *Fursenkoina schreibersiana* appear to be species that have a preference for a muddy substrate and slightly hyposaline conditions. The tolerance for slightly deviating salinities seems to be somewhat lower for *F. schreibersiana* than for *A. perlucida*.

Also *Reussella spinulosa* seems to reach its relatively highest frequencies in environments with some fresh-water supply, as can be concluded from the relatively high numbers of this species in the silty clays and silts of the middle and upper sequences.

The group of plano-convex, presumably epiphytic species generally reaches its highest frequencies in the silts and sands of the lower two sequences. Their number decreases to very low values in the entire uppermost sequence. If one assumes that such forms lived in areas of vegetation with fairly normal marine salinities, their presence in the Kallidhea area might be due to transport by currents. Evidently Kallidhea was no longer accessible for such currents during the deposition of the upper sequence.

*Elphidium* is an almost constant faunal constituent, which shows no relation between its relative numbers and lithology, and does not appear to respond to the regressive trends (except for sample 301 L) or to the repeated changes to more restricted, presumably lower salinity conditions. The same holds true for *Nonion boueanum*, although this form shows its highest frequencies in the relatively open marine, interstratified silty clays and sands of the lowermost sequence.

It is still difficult to fit the various assumptions about the changes in the sedimentary environment at Kallidhea into a more general paleogeographic reconstruction. At least five regressive sequences can be recognized. For some of them, especially the lowermost and uppermost ones, it is reasonable to assume that littoral bar systems crept over the more tranquil environments that existed in the off-shore direction whether these were truly lagoonal or more open marine. For the three shorter middle sequences we might also be dealing with shallowing successions, farther away from the coastline, of sand bars or shoals in the interior of an embayment. For a better understanding of the Kallidhea section we need further data from the other sections. The *Cardium*-beds and indurated tops of the sequences give the impression of rhythmic submergence followed by filling up, rather than of eustatic sea level oscillations or a repeated breaking-through of barriers.

## Chapter VI

### THE "LAGOONAL" SUCCESSIONS

Altogether eight sections were studied from the sand – silty clay sequences of the Vounargon Formation. All these successions we shall call lagoonal, anticipating with this term the final conclusions. Sections Vounargon, Lala, Neraida, Grillos and Paleovarvaisena are from the thick sequences of silty clays and sands in the central and southern parts of the area; section Kaiafas is located in the south-western part. Section Agios Andreas is from the Pleistocene deposits overlying the clays of Katakolon and section Pigadion is also representative for the sediments of the Vounargon Formation in the North.

Sections Vounargon, Lala, Neraida and Paleovarvaisena display alternations of thick units of sand (up to 30 m) and more fine-grained sediments of comparable thickness. The latter may be composed of alternations of silty clays and coarser beds. Their macrofossil content is highly variable; within one clayey unit barren intervals as well as beds rich in pelecypods may be present. Section Kaiafas, in the area adjacent to the Lapidhas Mountains, is representative for the alternations of thinner silty clays and sand units with numerous cemented levels, while section Grillos shows the transition from silty clays to a fresh-water carbonate. Section Pigadion displays sequences of relatively thin sands and silty clays with the high numbers of molluscs in the sandy parts instead of in the clays. In all sections the contents of the sediments display features of rapidly changing salinity. In some sections there are indications of complete isolation from the open sea.

In the following paragraphs a review will be given of the sedimentary and faunistic features of each section and an attempt will be made to give an interpretation of the faunal changes.

#### SECTION VOUNARGON

Section Vounargon (exp. 700, fig. 11, table V) is exposed along the track leading from the village Vounargon (8 km North-West of Pyrgos) to the monastery of Agios Nikolaos. It consists of two parts with a thickness of 40 m and 30 m, respectively, separated by a badly exposed and partly covered interval of about 30 m. In view of their position on the geological map the section must represent a fairly high part in the entire formation.

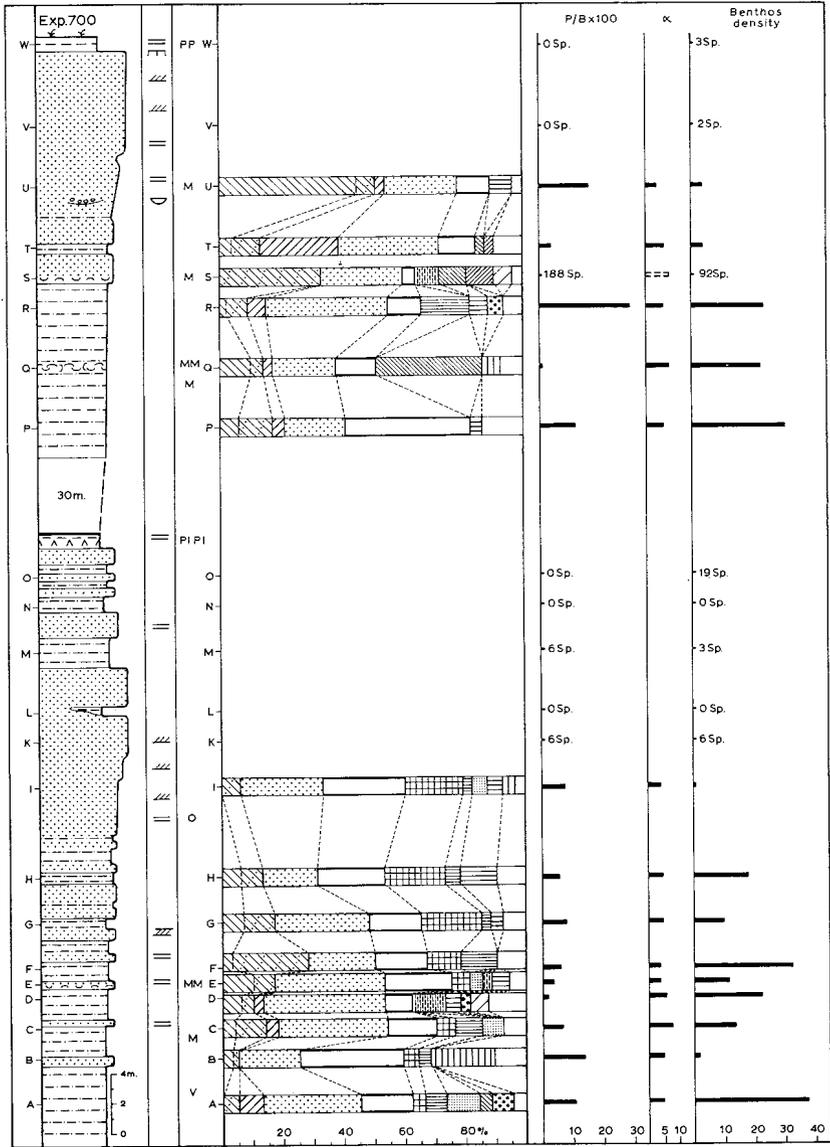


Fig. 11 Lithostratigraphic column and frequency diagram of benthic species at Vounargon, exp. 700. For the legend see fig. 7 or the last page.

In the lower part three units can be distinguished: a basal one with a thickness of 19 m (700 A-H), made up of grey, silty clays alternating with sandy strata, a middle part of 11 m (700 I-L) consisting mainly of sands, and an upper unit showing 9 m (700 M-O) of interstratified clays and sands. The two lower units together show an upwards-coarsening trend similar to the trend observed in section Kallidhea.

The silty clays of the lower unit contain randomly distributed molluscs, which are often fragmented and angular in shape, probably as a result of bioturbation. The sandlayers resemble the "storm-layers" of section Kallidhea, and again show an upward increase in average grain-size (from silt and fine sand to medium sand), in thickness (from 15 cm to 80 cm) and in frequency. Locally they contain basal shell-stringers, while horizontal lamination may be present. Sandy interbeds in the upper part of the silty clay unit may show small-scale cross-lamination in their top part, probably due to wave-action.

The sand body of the next higher unit (sampling interval 700 I-L) shows a superposition of fine-, medium- and coarse grained sands, and an intercalation of a lenticular clay body. The sand layers have a maximum height of 1 m. In East/West exposures they show large-scale cross-lamination with a main unidirectional dip of the laminae of about 20° to the West. Seen in this orientation the sand bodies have a convex upward shape. In North/South exposures horizontal lamination is the prevailing structure, while the individual sand bodies are bounded by more or less horizontal surfaces. These data suggest that the sands were deposited as elongated sand bodies, with an approximate North/South orientation, and growing in a western direction.

The sands are overlain by 9 m of alternating silty clays and sands. The individual sand and clay beds have a thickness of 2 m in the basal part of the unit to 20 cm higher up. The sands are bounded by straight, sharp surfaces and do not display sedimentary structures. The sediments do not contain macrofossils; one of the sands in the higher part of the unit is overlain by a seam of gypsum crystals. The top of the unit consists of a lignite bed with a thickness of 10 cm.

The upper part of section Vounargon shows a sediment succession similar to that described from the lower part. 14 m of silty clays with some sandy interbeds in the transitional interval to the next-higher unit are followed upwards by 13 m of sands. These sands are predominantly fine in the basal part of the unit and show some horizontal lamination. They contain intercalations of conglomeratic channel-fill deposits with a width of at least 10 m and a maximum height of 1 m. The upper 6 m of the sand body con-

sist of large-scale cross-stratified, medium and coarse sands, which are topped by an indurated level. This "hardground" is succeeded by a dark, non-fossiliferous clay with a thickness of at least 1 m.

### Benthic foraminifera

In the overall upwards-coarsening sequence of sampling interval 700 A-I, representatives of the *A. beccarii*-group, *Elphidium* and *Nonion boueanum* invariably constitute more than 50% of the associations. *Ammonia perlucida* is confined to the silty clays in the lower part of this interval, while *Cancris*, although present in all but one sample, reaches its highest relative frequencies (up to 20%) in the higher part; the same holds more or less for the arenaceous species. Amongst the remaining part of the fauna, *Fursenkoina*, miliolids, *Valvulineria* and the group of biconvex *Cibicides* show irregular distribution patterns. Plano-convex taxa and *Cassidulina* are almost entirely confined to the level of 700 D.

The upper samples from the lower part of the section (700 K-O) are either barren or contain only a few, generally ill-preserved specimens. In the latter case *A. beccarii* predominates. Thecamoebians and fructifications of *Chara* were found in sample 700 M.

Comparable dominance features were observed in the samples from the upper part of the section (700 P-W). In this part of the section, however, the composition of the additional fauna is highly variable: large fluctuations can be seen in the relative numbers of miliolids (almost 40% in the mollusc bed of 700 Q) and of *Ammonia perlucida* (25% in 700 T). Plano-convex taxa, the *Brizalina* group and *Cassidulina* are fairly numerous in the mollusc bed of 700 S, but these data are of doubtful value because only 92 specimens could be counted. The upper samples 700 V and W are barren or contain a few specimens only.

Except for the miliolids and *Ammonia perlucida*, there seems to be no consistent relation between peaks in relative frequency and certain types of lithology for the benthic foraminiferal groups of section Vounargon.

### Interpretation

Both the lower and upper parts of section Vounargon show fossiliferous fine-grained sediments passing upwards into sands and alternations of sands and silty clays that are entirely or almost completely barren. These regressive features can best be understood by assuming the repeated seaward migration of barrier-like sand bodies, which were followed at their leeward side by protected, tranquil environments which were isolated from the open sea. In

between both sequences a submergence and marine drowning phase must be postulated.

From the available strike and dip data of the laminae it can be inferred that the sands of the lower part of the section (700 I-K) were part of an elongated body with an approximately North-South orientation and that the open sea at the time was situated to the West.

The presence of storm-layers in the silty clays of the basal parts of both the lower and upper succession indicates that the source area of the sands was periodically exposed to intensive wave-action. The upward appearance of wave-ripples in the top parts of the sands probably reflects a shallowing of the environment (see also Broekman, 1973).

Remarkable features of the benthic foraminiferal assemblages of the lower upwards-coarsening sequence of section Vounargon (sampling interval 700 A-L) are the relatively minor importance of the *Ammonia*-group, the high frequencies of *Elphidium* and *Nonion boueanum*, the fair numbers of *Cancris*, *Reussella* and *Fursenkoina* and the irregular presence of plano-convex specimens and of various so-called open marine elements, such as *Valvulineria complanata* and occasional *Cassidulina* and Buliminidae. There is an upward decrease in frequency in the silty clays of *Ammonia perlucida* and *Fursenkoina schreibersiana*, and an increase in *Cancris auricula*, especially in the upper part of the sequence.

The absence of conspicuous faunistical trends, and the overall low frequency of representatives of the *Ammonia*-group, suggest that the approach of the sand body was not attended by important changes in the ecological conditions. The associations point to shallow water with fairly good connections with the open sea and only minor influence of fresh-water spill-over from behind the approaching barrier.

The minor importance of the group of assumedly epiphytic plano-convex species in this apparently rather normal saline environment is an indication for the absence of an extensive subaquatic vegetation near Vounargon. As stated by Blanc-Vernet (1969), prolific subaquatic vegetation can only exist in environments where there is hardly any supply of terrigenous material. This observation supports the assumption that there was a rapid supply of sands and silts during the deposition of the 700 A-I sediments of section Vounargon.

The relatively high numbers of *Cancris auricula* in the silty clays and sands of sampling interval 700 F-I suggest that this species has a preference for shallow, normal marine environments with a high sedimentation rate.

The scarcity or absence of foraminifera in the upper part of the sand body and in the overlying silty clay and sand alternations (sampling interval

700 K-O) and the local presence of thecamoebians and *Chara*-fructifications (sample 700 M) suggest that these sediments were deposited behind a closed barrier in a strongly hyposaline to fresh-water environment. If this conclusion is correct, the upper part of the thick sand body would represent the lagoon-ward side of the barrier, while the silty clay and sand alternation was deposited in the lagoon behind the barrier. The sandy intercalations probably represent periods of high energy, during which relatively coarse material was swept from the barrier into the lagoon. The few benthic foraminifera in these sandy intercalations suggest that these sediments were washed in with the barrier material. The decrease in the thickness of these "wash-over fans" in an upward direction suggests an increasing distance from the barrier during the deposition of the lagoonal sediments. The process of barrier migration probably continued during the deposition of these sediments.

The seam of gypsum crystals and the lignite at the top of the lower succession possibly witness to the final filling of the tranquil lagoon in the near-absence of sediment supply. The gypsum may represent an evaporation phase whereas the lignite would be the result of a densely vegetated, marsh-like environment.

After another invasion by the sea at Vounargon the upper part of the section (sampling interval 700 P-W) shows a kind of repetition of the lower part. Again the benthic foraminiferal faunas have a mixed character because of the presence of some open marine elements (*Valvulineria*, *Cassidulina*, *Buliminidae*) in assemblages consisting mainly of *Elphidium*, *Nonion boueannum* and *Ammonia*. In contrast to the succession in the lower part of the section there is an overall upward increase in the groups of rotaliid foraminifera (*Ammonia* and *Elphidium*). This increase, the relatively high frequency of *Ammonia perlucida* in the silty clays of sample 700 T, and the much lower numbers of *Cancris auricula* and *Fursenkoina schreibersiana* suggest that the diminishing of the distance to the sand body may have been attended by increasing hyposalinity of the waters.

The orientation of the pelecypods in the mollusc-bed of sample 700 Q is parallel to the bedding, and the convex sides are in an upward direction, which suggests that this deposit accumulated during a period of high energy. Probably it can also be considered as a storm-layer. The high numbers of miliolids in this mollusc bed may be explained by assuming transport from the littoral zone. It seems plausible that part of the elements in the higher samples 700 R, S and T were washed in from more marine environments.

The near-absence of foraminifera in the sands and silty clays in the upper

part of the section (sampling interval 700 V-W) indicates that a sand barrier again moved seawards, leaving at its leeward side a lagoon, entirely cut off from the sea.

SECTION LALA

Section Lala (exp. 2, fig. 12, table VI) is exposed along the road from Olimpia to Lala, approximately 5 km North-East of the former village (fig. 2). It consists of 22 m of sands and silty clays, which belong to the upper part of the Vounargon Formation. Some 30 metres above the top of the section brackish and lacustrine sediments of the Olimpia Formation are exposed.

Three units can be distinguished: a lower one, made up of at least 5 m of fine sands, a middle one composed mainly of greyish silty clays with a thickness of 11 m, and an upper one consisting of at least 25 metres of sands locally displaying a vague, large-scale cross-lamination. Only the lower six metres of this upper part are included in the microfaunistic analysis.

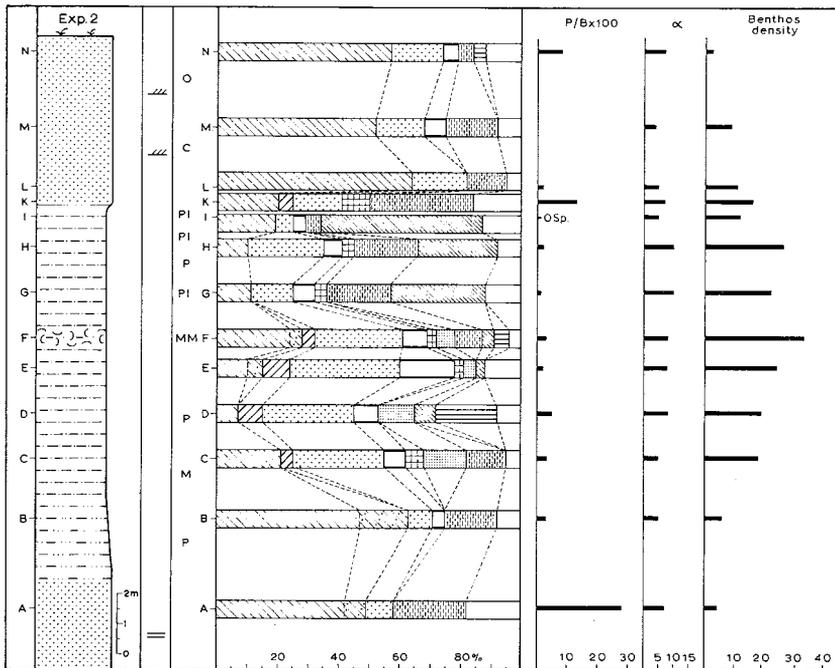


Fig. 12 Lithostratigraphic column and frequency diagram of benthic species at Lala, exp. 2. For the legend see fig. 7 or the last page.

The boundary between the lower sand and the silty clay is gradual but marked by an abrupt change in colour; that between the silty clay and the upper sand unit is sharp and slightly undulating.

Molluscs are locally abundant in the silty clays; several of them were found as complete bivalves. This observation and their random distribution suggest that the molluscs are still more or less in their living position. The association is dominated by *Cyrena*, *Venus*, *Pinna*, *Pecten*, *Cardium*, *Turritella*, *Natica* and *Ensis*.

The silty clays contain an intercalation of 30 cm (2 F) consisting of a mixture of silty clays and angular mollusc fragments. In the sands of the lower unit some small shell fragments were found. Partly decalcified remains and casts of *Cardium*, *Ostrea* and *Balanus* specimens occur in the higher sand unit.

### Benthic foraminifera

In the sands of the lower (2 A, B) and upper (2 L, M and N) parts of the section *Ammonia beccarii beccarii* is the predominating form; less frequent are plano-convex specimens and *Elphidium*. The transition from sands to clays (2 B-C) in the lower part of the section goes together with a strong decrease in numbers of *A. beccarii beccarii*, while *Elphidium*, *Ammonia per lucida* and *Fursenkoina schreibersiana* show an increase. In sample 2 D arenaceous species make up a considerable part of the fauna (21%).

The numbers of *Ammonia beccarii* in the mollusc-bearing interbed (sample 2 F) are high compared to those from the silty clay samples above and below.

The faunal composition of the silty clays above the shell-bearing level differs distinctly from that in the lower part of the silty clay unit. Plano-convex species and especially miliolids show a conspicuous increase in numbers. This trend is accompanied by the presence of abundant plant remains in the sediment. The miliolids reach a very high frequency in the uppermost part of the silty clay (sample 2 I) where they constitute 63% of the total fauna. In this sample *A. beccarii beccarii* also seems to reach a somewhat higher frequency than in the underlying sediments.

The abrupt transition from the silty clay to the uppermost sand unit is marked by an almost complete disappearance of the miliolids and an increase in frequency of the group of plano-convex species. Higher in the sand this assemblage is replaced again by an *Ammonia beccarii beccarii*-dominated fauna, which also in its other aspects, is reminiscent of the one of the lowermost sand unit.

Although *Nonion boueanum* is found in rather constant numbers throughout the section, its frequency is generally distinctly lower than in the sections Kallidhea and Vounargon. Buliminid groups, *Cassidulina* and *Valvulineria* are absent in the counts, or are reported in very low numbers only. *Cancris* is repeatedly present throughout the column, especially in the silty clays. Except in the lowermost sample (2 A) the number of planktonic foraminifera is very low throughout. The benthos density is highest in the mollusc-bearing interval, and in the silty clays.

### Interpretation

The sediments of section Lala give little information for the environmental analysis. The changes in hydrodynamic energy seem to be gradual, except for the change between 2 I and K.

The fine-sandy deposits in the lower and upper parts of the section with *Ammonia beccarii beccarii* as the dominating faunal constituent and with abundant plano-convex specimens are rather peculiar. It should be emphasized that there seems to be no mention of living faunas mainly made up of *Ammonia beccarii* and plano-convex species in the literature. Although the biotopes of both groups may occur in adjoining regions, representatives of the *Ammonia beccarii*-group are found in high numbers in areas without vegetation and with some salinity fluctuation stress, whereas the plano-convex forms occur in high frequencies in densely vegetated areas of more normal salinity, frequently in association with high numbers of miliolids. In these vegetated areas the plano-convex specimens generally live attached to the plants, while most of the miliolids occur on the sediments between the vegetation (Blanc-Vernet, 1969). Because miliolids are absent in the basal sands of the section Lala, it seems likely that the plano-convex forms in this part of the column were conveyed from a neighbouring environment by the currents, clinging to the vegetation. They settled in the high energy sandy environment in which occasional small deviations of the salinity possibly played an additional role. Our data are too scanty but possibly we are dealing with an off-shore area in front of the outlet of a river system.

In the lower part of the section, the fining upward of the sediments is attended by a decrease in frequency of both *Ammonia beccarii beccarii* and the plano-convex species, and an increase in frequency of *Elphidium*, *Ammonia perlucida*, *Cancris auricula* and *Fursenkoina schreibersiana*, which are taxa reaching high frequencies in environments with a more muddy substrate and slightly deviating marine conditions, have their highest relative frequencies in this part of the section. A possible explanation for this vertical

transition from a sandy environment with close-to-normal marine salinities to a more tranquil, shallow environment with similar salinity conditions, is that the sandbar or shoal area was gradually drowned and succeeded by an ill-protected marine environment. The rather diverse character of the benthic assemblages of the silty clays, and the low frequency of *Ammonia beccarii tepida* in these sediments suggest that during the deposition of the lower part of the silty clays the connection with open marine waters must have remained rather good. An incomplete development of another barrier system much further from the shore was probably the determining factor in this respect. The continued presence of plano-convex forms in the lower part of the succession pointing to a widespread submarine vegetation in the vicinity corroborates this assumption.

The presence of numerous agglutinated forms, all *Textularia*, in sample 2 D would also point to normal marine salinities during the deposition of the silty clays (Murray, 1973). The relatively high frequency of this group is not fully understood as yet, although it may have been caused by local pH deviations near the substrate during the deposition of this part of the silty clay.

A possible explanation for the high concentration of molluscs and mollusc-fragments at the level of sample 2 F, combined with a relatively high benthos density is that the sediments of this level accumulated after a period of high energy. The small peak in the frequency of the relatively large *Ammonia beccarii beccarii* in sample 2 F may be seen as another admixture due to transporting agents.

It is possible that the assumed high-energy level of sample 2 F coincides with a change in the paleogeographic configuration, for instance the further destruction of the distant barrier and the expansion of a more open marine vegetation in the bay. This idea is supported by the conspicuous difference between the microfaunas in the upper part of the silty clay (sampling interval 2 G-I), and those of the lower part. In the upper part the presence of abundant plant-remains is microfaunistically attended by a strong increase in frequency of plano-convex specimens and, especially, of miliolids, while *Ammonia perlucida* and *Fursenkoina schreibersiana* show a conspicuous decrease in numbers. As pointed out above, recent benthic foraminiferal faunas consisting of plano-convex forms and miliolids are generally found in shallow areas with normal salinities and an extensive subaquatic vegetation (Blanc-Vernet, 1969). However, such areas generally have a sandy substrate. To explain the presence of an association of plano-convex species and miliolids in the silty clays of section Lala the hypothesis might be defended that these faunal elements were transported from a more sandy area with

vegetation, into a tranquil, protected environment with clayey sedimentation, situated directly behind the vegetated realm. However, transport of the miliolids mainly living on the substrate, from a sandy to a clayey environment without clear evidence of transport of the sand seems to be rather unlikely. Also the irregular shape of the larger part of the *Cibicides lobatulus* specimens, the most important constituent of the group of plano-convex taxa, points to an environment with little turbulence, and, consequently suggests an autochthonous nature for this group. Therefore one must conclude that the larger part of the silty clays present in the upper part of section Lala (sampling interval 2 G-H) accumulated in a fairly protected, tranquil, baylike environment with a dense vegetation.

A remarkable feature of the silty clays of section Lala, as distinct from recent associations from vegetated areas, is the low diversity of the group of plano-convex forms caused by the predominance of *Cibicides lobatulus*. This feature may be a consequence of somewhat restricted marine conditions during the deposition of these silty clays.

Recent associations dominated by miliolids are often characteristic for hypersaline lagoonal environments (Murray, 1973). Consequently, the presence of the miliolid-rich association in the uppermost part of the silty clays of section Lala (sample 2 I), may be due to the fact that the final phase of the silty clayey deposition was accompanied by some increase in the salinity, caused by a greater effective character of the barriers. If there was no fresh-water run-off into the area evaporation may have occasionally exceeded the supply of open marine waters.

Although the plano-convex forms in the sands in the upper part of section Lala may have undergone some transport, the microfauna of these sediments seems to point to a nearby environment with vegetation and normal marine salinities. The radical change from the "hypersaline", lagoonal environment, reflected in the uppermost part of the silty clays, into the more normal marine environment in the basal part of the overlying sands, points to another drastic change in the paleogeographic configuration. It suggests that the barriers which caused the protection of the hypersaline lagoon were destroyed and that the Lala area became exposed again to wave action and a supply of sand, resulting in the construction of the upper sand body. Evidently we are dealing with another off-shore shoal area, but it is not certain whether it was caused by a general regression or by the migration of sand bars over the shallow bottom of the bay.

A striking feature of section Lala is the scarcity or even the absence in the benthic foraminiferal assemblages of open marine elements such as *Cassidulina*, *Valvulineria complanata* and species of the Buliminidae, and the

low number of planktonic foraminifera. These features are probably a consequence of the paleogeographic position of Lala in the bay, namely relatively far from the open sea as well as from a fresh-water input from the hinterland.

A possible explanation for the overall low frequencies of *Nonion boueatum* in section Lala is that this form may have a preference for environments situated closer to the open sea, although it seems to have some tolerance for hyposaline conditions.

#### SECTION PALEOVARVAISENA

Section Paleovarvaisena (exp. 109, fig. 13, tabel VII) is located along the main road from Pyrgos to Olimpia, about 1 km South-West of the village Paleovarvaisena (see fig. 2). It shows a succession of about 55 metres, which consists of a sand body, overlain by an upwards-coarsening sequence of clays, silty clays and sands. The lowermost sand body without sedimentary structures has a thickness of at least 5 metres; the upper sand unit, which has a thickness of about 30 metres shows locally horizontal lamination and large-scale cross-lamination. Both the lower and the upper sand body are capped by a cemented, organoclastic sediment, with numerous casts of *Cardium*.

Between these two sand bodies 20 metres of fine-grained deposits show at the base a horizontally laminated silt which rapidly passes upwards into homogeneous clays without macrofossils. At 12 metres above the base there is a lignitic intercalation which is succeeded by a silty clay with a rich and diverse mollusc association with *Cardium*, *Pecten*, *Venus*, *Ostrea* and *Dentalium*. Upwards the silty clay passes gradually into the upper sand body; this coarsening is attended by a conspicuous decrease in the diversity and frequency of the malacofauna, and an increase in the dimensions of the individual specimens. Oysters have been found in the upper sand body.

#### Benthic foraminifera

102 specimens of benthic foraminifera could be counted in sample 109 B; samples 109 A, C, D and E are devoid of foraminifera, or contain a few specimens only. The association of sample 109 B is almost completely composed of the *Ammonia beccarii*-group, mainly *A. beccarii tepida*. Sample 109 D is rich in ostracods of the brackish species *Cyprideis litoralis*.

The most diverse association of the silty clays overlying the lignite was found in sample 109 F. In addition to the predominating groups of *Am-*

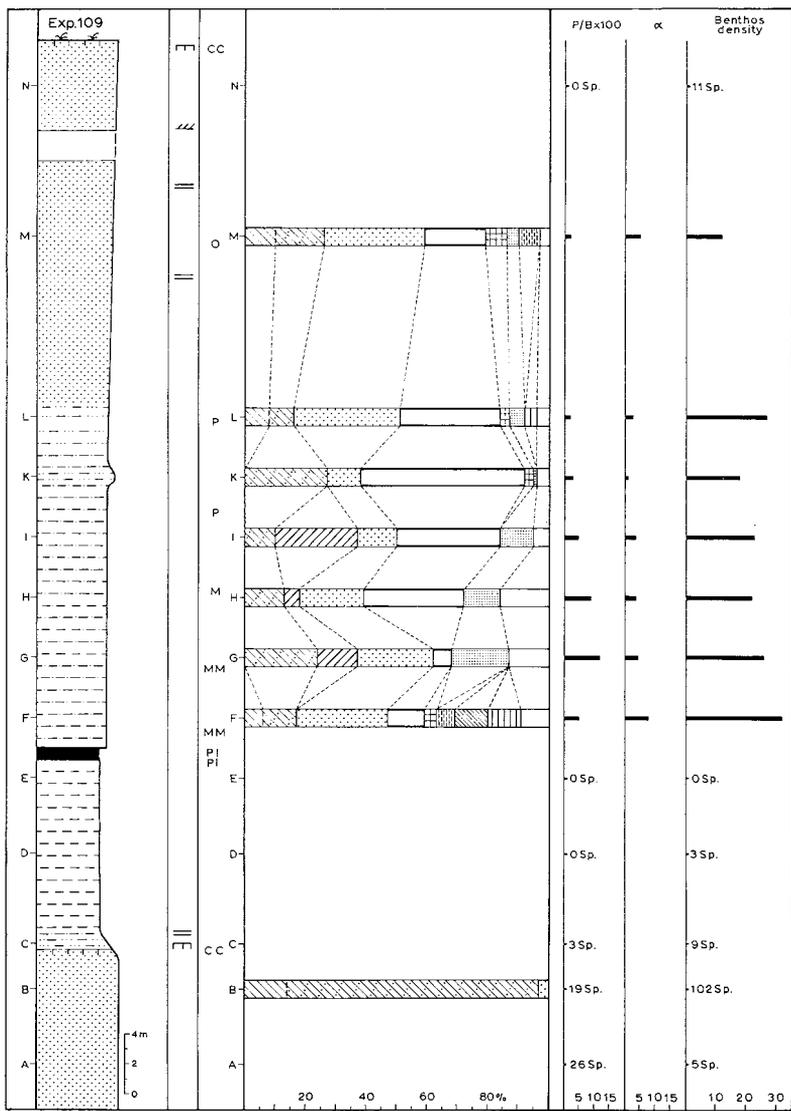


Fig. 13 Lithostratigraphic column and frequency diagram of benthic species at Paleovarvaisena, exp. 109. For the legend see fig. 7 or the last page.

*monia beccarii*, *Elphidium* and *Nonion boueanum*, this sample contains representatives of *Cancris auricula*, plano-convex taxa, miliolids and biconvex *Cibicides* species, each in percentages greater than 5. Upwards the numbers of the latter four groups rapidly decrease, while *Ammonia perlucida* and *Fursenkoina schreibersiana* become frequent in samples 109 G-I. *Cassidulina* too, although present in very low numbers only, is confined to the lower three samples of the silty clay.

Upwards the silty clays pass gradually into sands. The fossiliferous lower part of the sand unit retains the high percentage values of *Elphidium*, *Nonion boueanum* and *Ammonia beccarii*. It shows the reappearance, although in low frequencies, of *Cancris auricula* and plano-convex forms (109 M). *Fursenkoina* is less frequent than lower down. The uppermost sample (109 N) contains only a few, ill-preserved specimens of the *Ammonia beccarii*-group and *Fursenkoina*.

Amongst the representatives of the *Ammonia beccarii*-group, *A. beccarii tepida* strongly dominates in the larger part of the silty clays between the lignite and the upper sand unit.

### Interpretation

In section Paleovarvaisena three types of sediment can be distinguished: sands with a poor, *Ammonia beccarii tepida*-dominated fauna, clays and silts practically devoid of foraminifera and with locally an oligotypical, brackish-water ostracode fauna, and silty clays and sands with a rich benthic foraminiferal association of moderate to low diversity ( $\alpha = 8-4$ ).

The sedimentary and faunistic features of the lower part of the succession may best be explained by assuming that a sand barrier, represented by the basal sands, sheltered the Paleovarvaisena area from the open sea. The hyposaline lagoonal side of the barrier seems to be represented by sample 109 B with its poor, *Ammonia beccarii tepida*-dominated fauna. The overlying clays reflect the installation of an even more strongly hyposaline lagoon. Possibly this lagoon migrated seawards. This may be deduced from the presence of a thick lignite at the top of the clay, probably representing the marsh-like, densely vegetated landward part of the lagoon. This does not necessarily imply barrier migration, however; the lignite may just as well represent the final filling phase of the lagoon.

Renewed marine influence, probably caused by a sudden submergence and drowning of the area of Paleovarvaisena is reflected by the higher silt content of the sediment and the appearance of a rich macro- and microfauna in the silty clays directly on top of the lignite. Initially the salinities must have

been fairly normal, as can be concluded from the varied character of the benthic associations in the basal part of the silty clay. The low frequency of *Cassidulina* and the presence of an epiphytic-miliolid species combination in these sediments can be considered as an indication that the connection with the open marine waters must have been fairly good.

The upward decrease in the diversity of the benthic associations, and the increase in frequency of *Ammonia perlucida*, *Fursenkoina schreibersiana* and *Nonion boueanum* in the higher part of the silty clay (sampling interval 109 G-I) suggest an increasing degree of deviation from normal open marine conditions. The high frequencies of *A. perlucida* and *F. schreibersiana* may be attributed to the supply of some fresh water, as both species show a tolerance for slightly hyposaline conditions. The relatively low frequency in these associations of *Ammonia beccarii tepida* and the high frequency of *Nonion boueanum*, which are taxa with a high and very slight tolerance for hyposaline conditions respectively, also suggest that the salinity deviations must have been slight during the deposition of this part of section Paleovarvaisena. A remarkable feature of the silty clays is the absence of relatively coarse storm-layers. As both *A. perlucida* and *F. schreibersiana* are typical mud-dwellers, the limited supply of silts and sands may have been a very important factor favouring the presence of these two species.

In sampling interval 109 K-M, the increasing silt and sand content of the sediment is reflected in the microfaunas by a conspicuous decrease in frequency of these mud-dwellers, especially of *A. perlucida*, an increase in frequency of *Ammonia beccarii beccarii*, a species with a tolerance for greater hydrodynamic energy and a preference for normal marine salinities, and an increase of *Cancris auricula* which is another species that seems to flourish in environments where there is a high sedimentation rate. These data suggest that in the area in front of a possibly growing or approaching barrier the salinities had approximately normal marine values.

The upper part of the sand body must have been deposited in a very restricted marine environment, as is indicated by the very poor fauna in sample 109 N, which may have been entirely reworked. Possibly these sands belong to the leeward part of the barrier.

Since samples 109 M and N reflect an increased restriction of the environment while sand was the main constituent of the sediment, we might be dealing here with a seaward migrating sand body during a period of relative stability in the relation between sea level and bottom subsidence; the overall effect may have been regressive, leading to the filling up of the lagoon.

SECTION NERAIDA

Section Neraida (exp. 310, fig. 14, table VIII) is located at the base of a high escarpment in the northern bank of the river Enjiepeas, 3 km West of the village Neraida (see fig. 2). The section has a thickness of about 40 metres and shows a succession of silty clays, which pass gradually into a thick sand body. These sediments are overlain by at least another 450 metres of Vounargon deposits.

The lower 10 metres, of which only the upper 2 were studied, consist of homogeneous, silty clays with at some places randomly distributed molluscs, mainly *Venus*. These sediments are overlain by 10 metres of interstratified silty clays and silts to fine sands. The basal part of this unit (310 B) consists of an indistinctly delimited, homogeneous silt, 40 cm thick with numerous pebbles and mollusc fragments. The silty clays locally contain a rich mollusc association with *Pecten*, *Glycymeris*, *Arca*, *Venus*, *Cerithium* and *Turritella*. Many pelecypods occur as bivalves and are frequently found in their living position, whereas other mollusc remains are randomly distributed and often fragmented.

Upwards the silt-sand intercalations increase in frequency, thickness and

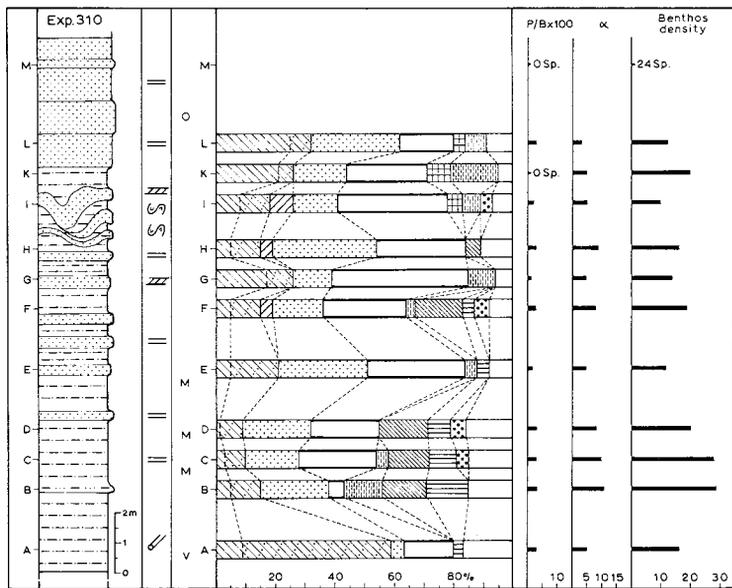


Fig. 14 Lithostratigraphic column and frequency diagram of benthic species at Neraida, exp. 310. For the legend see fig. 7 or the last page.

average grain-size. They show horizontally laminated structures and they are bounded by distinct bedding planes. Locally the sandy intercalations in the upper part of the unit show undulating upper bedding planes (which may be associated with small-scale cross-lamination), while their basal part may contain shell fragments. The upper 4 metres of the unit show intensely distorted bedding probably due to slumping. The fold structures have a maximum height of 2 metres and a lateral extension of more than 10 metres.

The upper 20 metres of the section consist of fine and medium grained, well bedded sands. The individual beds attain a thickness of 2 metres and occasionally show indistinct horizontal lamination. Discontinuous basal pebble-floors may be present. Samples could be taken only from the lower 5 metres of this sand body.

### Benthic foraminifera

The *Ammonia beccarii*-group, *Elphidium* and *Nonion boueanum* together constitute the bulk of the associations in all samples; the *A. beccarii*-group displays a conspicuous decrease in relative numbers from sample 310 A to 310 B, from 54 to 15%. In the former sample, the variety *A. beccarii tepida* strongly predominates. Miliolids reach relatively high frequencies (up to 16%) in several samples of the silty clay; arenaceous forms show an overall upward decrease from 310 B to the level of 310 G; higher in the section they were not encountered any more. Plano-convex taxa are present in most samples, but their frequency pattern is highly irregular. *Valvulineria* occurs in some samples, but always in low frequencies. *Ammonia perlucida* is confined to the sampling interval 310 F-I.

The residue of the uppermost sample 310 M contained only 24 specimens, mainly belonging to *Ammonia* and *Pseudopolymorphina*.

Planktonic foraminifera are scarce throughout the section.

### Interpretation

For the lowermost part of the section somewhat hyposaline conditions are indicated by the dominance of *Ammonia beccarii tepida*. The pebble and mollusc-fragment-bearing silt at the level of sample 310 B seems to mark an abrupt shift from restricted to relatively normal marine conditions, as is reflected by the moderately to highly diverse microfaunas in the silty clays in and above this interbed. The area may have undergone another submergence phase but it also seems possible that a sand barrier, which initially protected the lagoonal environment, was partly or totally destroyed during a storm. The sediment at the level of sample 310 B might represent this

event; the coarser elements of this silt may have been derived from the eroded parts of the barrier.

The succession above the level of sample 310 B shows characteristics reminiscent of the upward-coarsening sequences of the earlier described sections. Probably we are dealing with the approach of a seaward migrating sand bar or barrier over a shallow, near-normal marine environment with silty-clayey sedimentation. Since there is no evidence of a lagoon on top of these deposits we might be dealing with the expansion of an area of coastal sands. The considerable numbers of plano-convex specimens and miliolids point to the presence of vegetation in or near the depositional area.

A special feature of section Neraida is the presence of large slump structures, possibly a consequence of a rapid supply of large quantities of sediment and a high sedimentation-rate in combination with a steepening local bottom profile. This conclusion may lead one to expect that the groups characterizing the benthic associations of the sediments of section Neraida above the level of sample 310 G must have had a tolerance for the abundant supply of sediment. This seems to be true for *Cancris auricula*. One can explain the scarcity of *Fursenkoina schreibersiana* by assuming a low tolerance for a high sedimentation-rate, but the presence of *Ammonia perlucida* cannot be explained in this context.

The final regressive phase of well bedded sands with horizontal lamination, discontinuous pebble floors and the near-barren sample 310 M is ill-understood.

#### SECTION GRILLOS

At several places the successions of the Vounargon Formation contain intercalations of fresh-water limestones. These sediments are generally badly exposed. Section Grillos (exp. 723, fig. 15, table IX) is one of the few places where this type of sediment could be studied and sampled in some detail.

The section is located along the main road from Krestena to Kallidhea, about 1 km South-East of the village Grillos (see fig. 2). It shows some 3 m of brownish, horizontally laminated silty clays, which pass upwards over a short transitional interval into a whitish, platy, fine grained limestone with a thickness of 4 m. The top of the section consists of 2 m of brownish, silty clays. The contact between the upper clays and the limestone is sharp and straight. The silty clays are devoid of macrofossils; the limestones contain operculae, *Planorbis*, and numerous moulds of plant stalks with longitudinal ribs, probably of reed.

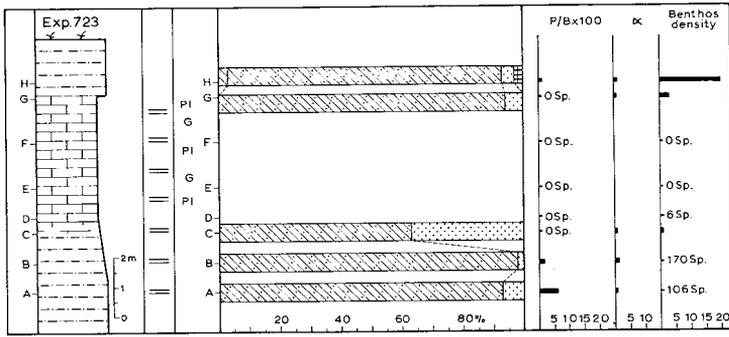


Fig. 15 Lithostratigraphic column and frequency diagram of benthic species at Grillos, exp. 723. For the legend see fig. 7 or the last page.

### Benthic foraminifera

The silty clays in the lower part of the section contain a poor microfauna, consisting almost entirely of *Ammonia beccarii tepida*, which is accompanied by some *Elphidium* specimens. There are numerous small foraminifera with irregularly arranged, globular chambers in sample 723 C (see plate 6, figs. 7 and 8). These specimens are probably aberrant individuals of *Elphidium granosum*, which is the second most important species in the sample and which has the same coarse perforate wall structure. Similar forms have been described by Arnold Bik (1964) as *Nonion demens* from the *Hydrobia* beds in the Miocene of the Mayence basin. Also this author concluded that there was a close relation between *Nonion* (= *Elphidium*) *granosum* and this aberrant form.

The larger part of the limestone is completely devoid of foraminifera; only in its topmost part is a low-diverse *Ammonia beccarii tepida* fauna present.

Also in the single sample from the uppermost silty clay (723 H) *A. beccarii tepida* is the most frequent form, accompanied by some *A. beccarii beccarii*, *Cancris auricula*, *Elphidium* and arenaceous specimens. Although the faunal composition of the silty clays in the lower and upper parts of the section is about the same, the benthos density in the upper silty clays is distinctly greater than in the silty clays in the basal part of the section.

### Interpretation

In the lower part of the section Grillos (sampling interval 723 A-F) the gradual, vertical transition from silty clay with a very poor, strongly *Am-*

*monia beccarii tepida* dominated fauna, to a fresh-water limestone practically devoid of foraminifera, clearly witnesses to an extreme decrease in salinity values. This sequence demonstrates the tolerance of *Ammonia beccarii tepida* for strongly hyposaline conditions. *Elphidium granosum* also appears to be a form with a relatively high tolerance for fresh-water supply, although the abundant aberrant individuals in sample 723 C, which probably belong to this species, suggest that the environmental conditions finally became very unfavourable for *E. granosum*.

In the middle part of the limestone (sampling interval 723 E-F) the complete absence of foraminifera and the presence of abundant *Planorbis* indicate that these sediments were deposited in a fresh-water environment. The high frequency of plant-moulds in the limestone suggests that an abundant vegetation caused the precipitation of CaCO<sub>3</sub>.

The return to somewhat higher salinities is indicated by the abundant *Ammonia beccarii tepida* in the silty clays on top of the limestones. In spite of the abrupt nature of the contact between both types of sediment, a gradual shift to somewhat more saline waters seems most plausible, in view of the fact that foraminifera are already present in the topmost part of the limestone (sample 723 G). The salinity during deposition of the upper silty clay may have been somewhat closer to normal than that below the limestone, but the presence of *Cancris auricula* and *Textularia agglutinans* remains enigmatic.

#### SECTION KAIAFAS

Section Kaiafas (exp. 313, fig. 16, table X) is in the area with relatively thin sand-clay sequences in the South-West. There are no data concerning the position of the section relative to the bottom or top of the formation.

Many of the sand bodies in this area have indurated top levels ("hard-grounds"), probably indicative of periods of non-deposition. These data suggest that the sections have to be considered as condensed; this may be related with the uplift of the nearby Lapidhas Mountains at the time.

Section Kaiafas is exposed along the main road from Pyrgos to Zacharo, about 5 km North-West of Kaiafas on the East side of the road (see fig. 2). It shows a sand – silty clay – sand succession with a thickness of about 18 metres. The lowermost sand body has an exposed thickness of 4 m and consists of fine sands without visible structures. At the top these sands are strongly indurated, which suggests a period of non-deposition or even emersion. The bulk of the overlying sediments consists of 9 m of homogeneous silty clays. The basal 30 cm are mottled and consist of a mixture of clay and

silt fragments and sand. The silty clays contain a randomly distributed malaco-fauna with *Venus* as the dominating form. This genus is accompanied by less frequent *Ostrea*, *Pinna*, *Chlamys*, *Melania*, *Aporrhais* and *Dentalium*. The gradual transition to the overlying sands takes place over a short interval. The uppermost sand body has a minimum thickness of 5 m; it consists predominantly of fine sands which show a vague horizontal lamination at some levels.

### Benthic foraminifera

Sample 313 A from the lower sand body has a very high benthos density (more than 60 specimens per cc sediment), and yields an assemblage with *Ammonia beccarii* and plano-convex forms as the dominant groups. From the base of the silty clays upwards, these groups show a distinct decrease in percentage values to the middle parts of the section. This decrease in relative numbers is balanced by an increase of *Elphidium* and *Ammonia perlucida*. *Nonion boueanum* and the less frequent *Cancris auricula*, *Fursenkoina schreibersiana* and *Reussella spinulosa* are present in fairly constant numbers throughout the lower and middle parts of the section. The uppermost sands are very poor in foraminifera; the composition of the fauna, however, is

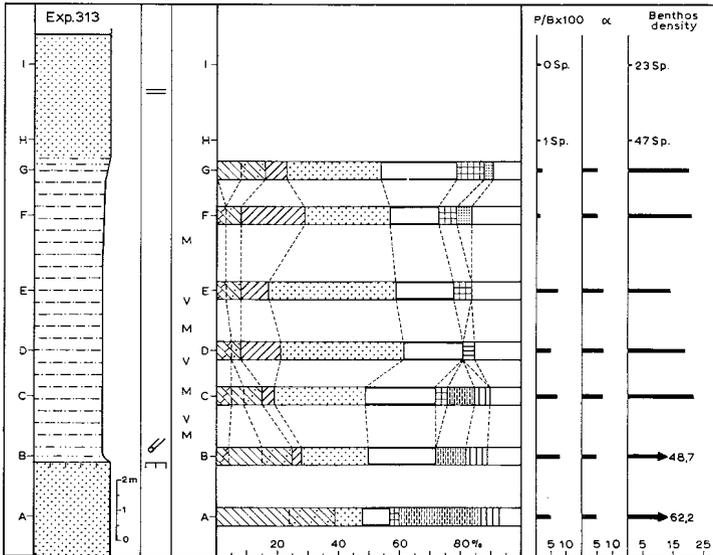


Fig. 16 Lithostratigraphic column and frequency diagram of benthic species at Kaiafas, exp. 313. For the legend see fig. 7 or the last page.

rather diverse, with rotaliid and elphidiid species dominating. Throughout the section the P-B ratio is low.

### Interpretation

The relatively high frequencies of *Ammonia beccarii beccarii* and plano-convex species in the lower sand body indicate that these sediments were deposited in, or in the vicinity of a vegetated environment with fairly normal salinities. The very high benthos-density, the abundance of plano-convex specimens and the more or less "normal" P-B values, suggest that the deposition rate was relatively low during the accumulation of these sands; the environment probably was too shallow and hydrodynamic energy too high for the settling of clay particles. In view of the indurated top of the underlying sands and the reworking phenomena immediately overlying, it can be concluded that there was a rapid subsidence phase.

For the overlying silty clays we can assume an increased sedimentation rate. The increase in the relative number of *Ammonia perlucida* may be connected with the absence of silty and sandy intercalations in these sediments. The low frequencies of *Ammonia beccarii tepida*, and the rather diverse character of the benthic associations point to an environment with fairly normal marine salinities.

In the sands of the upper part of the section, the very poor microfauna may have been entirely reworked.

The succession of Kaiafas cannot be easily explained as the reflection of seaward migrations of a system of sand barriers. The fauna of 313 A does not introduce a regressive phase terminating in a non-deposition below 313 B, unless perhaps such a change is hidden in the uppermost sands of which we have no samples. We might even be dealing with an open bay shoal which was submerged after an emersion period. The quiet sedimentation realm which followed is reminiscent of the slightly protected shallow bay environments we met with in the sections described earlier. Because of the lack of sedimentary data and the poor fauna the upper sand mass cannot be explained. The presence of a few *Ammonia beccarii*, *Nonion boueanum* and *Ammonia perlucida* in 313 H, which seems to be a reflection of the fauna underneath, may point to a sudden shallowing of the entire area followed by the arrival of "unfossiliferous" sands.

#### SECTION AGIOS ANDREAS

Section Agios Andreas (exp. 320, fig. 17, table XI) is located at the

western cliff coast of the Katakolon peninsula, approximately 1 km NNW of section Katakolon (see fig. 2). The section shows about 12 m of blue-grey, silty clays and yellowish clayey silts, which are unconformably overlain by an organoclastic limestone. Only the basal 7 m could be studied in detail.

The sediments are homogeneous in structure and contain, especially in the lower part of the section, some randomly distributed molluscs, mainly *Venus*. The field data suggest that these sediments represent a distinctly higher stratigraphical interval than those of section Katakolon, i.e. they are of Pleistocene age.

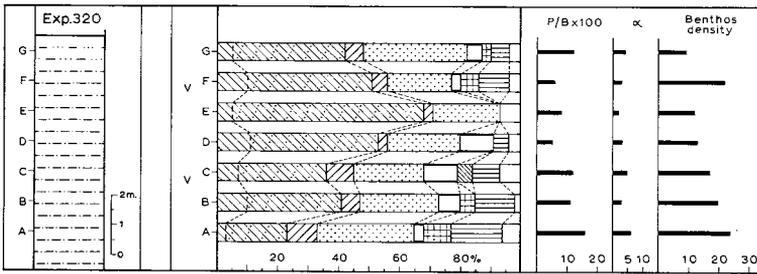


Fig. 17 Lithostratigraphic column and frequency diagram of benthic species at Agios Andreas, exp. 320. For the legend see fig. 7 or the last page.

### Benthic foraminifera

The benthic foraminiferal assemblages are characterized by low diversity and the dominance of *Ammonia* and *Elphidium*, these genera together constituting 65 to 90% of the total fauna. *Ammonia beccarii tepida* is the most important form and constitutes 20 to 60% of the assemblages. In the remaining part of the fauna *Nonion boueanum*, arenaceous species, *Ammonia perlucida* and *Cancris auricula* are the most frequent groups.

### Interpretation

The lithology in the section Agios Andreas gives little information for the paleoenvironmental analysis. The microfauna points to a somewhat restricted environment, as may be deduced from the dominance of *Ammonia* and *Elphidium* and the low diversity of the assemblages. The large numbers of *Ammonia beccarii tepida* point to a fresh water supply to the system, but the influence of the fresh water cannot have been excessive in view of the presence of *Nonion boueanum* and *Cancris auricula*. Since there are no indications in the section for an active role of a barrier it is not known

whether we are dealing with a “lagoonal” area or one in the off-shore near the mouth of a river system.

Although the thickness of the non-exposed interval between the successions of the sections Katakolon and Agios Andreas is unknown, the preceding data clearly indicate that in the Katakolon area too, deposition in more restricted systems did occur after the initial, open marine environment.

#### SECTION PIGADION

There are certain peculiarities in the successions of the Vounargon Formation in the North, particularly in the surroundings of Pigadion (fig. 2). The sediments differ from those in the central and southern parts of the area, because the individual sand and clay bodies are generally distinctly thinner and the quantity of marine molluscs is smaller, especially in the clayey intervals. Section Pigadion (exp. 703, figs. 18, 19 and 20) is representative for the type of sediment succession of the Vounargon Formation in the North.

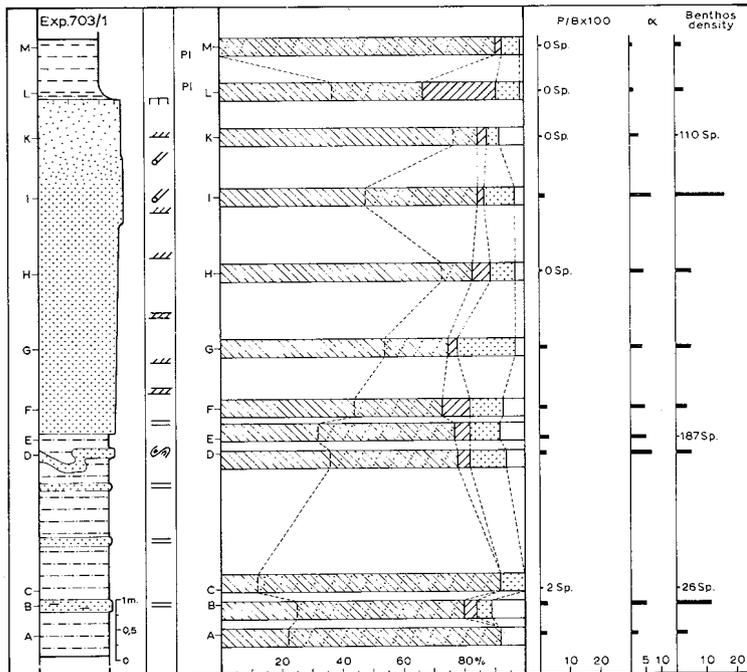


Fig. 18 Lithostratigraphic column and frequency diagram of benthic species at Pigadion I, exp. 703. For the legend see fig. 7 or the last page.

The section is composite and consists of three parts (exp. 703 I, II and III) separated by unexposed intervals of 15 and 10 metres, respectively. It is composed mainly of silty clays and sands. The section was measured along a track leading from the village to the North.

In the next pages the lithological and foraminiferal characteristics of the three parts of the section will be described separately, then the section as a whole will be interpreted.

#### SECTION PIGADION I

Section Pigadion I (fig. 18, table XII) has a thickness of about 20 metres. It shows 7 metres of interstratified silty clays and fine sands, which are succeeded by a sand body of 11 metres, which, in turn is in sharp contact with 2 metres of brownish clays. The individual silty to fine sandy beds in the basal 7 metres have a thickness of 1 to 60 cm and show sharp and straight, or indistinct lower and upper surfaces. Locally they display a delicate horizontal lamination, and the silty clays are homogeneous in structure. Some 50 cm below the contact with the overlying sand body an intercalation of a fine sand shows strongly distorted bedding probably due to loadcasting and slumping.

The overlying sand body coarsens upwards. The fine and medium sands show in the same direction an increase in large-scale cross-lamination and a decrease in small-scale cross-lamination. In the higher parts of the sand there are bodies with a horizontal lower boundary and a convex-upward upper boundary. Such bodies reach a maximum height of 1 metre. Internally they show two opposed directions of dip of the laminae; the axes of the "anticlines" have a North-West – South-East orientation. In the upper part of the sand there are vertical bioturbation structures; the top of the sand consists of a cemented level with marks of roots and plant remains at its upper surface.

The 2 metres of brownish clays in the uppermost part of section 703 I are homogeneous and contain abundant plant remains.

#### Benthic foraminifera

The foraminiferal associations of section Pigadion I are characterized by the extremely high relative frequencies of the *Ammonia beccarii* group and by the low P-B ratios. The number of specimens per cc seems to be higher in the silts and sands than in the clays and silty clays. The relative numbers of the *Ammonia beccarii* group are fairly constant and vary between 73 and

92%. Within this group, however, an overall change can be observed in the proportion of the varieties *Ammonia beccarii beccarii* and *A. beccarii tepida*. In sampling interval 703 A-K the *beccarii tepida* forms show a staggering decrease in relative numbers, whereas the *beccarii beccarii* forms increase. In the topmost sample 703 M 90% of the fauna suddenly consists of *A. beccarii tepida* again.

*Ammonia perlucida* and *Elphidium* are present throughout the section in variable, though usually low numbers. In the basal part of the uppermost silty clay (sample 703 L) *A. perlucida* constitutes 24% of the total fauna.

## SECTION PIGADION II

75 metres to the North and with a non-exposed stratigraphic interval of about 15 metres in between, the succession continues with Pigadion II (interval 703 N-FF, fig. 19, table XIII). It shows 16 metres of brownish silty clays alternating with sands that are often mollusc-bearing. The clays or silty clays have a maximum thickness of 4 metres and are homogeneous in structure. They are rich in plant remains and in the basal part of the section they contain a layer with small, fragile molluscs, which are double-valved and probably in living position.

The coarse clastic intercalations in the lower part of the section consist mainly of a mixture of molluscs, often broken, and sand; these beds vary in thickness from 30 to 150 cm. The mollusc-associations are very diverse and contain *Cardium*, *Venus*, *Pecten*, *Arca*, *Pinna*, *Glycymeris*, *Cerithium*, *Melania* and *Dentalium*. The specimens are randomly distributed in the sediment.

In the higher part of the section channel-fill deposits with a fining upward character are present. These lens-shaped bodies have a maximum height of 250 cm; their axes tend to have an East-West orientation.

### Benthic foraminifera

In section Pigadion II, sampling interval 703 N-FF, three groups of samples can be distinguished on the basis of the character of the microfaunas.

Samples 703 N and O are devoid of microfossils or contain a few specimens only.

Sampling interval 703 P-R displays a marked predominance of the *Ammonia beccarii* group and the same applies to interval 703 Z-FF. Samples 703 S-Y are characterized by very high benthos densities and very high relative frequencies of plano-convex forms, which in some samples are

accompanied by numerous miliolids. The miliolids are practically confined to this interval and attain highest frequencies (up to 39%) in the mollusc-bearing beds.

Within the *Ammonia beccarii* group, *A. beccarii inflata* predominates in some of the samples (703 T, W and CC) taken from silty clays. The variety *beccarii tepida* is predominant in silty clays, whereas *beccarii beccarii* reaches higher frequencies in some of the coarser sediments. It is remarkable that *A. beccarii inflata* and *A. beccarii tepida* seem to be mutually exclusive.

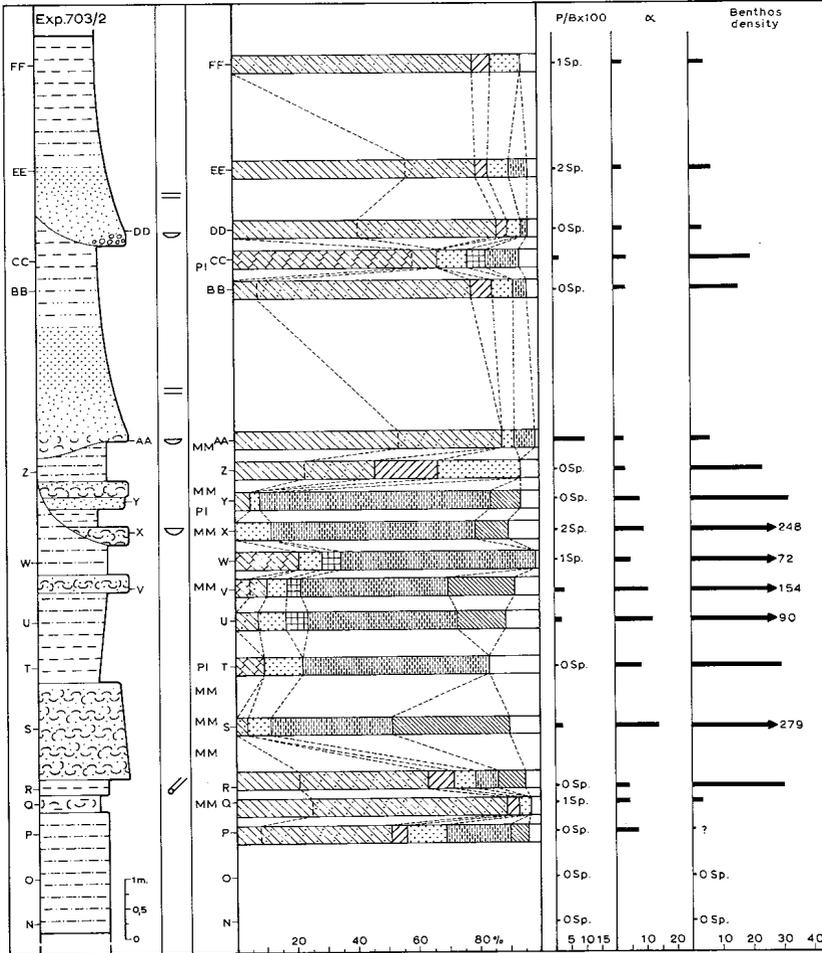


Fig. 19 Lithostratigraphic column and frequency diagram of benthic species at Pigadion II, exp. 703. For the legend see fig. 7 or the last page.

*Elphidium*, *Canceris auricula* and *Ammonia perlucida* are irregularly present; remarkable is the near-absence of *Nonion boueanum* and *Fursenkoina schreibersiana*.

### SECTION PIGADION III

After a non-exposed stratigraphic interval of about 10 metres, and approximately 60 metres to the North, the uppermost part of the section is exposed, Pigadion III (fig. 20, table XIV). This part has a thickness of about 20 metres. At its base it starts with 50 cm of grey silty clay, which are overlain by an irregular, vertical alternation of predominantly clays and sands with a total thickness of 14 metres.

The uppermost 6 metres are composed mainly of conglomeratic channel-fill deposits, which tend to show a fining upward to silty clays.

The lowermost four metres of sand are fine-grained with occasional horizontal lamination. The upper part of the sand shows orange and grey mottles and discontinuous lignite seams. The top of this sand is strongly

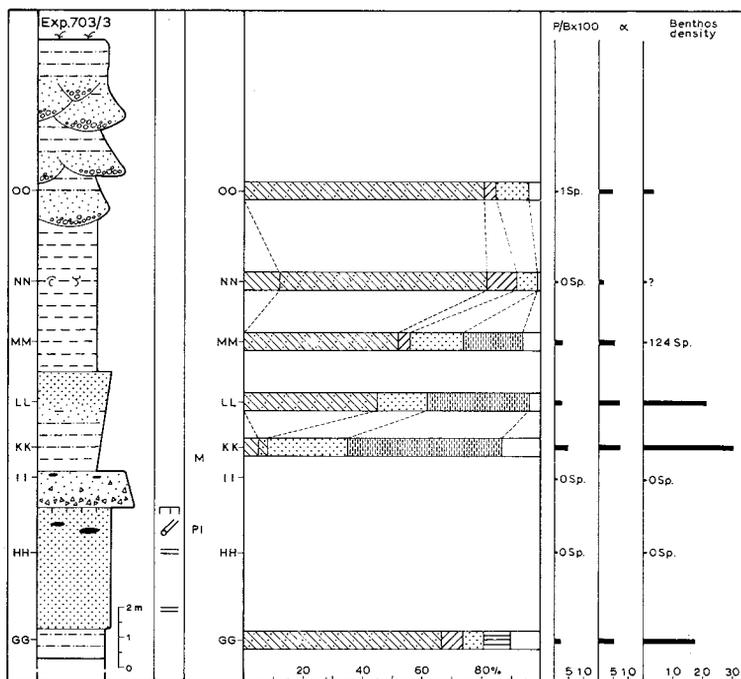


Fig. 20 Lithostratigraphic column and frequency diagram of benthic species at Pigadion III, exp. 703. For the legend see fig. 7 or the last page.

indurated and abruptly overlain by a breccious intercalation of 120 cm thickness. The maximum diameter of the components varies from 1.5 cm in the basal part of the layer to coarse sand in the upper part.

This coarse intercalation is overlain by an upwards-coarsening succession of 4 metres, showing brownish clays below which pass gradually into fine sands. The basal part of the clay contains abundant, often fragmented molluscs, mainly *Ostrea*, *Pecten*, *Pectunculus* and various gastropods. This upwards-coarsening sequence is abruptly overlain by 5 metres of homogeneous, brownish clays, which contain at 3 metres above their base a level with small, bivalved pelecypods. The uppermost 6 metres of the unit show an irregular alternation of conglomerates, sands, silts and clays, arranged in fining upward sequences, and deposited as lens-shaped bodies with a concave base and an indistinct upper boundary. These bodies, which may be truncated by the next higher one, have a maximum height of 1 metre and a lateral extension in the outcrop of about 5 metres; their axes have an approximately East-West orientation.

### Benthic foraminifera

The basal silty clays of Pigadion III (sample 703 GG) contain a fauna dominated by *Ammonia beccarii tepida*. The overlying sand and breccia are devoid of microfossils. The sediments above the breccia show a gradual decrease in the group of plano-convex forms, initially the dominating group, and a rapid increase in *A. beccarii tepida*, which constitutes 81% of the benthic foraminiferal association in the uppermost sample (703 OO). This change seems to be independent of the lithological differences.

*Ammonia perlucida* is present in higher numbers in the upper part; the percentages of *Elphidium* are fairly constant throughout this part of the section. The faunistical changes from 703 KK to 703 OO are accompanied by a conspicuous decrease in the benthos density of the sediment.

For section Pigadion as a whole, the most remarkable features relative to the sections described before are the scarcity of *Nonion boueanum*, and the occasional, relatively high frequencies of *Ammonia beccarii inflata*, a species generally absent or very rare in all other sections. The P-B ratios are invariably very low.

### Interpretation

The regressive upwards-coarsening sequence, constituting the larger part of section Pigadion I, may be interpreted again as the reflection of the filling up

of a lagoon, possibly by migration of a sand body over a more tranquil environment with accumulation of clayey deposits. However, in contrast to analogous successions in the sections in the central and southern parts of the Pyrgos area, in Pigadion I the poorest faunas, as far as the total number of benthic specimens per cc sediment and benthos diversity are concerned, are found in the clays. This suggests that the sedimentation-rate in the quiet environment was rather high. The vertical shift from silty clays with rather poor, *Ammonia beccarii tepida*-dominated faunas to sands with somewhat more diverse faunas and with increasing relative numbers of *Ammonia beccarii beccarii* suggests that the shallowing and increase in hydrodynamic energy was attended by an "amelioration" of the ecological conditions, i.e. there was a somewhat greater influence of more normal marine conditions. The upwards-coarsening sequence of Pigadion I can be taken to reflect the landward migration of a sand body over a quiet, strongly restricted marine environment, probably a hyposaline lagoon.

The faunal composition and the higher diversities of the silty and sandy intercalations in the silty clays (samples 703 B and D) suggest that these deposits were formed in a less restricted marine environment than the lagoon. Possibly these sediments were swept in during periods of high energy. This mechanism possibly also contributed to the landward migration of the barrier. The remarkable convex-up structures with large-scale cross-lamination in the upper part of the sand probably present transverse sections of fan-shaped bodies, formed on the lee of the barrier during storms. Such accumulations are constructed of material derived from the seaward-side of the obstructing sand body. The NW-SE orientation of the axes of these spill-over-lobes (Ball, 1967; Broekman, 1974) suggests an orientation of the barrier in an approximately NE-SW direction, perpendicular to the strike of these structures.

The occurrence on top of the sand body of a clay with a species-restricted *Ammonia beccarii tepida*-dominated fauna suggests that, as time went by, the lagoonal environment was re-established in Pigadion because of renewed submergence. The installation of these restricted marine conditions was preceded by a period of non-deposition and emergence, as may be concluded from the strongly indurated uppermost part of the sand body, and from the presence of root-prints on its upper surface.

In this uppermost clay body the upward decrease in relative frequency of *Ammonia perlucida* and *A. beccarii beccarii*, and the increase in frequency of *A. beccarii tepida* may be considered as the reflection of an increasing supply of fresh water or a greater isolation from the open sea. If we consider the base of Pigadion II as the uninterrupted continuation of the top of Pigadion

I, the lagoon must have received too much fresh water in the end for any foraminiferal life to survive.

The silty clays in the lower part of section Pigadion II, below the coarse interbeds (sampling interval 703 N-R), contain the shift from a fresh-water environment to restricted marine, probably hyposaline lagoonal conditions, as may be deduced from the absence of foraminifera in samples 703 N and O and the presence of an *Ammonia beccarii tepida*-dominated association in the next higher three samples. This increase in salinity must have been caused by increased access of marine waters.

In the middle part of Pigadion II (sampling interval 703 S-Y) both the lithological features and the fossil content show a radical change with respect to the underlying sediments, probably due to a sudden submergence of the area. The enormous numbers of plano-convex specimens and frequent miliolids point to a densely vegetated area of normal salinity. The intercalated coarse clastic beds show that the quiet sedimentation was repeatedly interrupted by deposition of coarse clastics during periods of high energy. The ill-sorted character of these coarse intercalations and their straight, sharp upper and lower boundaries probably reflect rapid deposition in sheet-like bodies. The sand grain-size and the presence of a rich and diversified malacofauna suggest that these sediments were derived from a littoral environment with normal marine salinities, probably adjoining the clayey area which had extensive subaquatic vegetation. The generally minor importance of miliolids in the silty clays and their relatively high frequencies in the coarse intercalations suggest that the representatives of this group were derived from a neighbouring environment, probably near or at the source area of the sands. The very high benthos density of the sediments of interval 703 S-X can be explained on the basis of an overall very low sedimentation rate. A similar sedimentation rate must have applied to the source area of the coarse intercalations.

A remarkable component of the benthic assemblages of the middle part of section Pigadion III is *Ammonia beccarii inflata*, a form which is present only in negligible quantities in the countings of the other sections of the Vounargon Formation. Because this form reaches relatively high frequencies in the clayey sediments without *A. beccarii tepida*, it seems likely that it represents an autochthonous element in a slow deposition environment of silty clays with possibly normal salinity.

In the upper part of Pigadion II (sampling interval 703 Z-FF) the silty clays and intercalated fining upward channel-fill deposits point to a quiet, muddy environment, intersected by channels, which frequently changed their position. The presence of associations of low diversity dominated by

the *Ammonia beccarii* group in the silty clays, indicates that the sediments were deposited in a restricted marine environment that was probably somewhat hyposaline. This implies that during the deposition of the upper part of Pigadion II there was a reduction in the influence of open marine waters, probably as a result of a new barrier system situated further away on the seaward side. The presence of similar low-diverse benthic associations in the channel-fill deposits, and their larger proportions of representatives of *Ammonia beccarii beccarii* may indicate that the source area of these sediments was about the same as that of the silty clayey deposits, but there must have been greater water energy at the place of deposition. Possibly the in-shore parts of the lagoon had steeper slopes causing repeated mass transport of its sediments through channels to the deeper parts.

The presence of *Ammonia beccarii inflata* in very high numbers (59% of the total fauna) with *Canceris auricula* and plano-convex species in the clay of sample 703 CC underlines the assumption that occasionally the lagoonal waters had near-normal salinity.

The lithology and faunistic features of section Pigadion III show the continuation of lagoonal conditions prevailing at Pigadion. The channel-fills constituting the top part of this section are probably fluvio-marine, indicating that the overall character of the succession is regressive, probably in connection with the more pronounced rise of the hinterland.

The sediment succession in the lower part of Pigadion III (sampling interval 703 GG-II), a silty clay with an *Ammonia beccarii tepida*-dominated association followed by a non-fossiliferous sand with lignite may be due to the progradation of coastal deposits over a hyposaline lagoon, in which the sands may represent the lagoon-beach sediments on the landward side. The discontinuous lignite seams and the indurated top of the sands may be the remnants of the final filling up and emergence.

The presence of a breccia on top of this sequence points to a sudden supply of nearby hinterland material, probably due to a combination of local subsidence and a more active uplift of the hinterland.

A renewed invasion of marine waters in Pigadion is indicated by the fossil-bearing sediments on top of the breccia. The relatively highly diverse benthic association with a relatively high number of plano-convex specimens in this silty clay (sample 703 KK) indicates that initially the salinity must have been fairly normal in a quiet area with vegetation. In the overlying sands and silty clays the overall upward decrease in numbers of these plano-convex forms and the strong increase in frequency of *Ammonia beccarii tepida*, which apparently occurred independent of lithological changes, may be considered as an indication for an increasing supply of fresh-water.

This increase in the fresh-water input at Pigadion was probably the result of a renewed progradation of a fluvial system over the lagoonal environment during the final phase of deposition of the Vounargon Formation. This can be deduced from the presence of coarse conglomeratic, probably fluvio-lagoonal channel-fill deposits in the top part of the section.

Summarizing the data on section Pigadion we can conclude that many of the sediments were deposited in lagoonal environments with frequently a more or less hyposaline character. During the time interval represented by the middle part of section Pigadion II deposition occurred in a normal saline environment in or in the vicinity of a densely vegetated area, which periodically received influxes of coarse, mollusc-bearing sediments from an adjoining littoral area.

As was pointed out before a remarkable feature of the benthic associations of Pigadion II is that *A. beccarii inflata* and *A. beccarii tepida* seem to be more or less mutually exclusive. This supports the idea that the varieties of *Ammonia beccarii* are ecophenotypes of this species, and that *A. beccarii inflata* has practically no tolerance for salinity fluctuations.

The benthic assemblages of section Pigadion differ from the "lagoonal" successions in the central and southern parts of the area in the overall low frequency of *Elphidium* and in the scarcity or even absence of *Fursenkoina schreibersiana*, *Reussella spinulosa* and especially *Nonion boueanum*.

#### SECTION KILLINI AND THE SOSTI DRILLING

In order to get a more complete picture of the character of the Vounargon Formation in the northern area, a long cliff-section (exp. 721) on the Killini peninsula was studied in some detail, while supplementary data were obtained from a drilling performed by ESSO near the village of Sosti (10 km East of Gastouni).

#### Section Killini

The Killini section (exp. 721, fig. 21) is exposed in the north-westernmost part of the peninsula (fig. 2) and consists of at least 400 m of alternating silty clays and sands, which are unconformably overlying preneogene limestones. The upper surface of these limestones often has a brecciated appearance and locally contains vertical bore holes due to lithophages. The overlying silty clay and sand units reach maximum thicknesses of 10 and 15 m, respectively, and are often arranged in upwards-coarsening sequences. Indurated levels occur only sporadically; locally lignitic intercalations are

present. *Cardium* and *Cerithium* are the most frequent molluscs; in the sands locally also *Ostrea* and *Venus* were found, and in the upper part of the section there was *Spondylus*. The silty clays are generally homogeneous in structure, the sands may show horizontal lamination, small-scale cross-lamination, and in their upper parts large-scale cross-lamination. In the upper parts of the sands, large (up to 20 cm) vertical burrows may be present, probably of decapod crustaceans.

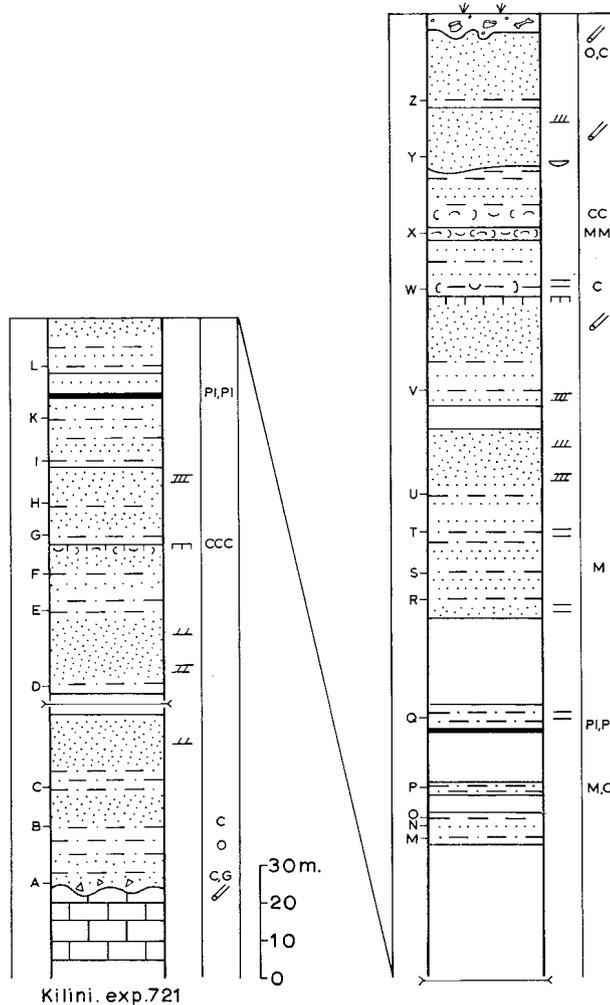


Fig. 21 Stratigraphic column of section Killini, exp. 721. See for the legend fig. 7 or the last page.

In order to get an impression of the character of the microfaunas of the Killini section, 25 mainly clayey samples, taken at regular intervals, were studied in some detail (721 A-Z).

In the microfaunas the *Ammonia beccarii*-group predominates and is often accompanied by less frequent *Elphidium* and *Nonion*. At some levels *Ammonia perlucida*, plano-convex forms and miliolids were recorded. The most diverse benthic assemblages were found in the upper 140 m of the section where occasionally also *Cibicides*, *Bulimina*, *Brizalina*, *Cancris* and *Fursenkoina* appeared to be characteristic faunal elements. In the whole section ostracods are occasionally present in fairly high numbers; planktonic foraminifera are invariably scarce.

In spite of the low-diverse character of most of the benthic assemblages, some samples (721 D, E and G) appeared to contain a calcareous nannofossil association, which could be used for biostratigraphical purposes. In addition to a great number of probably reworked, but amazingly well preserved Paleogene discoasters and Cretaceous coccoliths the following species were recorded: *Coccolithus doroconoides*, *C. pelagicus*, *Gephyrocapsa* sp., *Pseudoemiliana lacunosa*. The presence of these species and the absence of Pliocene discoasters suggest that the sediment can be assigned to the *Pseudoemiliana lacunosa* Zone, which is characteristic for the Lower Pleistocene (Schmidt, 1973). This conclusion is in conflict with the interpretation of Christodoulou (1969, 1971). This author assigned a Middle to Late Pliocene age to the sediments of section 721 because of the abundance of *Cyprideis torosa torosa* throughout the section and the presence of *Globorotalia inflata* and *Bulimina marginata* in the upper part.

### The Sosti drilling

The cutting samples demonstrate that the basement, consisting of whitish limestones, which probably are Preneogene in age, is at a depth of about 940 m below the surface. Only the basal 30 m of the overlying Vounargon-like deposits appear to contain more or less normal open marine faunas with *Uvigerina*, *Robulus* and biconvex *Cibicides*. Above this interval representatives of the *Ammonia beccarii*-group are predominant accompanied locally by *Elphidium*, miliolids and plano-convex forms. The malacofauna is mainly represented by *Cardium* and *Cerithium*.

Residues of two cutting samples, from the basal part of the drilling and from a depth of 800 m respectively, contain nannofossil assemblages which are reminiscent of that of section Killini. In addition to *Pseudoemiliana lacunosa*, also *Coccolithus doroconoides*, *C. pelagicus*, *Gephyrocapsa carib-*

*beanica*, *Cyclococcolithina leptoporus* and *Discolithina japonica* were recorded in fairly high numbers. This assemblage points to an Early Pleistocene age for the lower part of the Vounargon deposits of the Sosti drilling. This age assignment is contradicted by the determinations below 2,700 feet of the planktonic foraminiferal species *Globoquadrina dehiscens* and *Globorotalia peripheroronda* which indicate a Middle Miocene age (T. Freudenthal, written communication). Downhole contamination may account for the presence of the unmistakable Pleistocene nannofossil assemblages that we extracted from particles in the residues.

Both the sediments of Killini and the cutting samples of the Sosti drilling contain benthic microfaunas which seem to show little variation. Representatives of the *Ammonia beccarii* group are invariably dominating, and except in the basal part of the Sosti drilling, open marine mud-dweller associations, such as those recorded from the sections Katakolon and Grecka, appear to be absent. These data suggest that most of the deposition occurred in lagoonal systems. The sand/clay alternations indicate that rhythmic subsidence and filling-up again played an important role during the deposition of the Vounargon Formation in the North.

A remarkable feature of the Killini section is the absence of more or less open marine deposits in the basal part of the succession; this is in contrast with the Sosti drilling and the succession on the Katakolon peninsula. During the initial, open marine transgression in the North, Killini was probably still a relative "high". This hypothesis is confirmed by the presence of breccious and conglomeratic intercalations in other parts of Killini peninsula, which reflect the presence of an emerged, material supplying relief in the direct vicinity during the deposition of the Vounargon Formation.

## Chapter VII

### CONCLUSIONS CONCERNING THE HABITAT OF THE FORAMINIFERA

In the previous chapters a description was given of the distribution patterns of the benthic foraminifera in the sediments of the Vounargon Formation. Assumptions were made concerning the nature and the development of the various depositional environments on the basis of the sedimentary features and faunal succession. Major factors correlating with the composition of the benthic assemblages appeared to be the degree of isolation from open marine waters, salinity deviations, hydrodynamic energy in relation to nature and depth of the substrate, sedimentation rate and the presence of vegetation. It was concluded that the sediments of the Vounargon Formation were deposited in a variety of environments from open marine ones to ones that were completely isolated from the sea.

For several taxa habitat assumptions were made on the basis of their frequencies in the twelve sections. In the following paragraphs a summary will be given of these assumptions, and comparisons will be made with data from the literature on recent habitats.

The associations that are most open marine have no doubt been found in the Pleistocene of the section Katakolon. These faunas are characterized by high diversities ( $\alpha$  generally  $> 10$ ) and relatively large numbers of planktonic foraminifera (generally more than 10 planktonic specimens per 100 counted benthic specimens). The most important benthic constituents are *Cassidulina*, *Bulimina*, *Brizalina*, biconvex *Cibicides* and *Uvigerina*. Another characteristic feature of these associations is that these groups show very little fluctuation in their relative frequencies in the successive samples.

Associations largely made up of these groups are found today in normal marine environments with a muddy substrate, at depths below 100 metres and with bottom temperatures lower than  $10^{\circ}\text{C}$  (Murray, 1973).

A more detailed estimate of the depositional depth of these Katakolon sediments may be made by using data from the literature on the recent bathymetric distribution of their most important species. However, as demonstrated by Brolsma (1978), this method generally appears to be rather unsuitable, because of the wide depth-ranges in the literature for most species. For example, the important Katakolon species *Cassidulina carinata* has been described from open bays (van Voorhuysen, 1973) down to

bathyal depth (Phleger, 1964; Blanc-Vernet, 1969). *Bulimina marginata*, the most important constituent of the *Bulimina*-group in Katakolon, has been described from lagoonal environments (Kurc, 1961) down to a depth of 500 metres in the Ligurian Sea (Ruscelli, 1949).

Better results can be expected from a comparison with recent equivalents of the entire Katakolon association. It appears that benthic foraminiferal assemblages reminiscent of the ones of Katakolon, with approximately the same species in comparable frequencies, have been described from the recent Mediterranean at depths between 200 and 500 metres (Parker, 1958; Chierici et al., 1962). This suggests that the Pleistocene Katakolon sediments were deposited at depths approximately in the same interval.

Although in the Pliocene Grecka sections the benthic assemblages are also composed mainly of representatives of *Cassidulina*, *Bulimina* and *Brizalina*, these faunas differ from those of Katakolon in their lower diversity caused by the predominance of single species of these groups of mud-dwellers. Some of these species are not found at Katakolon. The relative frequencies of these groups show, moreover, a strongly fluctuating pattern in the successive samples. In the interpretation of the Grecka associations (Chapter IV) it was postulated that these features were probably caused by the location of Grecka further inwards in an open bay configuration. During the deposition of the sediments ill-documented fluctuations in the environmental characteristics may have been an important factor. Unfortunately, associations with approximately the same numerical species composition were not found in the literature. Open marine associations of mud-dwellers dominated by one or two species are known, however, from several modern environments. Pujos (1972) described faunas in which *Cibicides* cf. *ungerianus* and *Cassidulina laevigata* are present in relative frequencies of more than 50% from the continental shelf off the Gironde estuary (SW France). Drooger and Kaasschieter (1958) reported the presence of mud-dwellers associations dominated by *Uvigerina peregrina* in highly pelitic sediments on the Orinoco-Trinidad-Paria shelf, and Bandy et al. (1964) described living benthic associations largely made up of *Buliminella elegantissima* and *Bolivina vauhani* in front of the Laguna Beach outfall, California. All these environments have in common that they are situated in areas where there is deposition of nutrient-rich terrigenous muds. It might therefore be postulated that the composition of the Grecka associations is the reflection of abundant supply of organic material to the muddy sediment, possibly originating from the hinterland.

As demonstrated in section Kallidhea the transition from the open bay muddy environments of normal salinity to somewhat more restricted marine

conditions with increased sand supply and slight salinity deviations is reflected in the microfaunas by a strong decrease in *Cassidulina*, *Bulimina* and *Brizalina*, and the appearance of associations dominated by *Ammonia*, *Elphidium* and *Nonion boueanum*. Shallowing probably plays an additional role in this faunal change. The presence of *Nonion boueanum* in the mud-dwellers association of the basal part of section Kallidhea reflects a "transitional" stage between these faunas.

*Valvulineria complanata*, a species present in low numbers in sections Katakolon and Grecka, also reaches relatively high frequencies in the associations of the basal sediments of section Kallidhea, which suggests that it has a high tolerance or even a preference for this kind of environment. This interpretation seems to be approximately in accordance with the data from the literature. Although *V. complanata* has been recorded in low frequencies down to a depth of 700 metres in the recent Mediterranean (Parker, 1958), it reaches its highest frequencies in environments situated in the vicinity of areas with considerable run-off of fluvial waters and with a high deposition rate. This may be concluded from its presence in relatively high numbers on the off-shore delta flank of the Ebro (Scrutton, in Murray, 1973). In the Rhône delta it has been found in frequencies up to 9% (Ter Keurs, 1971). In this delta the distribution of *Valvulineria fabianii* (= *V. complanata*) would be restricted to distal fluvio-marine environments with rapid deposition. Its preference for this type of restricted marine environments is also demonstrated along the Atlantic coast of Spain, where it is rare on the shelf (Colom, 1952) but present in frequencies up to 5% in the deeper parts of the Ria de Arosa, a large open bay (van Voorthuysen, 1973).

In the more clayey deposits of the Vounargon Formation which are thought to have been deposited in quiet environments in front of shoals and sand bars, or in between, the microfaunas are generally dominated by representatives of the *Ammonia beccarii* group, *Elphidium* and *Nonion boueanum*. These taxa, which together constitute at least 50% of the total assemblages, are generally accompanied by less frequent *Ammonia perlucida*, *Fursenkoina schreibersiana*, *Reussella spinulosa* and *Cancris auricula*, while plano-convex species, miliolids and arenaceous forms, generally *Textularia*, may also be present. These associations are generally moderately diverse ( $\alpha$  approximately 5) and they contain a low relative number of planktonic foraminifera (generally less than 10 per 100 counted benthic specimens).

Although *Nonion boueanum* is present in high numbers in the larger part of these assemblages, this species reaches its highest relative frequencies in sediments of the Vounargon Formation which were deposited in environ-

ments with relatively good connections with open marine waters and approximately normal marine salinities (basal part Kallidhea, Paleovarvaisena, Neraida). In more hyposaline environments its frequencies are relatively low (section Agios Andreas, upper part Kallidhea) or very low (section Pigadion).

In recent shallow marine environments *Nonion boueanum* (= *N. asterizans* = *Nonionella atlantica*) is a common constituent of the benthic foraminiferal associations. In the Mediterranean it is rather frequent in all kinds of shallow open marine biotopes (Blanc-Vernet, 1969). It is common in associations along the Atlantic coasts of Spain and north-western Africa (Colom, 1950, 1952), and present in frequencies of up to 10% at depths shallower than 70 metres in the Gulf of Mexico (Phleger, 1951). Drooger and Kaasschieter (1958) reported this species to be frequent off-shore from the mouth of the Orinoco at depths between 30 and 50 metres. These authors reported that this form could stand slight salinity decreases; very high frequencies (up to 35%) were found in the pelite area off the Orinoco. However, the highest frequencies of this species were reported from open bay environments. In the Ria de Arosa, which is a large inlet of the Atlantic in NW Spain, it is present in the deeper parts of the open bay in frequencies up to 38% (van Voorthuysen, 1973); in the Gulf of Paria (van Andel and Postma, 1954) it is the dominating faunal constituent, and in the Gulf of Santa Fé it is generally present in frequencies of 35–80% and even higher (Sellier de Cievieux and Bermudez, 1973).

Although these data are in fair accordance with our own interpretation, it is remarkable that *Nonion boueanum* is practically absent in recent lagoonal environments. This suggests that either our "lagoons" usually had quite normal salinities or that during the deposition of the Vounargon Formation this species had a somewhat greater tolerance for conditions deviating from normal marine than it has in recent times. A change of biotope of *N. asterizans* (= *N. boueanum*) in the course of time has also been suggested by Blanc-Vernet (1969). Although it is probably true that during the Pliocene this form had a larger distribution in the Mediterranean waters than it has today (Parker, who studied surface samples from the Eastern Mediterranean did not mention a single specimen of *Nonion boueanum*), it seems more plausible that during the deposition of a large part of the Vounargon Formation the ecological conditions were fairly similar to those prevailing in modern open bays. This implies that, although the larger part of the silty clays of the Vounargon Formation were deposited in low energy environments between systems of shoals and imperfect barriers, the connections with open marine waters must have remained relatively good.

In these silty clays *Ammonia perlucida* and *Fursenkoina schreibersiana* are often characteristic additional components of the benthic associations. Both species seem to be able to stand some salinity decrease, although the tolerance for hyposaline conditions of *A. perlucida* is distinctly higher than that of *F. schreibersiana*. This is demonstrated in successions witnessing to deposition in distinctly hyposaline environments (Agios Andreas, Pigadion), in which only *A. perlucida* is present. The preference of *F. schreibersiana* for somewhat more open marine conditions is also expressed by the relatively high frequency of this species in the basal part of section Kallidhea and by its presence, although in low numbers, in section Grecka 305. A very important factor favouring the presence of both *A. perlucida* and *F. schreibersiana* seems to be the absence of true silts and sands, as both species reach their highest frequencies in silty clays without sandy or silty intercalations (sections Paleovarvaisena and Kaiafas, and the middle part of section Kallidhea).

In the literature on recent habitats *F. schreibersiana* (= *F. pontoni*) has generally been described from the same environments as *Nonion boueanum*, although it is generally present in lower numbers. It also reaches relatively high frequencies in open bay-like environments (Sellier de Civrieux and Bermudez, 1973; van Voorthuysen, 1973). It has been recorded in relatively high numbers off the Orinoco estuary (Drooger and Kaasschieter, 1958).

The distribution of *Ammonia perlucida* in modern environments is more difficult to determine, due to taxonomic confusion. When lying on its spiral side, it is almost indistinguishable from *Nonion paraliium* (Tintant), which in turn, is often mistaken for *Nonion depressulum* (Walker and Jacob). It seems likely that *A. perlucida* has often been mistaken for one of these two species.

Although *A. perlucida* originally has been described from shallow, but normal marine deposits off the Atlantic coast of Ireland (Heron-Allen and Earland, 1913), it seems to be a typical "lagoonal" species. It has been described from "Pleistocene and Holocene tidal marshes" in the North Sea basin (van Voorthuysen, 1950), it was recorded in the lagoon of Venice in frequencies of up to 10% in assemblages dominated by *Ammonia beccarii* (Cita and Premoli Silva, 1967), and Broekman (1973, 1974) reported this species from Pliocene open bay-lagoonal deposits of Rhodes, where it was found in associations dominated by *Ammonia beccarii* and *Elphidium*.

Summarizing these data from the literature we can conclude that recent *Fursenkoina schreibersiana* is an open-bay species, while *Ammonia perlucida*

prefers environments that are somewhat more isolated from open marine waters. The co-occurrence of these species in silty clays of the Vounargon Formation confirms the notion that these sediments were deposited in protected, "lagoonal" environments, which most of the time had a relatively good connection with open marine waters.

Although generally present in low frequencies only, *Reussella spinulosa* is also a characteristic component of the *Ammonia-Elphidium-Nonion boueanum*-associations of the "lagoonal" deposits of the Vounargon Formation. As far as salinity tolerance is concerned it is comparable to *Ammonia perlucida* and *Fursenkoina schreibersiana*. Its tolerance for hyposaline conditions seems to be somewhat higher than that of *Fursenkoina schreibersiana*, and somewhat lower than that of *Ammonia perlucida*. In contrast to the latter two species, the frequencies of *R. spinulosa* are only slightly affected by the type of sediment; although it reaches its highest frequencies in silty clays, it is also present in sandy deposits.

The distribution of *R. spinulosa* in the recent Mediterranean seems to be different from its distribution during the deposition of the Vounargon Formation. Today it is a stenohaline form (Lévy, 1971), which has been reported from an open bay environment down to a depth of 3,300 metres (Parker, 1958) but which reaches its highest frequencies in terrigenous muds on the shelf (Blanc-Vernet, 1969). However, during the Pliocene it seems to have been more frequent in more diverse, shallow, marginal marine environments (Blanc-Vernet, 1969). For example, although present in low numbers, it is an element of Pliocene, lagoonal deposits of Rhodes (Broekman, 1974).

One may be inclined to assume that climatological changes in the course of time have caused this change in distribution of *R. spinulosa* in the Mediterranean. However, also outside the Mediterranean recent *R. spinulosa* seems to be a typical shallow water, open marine species. In the Gulf of Mexico *R. atlantica* (= *R. spinulosa*) is most common (up to 10%) down to a depth of 120 metres (Phleger, 1951), and it has also been described from the shallower parts off the Atlantic coast of the southern U.S.A. (Wilcoxon, 1964), and from the Orinoco-Trinidad-Paria shelf (Drooger and Kaasschieter, 1958). Records of *R. spinulosa* from recent hyposaline environments have not been found. These data suggest that the habitat of *R. spinulosa* may have changed in the course of time.

At first sight a similar conclusion may be drawn with regard to *Cancris auricula*. In the sand-clay successions of the Vounargon Formation it is frequently present; it seems to be able to stand salinity deviations, as is indicated by its presence in sections Pigadion and Agios Andreas. It occurs in

relatively high numbers in transitional intervals between silty clays and sands, in successions reflecting the replacement of more clayey sediments by sands (sections Vounargon, Neraida and Paleovarvaisena). However, in the recent Mediterranean *Cancris oblonga* (= *C. auricula*) is a species occurring from the shelf to bathyal depths. Along the Atlantic coast of Europe it seems to be a typical shelf species (Colom, 1952; Murray, 1971; Rouvillois, 1970), while from the Gulf of Mexico *C. oblonga* (= *C. auricula*) has been reported especially from depths between 45 and 75 metres (Phleger, 1951). In the Todos Santos area it is a typical off-shore species, still present at a depth of 1,100 metres. According to Van Andel and Postma (1954) it may tolerate a considerable decrease of salinity in the Gulf of Paria, and Drooger and Kaasschieter (1958) recorded *Cancris sagra* (= *C. auricula*) in relatively high frequencies off the mouth of the Orinoco. These data indicate that, although *C. auricula* has often been considered to be a species which prefers the shelf environment of the open ocean (see also Van Voorthuysen, 1973), it is evidently rather indifferent to depth-related factors, and has a tolerance for slightly hyposaline conditions. Unknown ecological factors may control the distribution of this species. Its distribution in the successions of the Vounargon Formation suggests that high sedimentation rates are favourable for this species.

The group of plano-convex species is present in strongly varying frequencies in the Vounargon successions. These forms appear to have a low tolerance for salinity deviations and if they are present in relatively high frequencies they indicate the presence of subaquatic vegetation in or near the depositional environment. In sands where they are present in high frequencies together with *Ammonia beccarii beccarii* they were probably derived from a neighbouring, vegetated area, as *A. beccarii beccarii* and epiphytic species seem to exclude each other in modern environments (Blanc-Vernet, 1969). Mollusc-bearing sands with a rich, highly diverse association largely made up of several plano-convex species and miliolids, such as in the middle part of section Pigadion, have been described by Blanc-Vernet (1969) from shallow areas with a dense vegetation of especially *Posidonia*. However, silty clayey sediments with an association of plano-convex forms and miliolids, in which the plano-convex forms are mainly represented by one species (*Cibicides lobatulus*) have not been found in the literature on recent foraminifera.

*Elphidium* is generally present in fairly constant and high frequencies in the sand and clay successions of the Vounargon Formation. Although representatives of this group are present in section Grillos as well as in the

upper part of the silty clays of section Lala, indicating that *Elphidium* can stand both hyposaline and hypersaline conditions, it reaches its highest frequencies in normal, slightly hyposaline environments. In most sections *Elphidium* shows only slight fluctuations in its relative frequency, indicating that it has a great tolerance for various conditions prevailing in all kinds of shallow, restricted marine (sub)environments. Only in "normal" marine sands with associations dominated by *Ammonia beccarii beccarii* and plano-convex species (section Kaiafas and Lala) and in sediments deposited in distinctly hyposaline environments does the *Elphidium*-group dwindle to relatively low numbers.

In the successions of the Vounargon Formation, both increase in sand content and decrease in salinity are reflected in the microfaunas by an increase in the relative frequency of representatives of the *Ammonia beccarii* group. In sands deposited in an environment with more or less normal salinities *Ammonia beccarii beccarii* generally is an important faunal constituent. Decrease of the salinity in environments with either sandy or clayey deposition is invariably attended by an impoverishment of the benthic association and a conspicuous increase in the relative frequency of *A. beccarii tepida*. Even in the sediments of sections Grillos and Paleovarvaisena, which were deposited under strongly hyposaline conditions, *A. beccarii tepida* remains present, although in low numbers.

These interpretations of the ecological factors controlling the distribution of *Elphidium*, *A. beccarii beccarii* and *A. beccarii tepida* in the Vounargon successions seem to be in good agreement with the data from the literature concerning their distribution patterns in recent environments (Blanc-Vernet, 1969; Murray, 1973; Phleger, 1964). Associations dominated by *A. beccarii tepida*, such as occur in sections Grillos and Pigadion, are well known from recent hyposaline lagoonal environments. They have been described from lagoons along the South coast of France (Blanc-Vernet, 1958; Le Calvez and Le Calvez, 1951; Kruit, 1955), from the lagoon of Venice (Cita and Premoli Silva, 1967) and from the Laguna de Terminos, Mexico (Ayala-Castanares, 1963), all being environments with a supply of fresh-water. Blanc-Vernet (1958) observed that in the benthic associations, in which *A. beccarii tepida* may constitute up to 96% of the total fauna, the number of *A. beccarii beccarii* specimens increases with increasing salinity, a feature which was also concluded from the faunas of the Vounargon Formation.

In the successions of the Vounargon Formation *Ammonia beccarii inflata*, the third representative of the *Ammonia beccarii* group, is practically re-

stricted to section Pigadion. It was concluded that this form has possibly a preference for an environment with normal salinities in or in the vicinity of a densely vegetated area.

The factors controlling the distribution of *Ammonia beccarii inflata* in modern environments are difficult to determine. Blanc-Vernet (1969) reported *inflata*-like forms from vegetated areas, especially in the eastern part of the Mediterranean; Colom (1952) described *A. beccarii inflata* from the continental shelf of Galicia, NW Spain, from depths between 42 and 54 metres. The variant is absent in the lagoon of Venice, but present in the beach sands of the Lido of Venice (Cita and Premoli Silva, 1967). In clayey deposits of the outer-bay zone of the Ria de Arosa it is locally present in frequencies of 10–23% together with the same numbers of *Nonion boueatum* (Koldijk, 1968; van Voorthuysen, 1973). However, the question why *Ammonia beccarii inflata* reaches high frequencies only in the middle part of section Pigadion II remains unanswered.

Finally, a marginal note should be added regarding the overall minor importance of arenaceous taxa in the Vounargon deposits. In various recent hyposaline environments this group and especially genera like *Ammotium*, *Eggerella*, *Miliammina* and *Trochammina*, occur in high numbers (see Murray, 1973). The (near-) absence of these taxa in the Vounargon deposits may be due to the fact that these elements were lost during the treatment of the washed samples with carbon tetrachloride. However, some checks on residues not submitted to this floating method indicated that agglutinated forms are not represented in greater relative numbers. Evidently these taxa were of restricted importance in the benthic associations of the Vounargon Formation.

In modern seas arenaceous species reach relatively high frequencies in environments with a low pH. In hyposaline lagoonal environments such conditions are thought to prevail especially along densely vegetated marginal areas. The overall low frequencies of agglutinated forms in the Vounargon deposits thus suggest that marshes were generally absent.

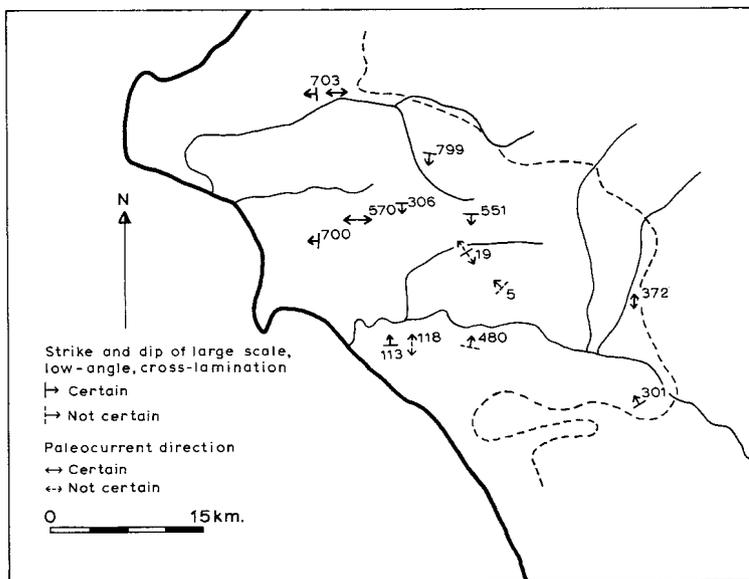


Fig. 22 Data concerning the pale-orientation of sand bodies of the Vounargon Formation and paleocurrent directions of fluvial systems related to these deposits.

## Chapter VIII

### SEDIMENTARY HISTORY AND PALEO GEOGRAPHIC RECONSTRUCTIONS

In the author's earlier paper (Hageman, 1977) the field data led to the recognition of four phases or episodes in the Plio-Pleistocene history of the Pyrgos area, each with its own paleogeographic configuration. A large part of this earlier reconstruction is confirmed by the faunistic and sedimentary data, but with regard to certain details the new data suggest a historical reconstruction which is in conflict with the one given earlier.

The Plio-Pleistocene benthic foraminiferal faunas of the fifteen sections treated more or less in detail in the preceding chapters confirm the previously made assumptions concerning the sedimentary environments which played a role during the deposition of the sediments of the Vounargon Formation. The faunas and sediments point to a wide array of biotopes, varying from open bays to fresh-water lakes. In their composition the faunal associations show various kinds of differences which seem to be connected with the type of sediment as well as with factors such as depth, subaquatic vegetation and salinity fluctuations.

However, there are other data, mainly of a sedimentological character, which seem to be in conflict with our former interpretation of the Pliocene Pyrgos embayment. The shape and slope of this embayment were thought to have approximately coincided with the recent Alfeos drainage area which has a NW-SE coastline and a connection with the open sea to the West. This interpretation is untenable for the older Vounargon deposits in the southern and central parts of the area.

There are numerous indications suggesting that a large part of the foraminiferal assemblages are from protected environments situated behind shoals, bars or even barriers. Although our sedimentological data are rather limited and consequently insufficient to determine changes in position and in possible migration directions of such sand bodies, the combination of large scale low-angle cross-lamination and horizontal lamination in the sands suggests that these sand bodies had predominantly E-W to NE-SW orientations (see fig. 22). These directions are valid for the older part of the Vounargon Formation in the south-central part of the area. If this conclusion is correct it follows that the coastline also had a roughly East-West orientation, and that the seafloor had an overall dip towards the North because the

notion of a rising hinterland in the South still stands. This picture does not fit in with the recent NW-SE coast of the Pyrgos area. Furthermore, the strikes measured in the sand bodies suggest that the southern coastline must have continued towards the West, into the recent Ionian Sea, with a direction approximately parallel to that of the recent Lapidhas Mountains. Measurements in the eastern Kallidhea-Okhtia strip suggest that the basin continued in NE direction, into the region of today's Erymanthos Mountains.

There are more arguments that such a configuration actually existed at the time. The strike of the strata of the Vounargon Formation in the South often suggests the same picture. These strike data are of course influenced by WSW-ENE faults in the basement which still seem to be active in recent times. The few data of dips towards and close to the recent coast may be due to sub-recent tilting in the coastal area.

The general tectonical picture shows predominantly E-W structures, which are abruptly cut off in the West, possibly as a result of more recent activity of NW-SE faults. This fault direction is also in good agreement with the tectonical patterns in the surrounding mountains, which probably continue in the basement of the Pyrgos area.

Also the directions of the coarse channel-fill deposits in the top part of the Vounargon Formation and in the overlying fluvial deposits of the Olimpia and Erymanthos Formations seem to confirm our assumption of a northward dipping bottom in the south-central area. The transport directions in these coarse clastics, both in the area near the mouth of the Alfeos, and in the surroundings of the recent eastern border-line of the Neogene deposits with the folded basement, invariably point from South to North. This implies that the drainage systems and consequently the dip of the basin floor were still towards the North, and not in a direction towards today's coast line.

If we accept this hypothesis to be correct some important questions arise concerning the location and nature of the source area of the enormous quantities of Vounargon sands. Furthermore the configuration of the sea in the Pyrgos area must have been such that currents were able to construct elongated sand bodies in an open sea. Continuous activity of the WSW-ENE growth faults during the general but rhythmic subsidence of the depositional area may be helpful in the explanation, but for a more complete answer to these questions we need further speculations, which will be supported by less information, or none at all.

It seems reasonable to suppose that any pronounced relief of the Pelopon-

ness had not yet been formed during the Late Pliocene transgression. Peneplainisation of the alpine basement, prior to the post-orogenic Neogene fault movements and basin formation, has been observed in other Greek areas as well. Crete is one of the best documented examples (Meulenkamp, in prep.), although it must be admitted that the subsidence phase had already started here in the Middle Miocene. In the discussion of the Platana Formation (Hageman, 1977), it was concluded that its lacustrine deposits, exposed below the Vounargon Formation in the vicinity of the Lapidhas Mountains, probably represent the remnants of a much larger sedimentary cover. The sedimentation area of these deposits may have extended over large parts of a flat, denudated Peloponnesus. In this context it is plausible to suppose that the Late Pliocene transgression also affected large parts of the northern Peloponnesus. The marine realm of the Pyrgos area possibly continued in North-East direction, towards the Gulf of Corinth, and maybe even beyond. The geological map of the Peloponnesus (Dufaure, 1977), which shows a badly known Plio-Pleistocene in these areas, does not contradict this assumption. In this much larger sea with an ill defined coastline with a low hinterland to the South it becomes feasible that material for the sand ridges could be transported by long-shore currents. Eastward directions of such currents seem to be most plausible if the Late Pliocene seas had some resemblance with today's Mediterranean.

The origin of the sands of the Vounargon Formation evokes still greater problems. Although no remnants of important fluvio-deltaic systems were found anywhere in the area studied, there are repeated microfaunistic indications for a fresh-water supply during the deposition of the Vounargon Formation. However, our conclusion that the recent distribution of the Vounargon Formation is probably a remnant of a much larger sediment cover implies that a hypothetical delta may well have been situated outside the investigated area. But a large delta needs a fair-sized hinterland with erosion, which might seem to be in conflict with our previous assumption of a peneplain not long before. It seems possible to explain the availability of large quantities of sands in another, equally speculative way. If one considers the geological map the most important tectonical-stratigraphical unit of the western part of the Peloponnesus appears to be the Gavrovo-Tripolitza unit (fig. 23) which is exposed in a broad strip running from Patras to the South. The strip is interrupted in the Pyrgos area, where the unit is probably buried under the Upper Cenozoic, and in the Gulf of Kyparissia, approximately SW of the Pyrgos area. If this unit became exposed in the latter area during the Late Pliocene, its sediments and especially its Paleogene flysch, may have been an important source of supply for the sands of the Vounargon Forma-

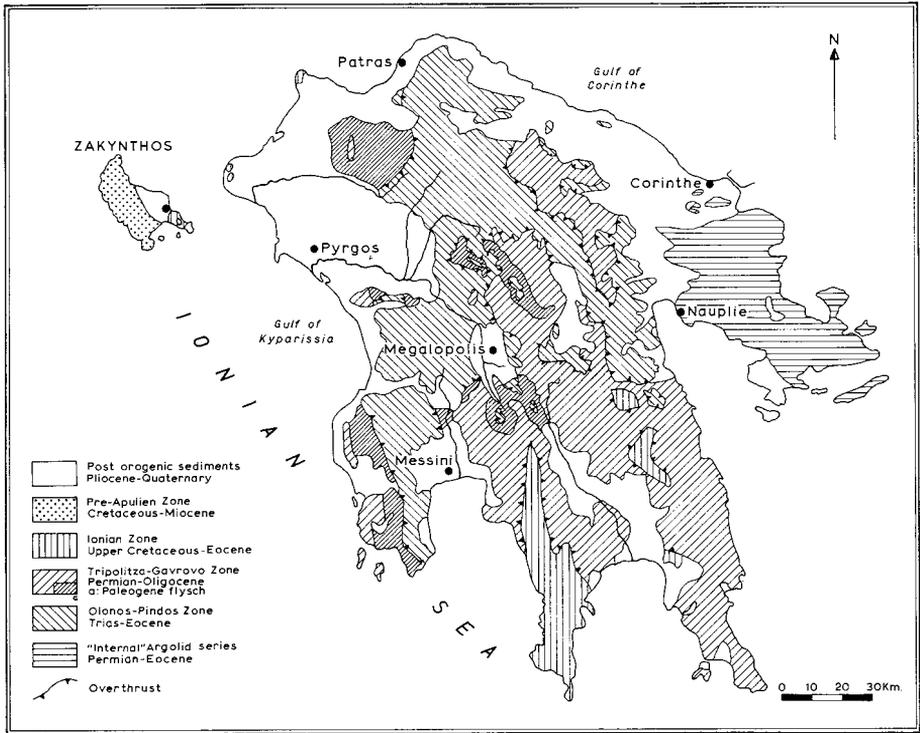


Fig. 23 Schematic map of the geological zones of the Peloponnese. Simplified after Dufaure (1977), Temple (1968) and Wade (1932).

tion. This idea may find support in the presence of numerous Paleogene radiolarians in the Vounargon sands. Consequently, an uplifted and emerged area in the Gulf of Kyparissia may have been the source area of the Vounargon sands, while an unknown continuation of this landmass towards the N or NW in the direction of Zakynthos may have formed the western border of the Pyrgos basin. Because of the preservation of the radiolarians an intermediate phase of long fluvial transport and delta construction seems less probable than transport of the sands directly from a Gavrovo headland into the Pyrgos area.

The picture is still not complete. In the conclusions of Hageman (1977) a tectonical hingeline was proposed, approximately along the line Pyrgos-Agios Trias. It was thought that during the deposition of the older part of the Vounargon Formation in the South, an emerged block was present North of this line. During or after the next phase of fluvial transport, which left

the sediments of the Olimpia and Erymanthos Formations, the area of maximum subsidence would have shifted from the South to this northern block. This latter conclusion is without doubt correct, if only because of the different orientation of the sand bodies in the North, which are more or less parallel to the recent coastline. However, an emerged block in the North during the earlier Late Pliocene sedimentation phase, and as a consequence a narrow sea passage in the Pyrgos area with sand ridges over the entire width and with a great diversity of faunas does not seem likely any more. An open sea in the North, possibly with islands and with a restricted rate of subsidence seems more plausible in our new concept.

It should be emphasized that our previous model emanated from a subdivision of the Vounargon Formation into an older part with predominantly thick sand bodies (present in the central and southern parts of the area) and a younger part with relatively thin sand bodies (present in the North), and from the observation that both types are found in continuous succession along the road from Pyrgos to Oinoi, separated from each other by an offshoot of the southern fluvial formations. Possibly the time-stratigraphic character assigned to both parts of the formations needs to be revised. We only had some local datings based on the recognition of two nannoplankton zones, the one but highest zone of the Pliocene at the base of the southern Vounargon sequences, and the lowest zone of the Pleistocene at the base of some northern sequences.

It should be realized that the thickness of the individual sand bodies in the supposed environments is mainly controlled by the interplay of sediment supply and rate of subsidence of the separate parts of the basin. The predominance of upwards-coarsening points to rhythmic downward movements. Each phase of active subsidence is followed by a more stable period during which the depression is filled up, often up to wave-base and even to sea level, followed by emergence. The relatively restricted thickness of the units along the recent southern and eastern margins of the distributional area of the Vounargon Formation may be explained by assuming that the downward movements of the basement were less than in the more centrally situated areas. A relatively low rate of subsidence of the northern block already during the deposition of the sand bodies in the South would certainly simplify the picture. Contingent islands in this realm are acceptable in this hypothesis.

Yet, the earlier procedure to date the successions of the Vounargon Formation seems to be in conflict with the new model. The transgression that left open marine sediments in Katakolon and Killini as late as the

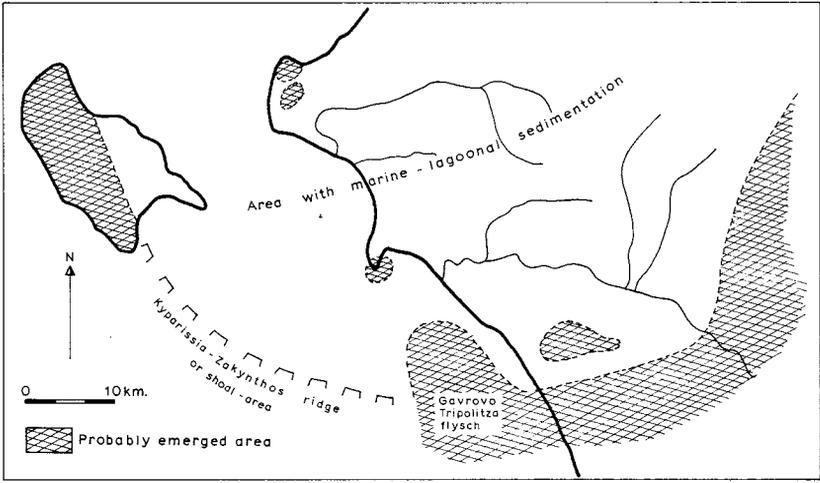


Fig. 24 Paleogeographic configuration of the western Peloponnese after the Late Pliocene transgression.

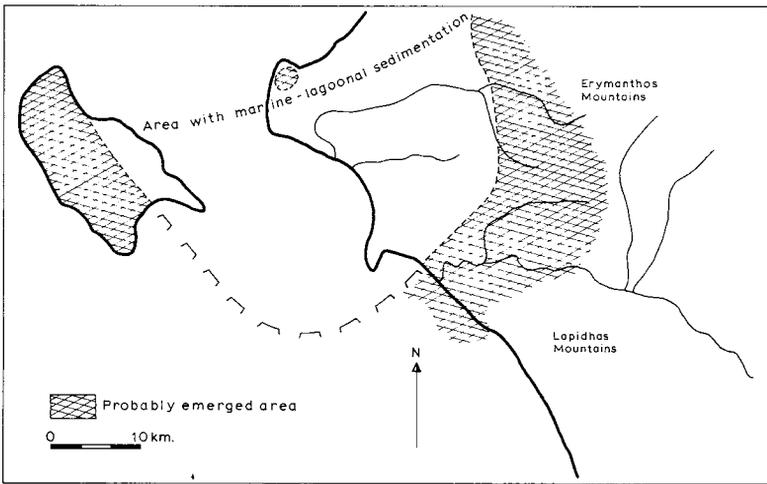


Fig. 25 Paleogeographic configuration of the western Peloponnese after the maximum extension of the off-lap succession of the Olimpia Formation.

Pleistocene is understandable if we assume that these areas formed part of the previously suggested hypothetical Kyparissia-Zakynthos ridge or shoal area. However, the supposed Pleistocene age of the basal sediments of the Sosti drilling cannot be easily explained by assuming that this area also formed part of an island during the Late Pliocene. Actually, there is conflicting evidence for the age of the basal sediments in the Sosti drilling, either Middle Miocene or Pleistocene. The assumption of a condensed Mio-Pliocene sequence, possibly with several hiatuses, followed by a long Pleistocene part of the column, seems to fit best. Such a thick series of Pleistocene sediments remains difficult to understand, however, because then we are faced with the problem of some 900 metres of Pleistocene at Sosti, whereas at a distance of only 20 km to the SE, at Karatoula close to or on the other side of the hingeline a succession of about the same thickness would be of Pliocene age.

If we assume that the age determinations of the major marine incursions in the North and South (i.e. Pleistocene and Pliocene respectively) are correct, the question arises whether the upper Vounargon sediments which are found on top of the fluvial deposits along the road from Pyrgos to Oinoi are time equivalent with the larger part of the deposits of the Sosti drilling. Apart from the data on the age of the basal part of the Vounargon Formation in the South, in outcrops adjoining the Lapidhas Mountains, we have no biostratigraphical information about the higher parts of the formation in this area. The higher part may even be of Pleistocene age and the base of the Pleistocene hidden in the thick-bedded sequences of the South. This would imply that large parts of the Vounargon deposits of the southern and northern types are time equivalent. An important consequence of this assumption is that the off-lap phase of the Olimpia and Erymanthos Formations took place well after the beginning of the Pleistocene and not at the end of the Pliocene.

Although there are no actual data which prove or disprove this theory, the strong downward movements, firstly of the southern block and afterwards of the northern basement along the same hingeline, are not needed anymore. The larger part of the successions of Sosti and Karatoula may be time equivalent now, and the apparently continuous succession along the Pyrgos-Oinoi road and the absence of a clear fault expression at the surface of the assumed hingeline may be understood better in this new concept. Figure 24 shows a paleogeographic reconstruction of the western Peloponnesus after the Late Pliocene transgression.

The modifications of our former paleogeographic reconstructions appear to be useful for the interpretation of the sedimentary history of the area

during the later phase as well. It is still likely that during this next phase and after the uplift of the southern areas, the marine connections to the North-East were disrupted because of the uplift of parts of the Pindus nappes. Especially in the northern area a westward dipping bottom profile came into existence, while the supply of clastics and the construction of sand ridges continued in a shallow area.

The recent distribution of the Vounargon Formation in the North probably represents only a part of the depositional realm of the formation during this episode. The abrupt cut-off of hundreds of metres of sands and brackish intercalations at Katakolon and Killini indicates that the real boundary with the open sea must have been situated somewhere West of the recent coast. It is possible that the Kyparissia-Zakynthos shoal area of the preceding phase still played a role.

Although sedimentological data concerning the orientation of sand ridges and the direction of channel-fill deposits of the northern Vounargon Formation are rather limited, they all seem to fit in with the paleogeographical model outlined above.

The sediments of the section of Vounargon, with its relatively thick sand bodies, also seem to have been deposited in a configuration with a North-South coastline (see fig. 22). Although a local deviation from the older North sloping model certainly can be defended, especially when the geographic position of the section is taken into consideration, it is equally possible that the sediments at Vounargon were deposited during the later phase. Once more it should be stressed that the thickness of the sand bodies is not geologic time-controlled, but subsidence-controlled. Figure 25 shows a paleogeographic reconstruction of the western Peloponnesus after the maximum extension of the off-lap successions.

Today's Peloponnesus came into existence during a final phase with important vertical movements, especially along the NW-SE directed fault systems. During this episode, which may have continued up to recent time, the mountain chains of the hinterland were rising, while the western areas beyond the present coast line, which played an important role during the sedimentary history of the Pyrgos area, disappeared under the surface of the Ionian Sea. The narrow clayey-sandy strip with coastal lakes behind the shoreline from Katakolon to Kaiafas evidently is the only sedimentary expression on land of the conditions after the final tectonic phase, apart from the fluvial sediments along the Alfeos, Pinios and other parts of today's drainage system.

## Chapter IX

### TAXONOMIC AND ECOLOGICAL REMARKS

In this chapter short remarks will be made on the assumed habitat of the most frequent constituents of the sixteen groups. These paleoecological interpretations are based on the distribution and frequency of the individual taxa in the sections.

Furthermore species on which a taxonomic remark are to be made, are treated as well. The order of the species is alphabetic.

The relative frequencies given are based on the following percentages: very rare < 3%; rare 3–6%; common 7–12%; frequent 13–25%; abundant 26–50%; dominant > 50%.

Representative specimens of the species recorded in the twelve sections are stored in the collections of the department of Stratigraphy and Micro-paleontology of the Geological Institute of the State University of Utrecht.

#### *Ammonia beccarii* (Linnaeus)

For paleoecological purposes it appeared desirable to distinguish three varieties: *A. beccarii* var. *beccarii*, *A. beccarii* var. *inflata* and *A. beccarii* var. *tepida*. Because these varieties show a morphological intergradation, their separation in the countings needs further definition.

#### *Ammonia beccarii* (Linnaeus) var. *beccarii* (Linnaeus)

Pl. 1, figs. 1a-c

*Nautilus beccarii* Linnaeus, 1758, Syst. Nat. Ed. 10, 1, p. 710, pl. 1, figs. 1a-c.

*Rotalia beccarii* (Linnaeus), Cushman, 1931, U.S. Nat. Mus. Bull., 104 (8), p. 58, pl. 12, figs. 1–7, pl. 13, figs. 1, 2.

*Remarks:* Only *A. beccarii* specimens displaying the following features have been assigned to this variety: test compressed, eight or more chambers in the last whorl, sutures depressed with feathered fissures, umbilical region covered with granular glassy material and generally with a central plug. Diameter at least 400  $\mu$ .

*Occurrence:* Nearly absent in sections Katakolon, Grecka and Grillos. In the other sections often abundant to dominant in the sands; in the clays generally rare to frequent.

*Interpretation:* A typical shallow water form, with a preference for environments with high hydrodynamic energy and normal to slightly hyposaline conditions.

***Ammonia beccarii* (Linnaeus) var. *inflata* (Seguenza)**

Plate 1, figs. 2a-c

*Rosalina inflata* Seguenza, Atti Acc. Gioenia Sci. Nat., 2, 18, p. 106, pl. 1, fig. 6.

*Ammonia inflata* (Seguenza), Van Voorthuysen, 1973, Zool. Verh., 123, p. 38, pl. 1, figs. 9a-c.

*Remarks:* Test biconvex (diameter-thickness ratio about 3/2), generally less than 8 chambers in the last whorl. Plates cover a large part of the umbilical region, which is entirely covered with granular material. Diameter generally more than 400  $\mu$ .

*Occurrence:* In clayey sediments of section Pigadion locally frequent to dominant; occasionally rare in section Kaiafas.

*Interpretation:* This variety probably has a preference for ill-defined clayey habitats with normal marine salinities in or in the vicinity of a vegetated area. It may be a Pleistocene immigrant to the Mediterranean.

***Ammonia beccarii* (Linnaeus) var. *tepida* (Cushman)**

Plate 1, figs. 3a-c

*Rotalia beccarii* (Linnaeus) var. *tepida* Cushman, 1926, Publ. Carnegie Inst. Washington, 344, p. 79, pl. 1.

*Ammonia tepida* (Cushman), Van Voorthuysen, 1973, Zool. Verh., 123, p. 38, pl. 1, figs. 8a-c.

*Remarks:* The test is slightly plano-convex, with 5 to 8 chambers in the last whorl. The sutures are deeply depressed and without fissures. The umbilical region is more or less open. Diameter generally less than 400  $\mu$ .

*Occurrence:* In the sections Katakolon and Grecka this variety is very rare; in the other sections it is frequent to dominant in many of the samples from the silty clays; in the sands it may be common locally. In sediments with a very low benthos diversity, whether sands or clays, this variety is often the most important faunal constituent.

*Interpretation:* A shallow water form with a relatively great tolerance for restricted marine conditions. Amongst all recorded taxa, it has the greatest tolerance for hyposaline conditions.

***Ammonia perlucida* (Heron-Allen and Earland)**

Plate 1, figs. 4a-c

*Rotalia perlucida* Heron-Allen and Earland, 1913, Proc. Roy. Acad., 31, 64, p. 139, pl. 13, figs. 7-9.

*Ammonia perlucida* (Heron-Allen and Earland), Broekman, 1974, Utrecht Micropal. Bull., 8, pl. 1, figs. 10a, b.

*Remarks:* If lying on its spiral side, this species is difficult to distinguish from *Nonion paraliium* Tintant.

*Occurrence:* Almost absent in sections Katakolon, Grecka and Grillos; in clayey deposits of the other sections it may be rare to common.

*Interpretation:* A shallow water mud-dweller with a preference for environments with normal to slightly hyposaline conditions.

### **Brizalina aenariensis** Costa

Plate 2, figs. 1a, b, 2

*Brizalina aenariensis* Costa, 1856, Atti Acc. Pont., 8, 2, p. 297, pl. 15, figs. 1a, b.

*Bolivina aenariensis* (Costa), Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 57, pl. 7, figs. 23, 24.

*Occurrence:* Abundant in the Grecka sections, almost absent in the other sections.

*Interpretation:* This species has a preference for a muddy environment with normal salinities, and possibly a tolerance for fluctuations in the composition of the substrate, because it is most frequent in the assumedly open marine part of the Pyrgos embayment.

### **Brizalina dilatata** (Reuss)

Plate 2, figs. 3a, b, 4

*Bolivina dilatata* Reuss, 1850, Denkschr. K. Akad. Wiss., Wien, 1, p. 381, pl. 48, fig. 15.

*Bolivina dilatata* Reuss, Dieci, 1959, Paleontogr. Ital., nov. ser., 24, p. 67, pl. 5, figs. 29, 30.

*Occurrence:* Frequent in section Katakolon.

*Interpretation:* Probably a mud-dweller under open marine conditions.

### **Brizalina spathulata** (Williamson)

Plate 2, figs. 5a, b

*Textularia variabilis* var. *spathulata* Williamson, 1858, Rec. Foram. G.B., p. 76, pl. 6, figs. 164, 165.

*Brizalina spathulata* (Williamson), Murray, 1971, Atlas Brit. Rec. Foram., p. 111, pl. 45, figs. 1-4.

*Occurrence:* Locally abundant in the Grecka sections, rare in Katakolon and in the basal part of Kallidhea.

*Interpretation:* Although this species is apparently a normal marine mud-dweller, its presence in the basal part of Kallidhea points to a somewhat greater tolerance for conditions deviating from normal open marine than the other *Brizalina* species.

**Bulimina elongata** d'Orbigny subsp. **subulata** Cushman and Parker  
Plate 2, fig. 6

*Bulimina elongata* d'Orbigny *subulata* Cushman and Parker, 1937, Cushman Lab. For. Res., Contr., 13, p. 49, pl. 17, figs. 1-3.

*Bulimina elongata* d'Orbigny *subulata* Cushman and Parker, Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 151, pl. 13, fig. 6.

**Occurrence:** Abundant to rare in the Grecka sections, common in the basal part of Kallidhea, occasionally rare to very rare in clayey intervals of the other sections.

**Interpretation:** An open marine mud-dweller with possibly some tolerance for conditions deviating slightly from normal marine.

**Bulimina marginata** d'Orbigny  
Plate 2, fig. 7

*Bulimina marginata* d'Orbigny, 1826, Ann. Sci. Nat., Paris, 1, 7, p. 269, pl. 12, figs. 10-12.

*Bulimina marginata* d'Orbigny, Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 262, pl. 2, fig. 23.

**Occurrence:** Common to frequent in Katakolon and in the basal part of Kallidhea, rare in the Grecka sections.

**Interpretation:** An open marine mud-dweller.

**Cancris auricula** (Fichtel and Moll)  
Plate 2, figs. 8a-c

*Nautilus auricula* Fichtel and Moll var.  $\beta$  Fichtel and Moll, 1798, Test. Micr., p. 110, pl. 20, figs. d-f.

*Cancris auricula* (Fichtel and Moll), Murray, 1971, Atlas Brit. Rec. For., p. 137, pl. 57, figs. 1-7.

**Occurrence:** Absent in sections Katakolon and Grecka; common in transitional intervals from clayey to sandy deposits in the sections Vounargon and Neraida. In the other sections generally rare.

**Interpretation:** A shallow water species with tolerance for slightly hyposaline conditions. The species seems to flourish in environments where there are increasing sedimentation rates and not too high energy conditions.

**Cassidulina carinata** Silvestri  
Plate 3, figs. 1, 2

*Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896, Acc. Pont. Nuovi Lincei, Mem., 12, p. 104, pl. 2, fig. 10.

*Cassidulina carinata* Silvestri, Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 271, pl. 4, fig. 15.

**Occurrence:** In the Grecka sections present in frequencies varying from less than 1% to 55%. Abundant in Katakolon and in the basal part of Kallidhea.

In the other sections occasionally rare to very rare.

*Interpretation*: An open marine mud-dweller.

### *Cibicides burdigalensis* Colom

Plate 3, figs. 3a, b, 4a-c

*Cibicides floridanus* (Cushman) subsp. *burdigalensis* Colom, 1943, R. Soc. Esp. Hist. Nat., Bol., 41, p. 326, pl. 22, figs. 18–23.

*Cibicides* aff. *C. floridanus* (Cushman), Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 274, pl. 4, figs. 36–38.

*Remarks*: According to the original description and figure *Truncatulina floridana* Cushman (1918, U.S. Geol. Surv., Bull., p. 62, pl. 19, fig. 2) has a ventrally situated aperture consisting of an elongated slit parallel to the periphery. This implies that this form belongs to the genus *Epistominella*. The existence of a close relationship between this species and our form is thus considered doubtful.

*Occurrence*: This species of the trochoid-biconvex group is common to frequent in section Katakolon.

### *Cibicides dutemplei* (d'Orbigny)

Plate 3, figs. 5a, b

*Rotalina dutemplei* d'Orbigny, 1846, For. Foss. Vienne, p. 157, pl. 8, figs. 19–21.

*Heterolepa dutemplei* (d'Orbigny), Loeblich and Tappan, 1964, Treat. Invert. Pal., C, p. 759, pl. 623, figs. 3a-c.

*Occurrence*: This species of the trochoid-biconvex group is very rare to absent in sections Grecka, Katakolon, Pigadion and Agios Andreas. In the other sections occasionally rare in both silty clays and sands. Common to frequent in samples 700B, 109F and 313B.

*Interpretation*: A shallow water species with a low tolerance for salinities deviating from normal. Its distribution seems to be independent of the type of substrate. Because its frequency pattern resembles that of the plano-convex species and/or miliolids it seems likely that *C. dutemplei* is an epiphytic form.

### *Cibicides lobatulus* (Walker and Jacob)

Plate 3, figs. 6a, b, Plate 4, figs. 1a, b

*Nautilus lobatulus* Walker and Jacob, 1798, Kanmacher, p. 642, pl. 14, fig. 36.

*Cibicides lobatulus* (Walker and Jacob), Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 182, pl. 6, fig. 12.

*Remarks:* The very variable shape of this plano-convex form is well known in the literature. In our countings two varieties have been distinguished. In variant 1 the chambers are irregular in shape and increase rapidly in size as added; ratio height/diameter 1/3 to 1/4. In variant 2 the chambers are regular in shape and increase gradually in size as added; ratio height/diameter 1/2 to 1/1. Specimens with a relatively great height resemble *C. refulgens* Montfort.

*Occurrence:* Very rare in sections Grecka and Katakolon. In the other sections locally in high frequencies, especially in sands and in clayey sediments with abundant miliolids. Var. 1 generally reaches its highest frequencies in the silty clays, while var. 2 is more common in the sands.

*Interpretation:* Amongst the plano-convex species, *C. lobatulus* seems to have the greatest tolerance for restricted marine conditions. The relation that apparently exists between the frequencies of the two varieties and the grain-size of the sediment suggests that variety 2 could live in more turbulent waters than variety 1.

### *Cibicides ungerianus* (d'Orbigny)

Plate 4, figs. 2a-c, 3a, b

*Rotalina ungeriana* d'Orbigny, 1846, For. Foss. Vienne, p. 157, pl. 8, figs. 16-18.

*Cibicides ungerianus* (d'Orbigny), Marks, 1951, Cushman, Found. For. Res., Contr., 2, p. 73, pl. 8, figs. 2a, b.

*Remarks:* Our specimens differ from the individuals figured by d'Orbigny and Marks in that ours have less compressed tests and show a less rapid increase in the size of the chambers as they are added. This species differs from *C. burdigalensis* in that it has a greater number of chambers in the last whorl (10 to 12 instead of 8 to 10), in the visibility of all whorls at the dorsal side, in the absence of a strongly compressed peripheral part of the chambers and in the presence of coarse perforations on the ventral side. In juvenile specimens these features become indistinct, however, and determination then often becomes a matter of personal appreciation.

*Occurrence:* This species of the trochoid-biconvex group is very rare in sections Grecka, rare in section Katakolon.

### *Coryphostoma silvestrina* (Cushman)

Plate 4, fig. 4

*Bolivina silvestrina* Cushman, 1936, Cushman, Lab. For. Res., Spec. Publ., 6, p. 56, pl. 8.

*Bolivina italica* Cushman, 1936, Cushman, Lab. For. Res., Spec. Publ., 6, p. 56, pl. 8.

*Remarks:* This species shows a variation in the degree of slenderness of the test, in the height and degree of inflation of the chambers and in the dimensions of the aperture. The figured type of *B. italica* is distinctly within the range of variation of our specimens.

*Occurrence:* Absent in sections Katakolon, Kallidhea and Agios Andreas; in the other sections present in low frequencies.

### **Coryphostoma sp.**

Plate 4, fig. 5

*Remarks:* This form differs from the preceding species in the character of the sutures, which are not depressed, or very slightly so, in its rounded initial part, and in its very large aperture. The wall of the early portion may be very thick.

*Occurrence:* Rare to very rare in sections Grecka and Katakolon and in the basal part of section Kallidhea. Scattered specimens in the other sections.

### **Elphidium aculeatum (d'Orbigny)**

Plate 5, figs. 1a, b

*Polystomella aculeata* d'Orbigny, 1846, For. Foss. Vienne, p. 131, pl. 6, figs. 27, 28.

*Elphidium aculeatum* (d'Orbigny), Cushman, 1929, U.S. Geol. Surv., Prof. Paper, 191, p. 44, pl. 11, figs. 11a, b.

*Occurrence:* Very rare to rare in the sections Kallidhea, Neraida and Pigadion. The species reaches its highest frequencies in sandy deposits in association with frequent to dominant plano-convex species.

*Interpretation:* *E. aculeatum* is apparently a form with a preference for densely vegetated, normal marine environments with a sandy substrate.

### **Elphidium advenum (Cushman)**

Plate 5, figs. 2a, b, 3

*Polystomella advena* Cushman, 1922, Carnegie Inst. Publ., 311, p. 56, pl. 9, figs. 11, 12.

*Elphidium advenum* (Cushman), Hansen and Lykke-Andersen, 1976, Fossils and Strata, 10, p. 6, pl. 2, figs. 10-12, pl. 3, fig. 1.

*Remarks:* *E. advenum* differs from related species in that it has a relatively large number of chambers in the last whorl, hollow retral processes, and a lenticular test with an acute periphery and a smooth wall surface. Our specimens have a variable number of chambers in the last whorl, ranging from 10 in small specimens to 15 in large. The umbilical knobs have strongly varying dimensions, and may be entirely absent.

*Occurrence*: Absent in sections Katakolon, Grecka, Agios Andreas and Grillos; rare to common in the other sections.

*Interpretation*: This species seems to have a preference for both clayey and sandy shallow marine environments with normal marine salinities.

### **Elphidium articulatum** (d'Orbigny)

Plate 5, figs. 4a, b

*Polystomella articulatum* d'Orbigny, 1839, Voy. Amer. Merid., 5, p. 30, pl. 3, figs. 9, 10.

*Elphidium excavatum* Cushman (not Terquem), 1949, Mem. Inst. R. Sc. Nat. Belg., 111, p. 28, pl. 6, fig. 2.

*Cribronionion articulatum* (d'Orbigny), Lutze, 1968, Meyniana, 18, p. 27, pl. 1, figs. 1, 2.

*Occurrence*: Rare in section Kallidhea; scattered occurrences in the other sections.

### **Elphidium crispum** (Linnaeus)

Plate 5, fig. 6a, b

*Nautilus crispus* Linnaeus, 1758, Syst. Nat., Ed. 10, 1, p. 709, pl. 19, figs. a-d.

*Nautilus macellus* Fichtel and Moll, 1798, Test. Micr., p. 66, pl. 10, figs. h-k.

*Elphidium crispum* (Linnaeus), Cushman, 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 50, pl. 13, figs. 17-21.

*Elphidium macellum* (Fichtel and Moll), Cushman, 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 51, pl. 14, figs. 1-3.

*Remarks*: Our specimens show a continuous gradation from lenticular forms with a large umbilical knob corresponding to typical *E. crispum* to individuals with a laterally compressed test without, or with a small umbilical knob, which closely resemble the type of *E. macellum*.

*Occurrence*: Absent in sections Katakolon, Grecka, Agios Andreas and Grillos. In the other sections occasionally very rare both in silty clays and in sands. Frequent in one sample from a silt of section Paleovarvaisena (109 L).

### **Elphidium excavatum** (Terquem)

Plate 6, figs. 1a, b

*Polystomella excavata* Terquem, 1875, Mém. Soc. Dunkerquoise, 19, p. 429, pl. 2, figs. 2a, b.

*Cribronionion excavata* (Terquem), Lévy et al., 1969, Rev. Micropal., 12, p. 93, pl. 1, figs. 4a, b.

*Remarks*: In our material this species is represented by very small individuals with a diameter generally less than 250  $\mu$ .

*Occurrence*: Very rare in silty clayey sediments of sections Lala, Neraida, Agios Andreas, Kaiafas and Pigadion.

*Interpretation*: A shallow water form with a preference for a muddy substrate and some tolerance for slightly hyposaline conditions.

## *Elphidium fichtelianum* (d'Orbigny)

Plate 6, figs. 2a, b

*Polystomella fichteliana* d'Orbigny, 1846, For. Foss. Vienne, p. 125, pl. 6, figs. 7, 8.

*Elphidium fichtelianum* (d'Orbigny), Cushman, 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 42, pl. 11, fig. 12.

*Occurrence*: Very rare to common in associations in which plano-convex forms are common to dominant (sections Kallidhea, Lala and Pigadion).

*Interpretation*: Probably an inhabitant of densely vegetated areas with normal marine salinities.

## *Elphidium granosum* (d'Orbigny)

Plate 6, figs. 3, 4, 5, 6a, b

*Nonionina granosa* d'Orbigny, 1846, For. Foss. Vienne, p. 110, pl. 5, figs. 19, 20.

*Elphidium lidoense* Cushman, 1936, Cush. Lab. For. Res., Contr., 12, p. 86, pl. 15, figs. 6a, b.

*Protelphidium granosum* (d'Orbigny), Brodniewicz, 1972, Acta Paleont. Polonica, 17, 4, p. 484, pl. 11, figs. 4–8, pl. 12, figs. 1–6, pl. 24, figs. 6–8, 11, 12, text. figs. 25–27.

*Remarks*: Our specimens show considerable variation in dimensions, number of chambers in the last whorl, presence of sutural bar-like chamber elongations and the amount of pustulous, glassy material in the umbilical region. Our material shows a continuous gradation from “*lidoense*-like” specimens, with a great number of glassy bosses in the umbilical region, with up to 13 chambers in the last convolution and with some irregular sutural bars (plate 6, figs. 5, 6a, b) to “*granosum*-like” specimens with few chambers (6 to 8), without sutural bars and with little glassy material in the umbilical region (plate 6, fig. 4). *E. granosum* may be related with *E. gunteri* Cole, which is different in having well developed sutural bars.

*Occurrence*: Very rare in sections Grecka and Katakolon; in the other sections an often common faunal element, the distribution of which seems to be independent of the type of sediment. Specimens with a “*lidoense*-like” morphology are mainly found in sandy deposits in association with *Ammonia beccarii beccarii*.

*Interpretation*: A shallow water species with a relatively great tolerance for hyposaline conditions.

## *Elphidium granosum* (d'Orbigny) var. *demens* (Arnold Bik)

Plate 6, figs. 7, 8

*Nonion demens* Arnold Bik, 1964, Notizbl. hess. L.-Amt Bodenforsch., 92, p. 71, pl. 5, figs. 3–6 (non pl. 5, figs. 7, 8).

*Remarks:* This form occurs in one species-restricted assemblage with predominantly *Ammonia beccarii tepida* and *Elphidium granosum*. Because the specimens show affinity with *E. granosum* in their umbilical and sutural features, and in the presence of a coarsely perforate wall, they have tentatively been considered as an aberrant variety of *E. granosum*.

*Occurrence:* This form is abundant in sample 723, Grillos, in a clayey sediment just below a fresh-water limestone. In all other sections it is absent.

*Interpretation:* The presence of this form in a clay just below a freshwater limestone suggests that a strong decrease of salinity was responsible for its aberrant shape. Since the variety is absent in other Vounargon deposits, it seems likely that also other (chemical?) factors may have played a part. Similar conclusions were drawn by Arnold Bik (1964) concerning *Nonion demens* from the *Hydrobia*-beds of the Miocene of the Mayence basin.

### *Elphidium incertum* (Williamson)

Plate 6, figs. 9a, b

*Polystomella umbilicata* var. *incerta* Williamson, 1858, Rec. Foram. G. B., p. 44, pl. 3, fig. 82a.

*Elphidium incertum* (Williamson), Buzas, 1966, Journ. Pal., 40, p. 592, pl. 72, figs. 1-4 (not 5, 6).

*Remarks:* The larger part of our specimens have very poorly developed retral processes or none at all and seem to be identical with the individuals figured by Buzas (pl. 72, figs. 3 and 4). This author, who examined the original material of Williamson, also figured a specimen with distinct retral processes (pl. 72, figs. 5 and 6), which form is absent in our assemblages.

*Occurrence:* Absent in sections Grecka and Katakolon, occasionally common in the upper part of section Lala in associations with frequent plano-convex forms; rare in the other sections.

*Interpretation:* A shallow water species with a preference for vegetated areas.

### *Elphidium minutum* (Reuss)

Plate 6, figs. 10a, b

*Polystomella minuta* Reuss, 1864, Denkschr. K. Akad. Wiss., Wien, 50, p. 478, pl. 4, figs. 6a, b.

*Elphidium minutum* (Reuss), Cushman, 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 40, pl. 10, figs. 23, 24.

*Remarks:* This species shows resemblance to *E. gerthi* Van Voorthuysen which is different in that it has almost parallel sides and a more rounded periphery, and a large umbilical knob.

*Occurrence:* Absent in sections Katakolon, Grecka 305 and Grillos; very rare in section Grecka 300 and the basal part of Kallidhea. Occasionally rare to

common in predominantly clayey deposits of the other sections.

*Interpretation:* Amongst the *Elphidium* species we distinguished, this seems to be the most open marine form, although it has apparently some tolerance for hyposaline conditions.

### *Elphidium pulvereum* Todd

Plate 7, figs. 1a, b

*Elphidium pulvereum* Todd, 1958, Rep. Swed. Deep Sea Exped., 8, p. 201, pl. 1, figs. 19, 20.

*Elphidium margaritaceum* Cushman, Hansen and Lykke-Andersen, 1976, Fossils and Strata, 10, pl. 3, figs. 2–6.

*Remarks:* According to Cushman's original description *Elphidium advena* (Cushman) var. *margaritaceum* Cushman (1930, U.S. Nat. Mus. Bull., 104, 7, p. 25, pl. 10, fig. 3) has a coarsely perforate wall. Because it is not clear whether this observation is correct, or is a misinterpretation of the dense tuberculation of the wall, we prefer to use the species name introduced by Todd.

*Occurrence:* Absent in sections Katakolon, Grecka, Agios Andreas and Grillos; rare in sediments of sections Lala and Pigadion in associations with frequent to abundant plano-convex species. Scattered occurrences in the other sections.

*Interpretation:* Probably a form with a preference for vegetated areas.

### *Elphidium semistriatum* (d'Orbigny)

Plate 7, figs. 2a, b

*Polystomella semistriata* d'Orbigny, 1826, Ann. Sci. Nat., 7, p. 284, nr. 7.

*Polystomella semistriata* d'Orbigny, Fornasini, 1899, Mem. R. Accad. Sci. Inst., Bologna, 5, 7, p. 17 (653), text. fig. 4.

*Elphidium semistriatum* (d'Orbigny), Cushman, 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 48, pl. 12, figs. 21a, b.

*Elphidium articulatum* Cushman (not d'Orbigny), 1939, U.S. Geol. Surv., Prof. Paper, 191, p. 53, pl. 14, figs. 18, 19 (not 17).

*Elphidium lidoense* Cushman var. *camarguensis* Kruit, 1955, Sed. Rhône delta, p. 113, pl. 3, figs. 9a, b.

*Elphidium cuvillieri* Lévy, 1966, Vie et Milieu, 17, p. 5, pl. 1, figs. 6a-c, pl. 2.

*Elphidium excavatum* Cita and Premoli Silva (not Terquem), 1967, Mem. Biogeogr. Adr., 7, pl. 2, fig. 3.

*Cribroelphidium poeyanum* Van Voorthuysen (not d'Orbigny), 1973, Zool. Verh., 123, p. 43, pl. 13, figs. 9a, b.

*Remarks:* Fornasini's figure of d'Orbigny's original material is too poor to allow a reliable comparison with our specimens. Our material, however, seems to be identical with the topotype material of Cushman, 1939. In our assemblages specimens with a low number of chambers in the last convolu-

tion (about 8) appeared to be distinctly more lobulate than individuals with more (about 11) chambers in the last whorl. These lobulate forms seem to be identical with *E. lidoense* Cushman var. *camarguensis* Kruit. Our specimens have hollow retral processes and a basal row of apertural pores. In older chambers additional openings are present, probably due to resorption. For this reason specimens with their last chamber broken off may be mistaken for *E. poeyanum* (d'Orbigny) which resembles *E. semistriatum*, but which is different in that it has areal apertures.

*Occurrence*: Practically absent in sections Katakolon, Grecka and Grillos; frequent to abundant in section Kaiafas; rare to common especially in individual samples from silty clayey sediments of the other sections.

*Interpretation*: Apparently a shallow water species with a preference for muddy environments with normal marine salinities, but also with some tolerance for slightly hyposaline conditions.

### *Elphidium semistriatum* (d'Orbigny) var. *minimum* (Seguenza)

Plate 7, figs. 3a, b

*Polystomella minima* Seguenza, 1880, R. Accad. Lincei Atti, 3, p. 333, pl. 17, figs. 38, 38a.

*Elphidium* cf. *Elphidium minimum* (Seguenza), Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 271, pl. 4, figs. 8, 9.

*Remarks*: *E. semistriatum* specimens with a biconvex test, a periphery tending to subacute, and relatively little depressed sutures, have been counted separately as *E. semistriatum* (d'Orbigny) var. *minimum* (Seguenza). This form resembles *E. gunteri* (Cole) and *E. discoidale* (d'Orbigny), but has no umbilical knob and the shape of the test is different.

*Occurrence*: Absent in sections Katakolon, Grecka and Grillos; frequent in section Agios Andreas; in the other sections rare to common, especially in silty clays.

*Interpretation*: A shallow water species with a preference of environments with a muddy substrate and salinities varying from normal marine to slightly hyposaline.

### *Fursenkoina schreibersiana* (Czjzek)

Plate 7, fig. 4

*Virgulina schreibersiana* Czjzek, 1848, Haidinger's Nat. Abh., 2, p. 11, pl. 13, figs. 18–21.

*Fursenkoina schreibersiana* (Czjzek), Murray, 1971, Atlas Brit. Rec. For., p. 185, pl. 77, figs. 6–9.

*Occurrence*: Absent in sections Katakolon and Grillos, very rare in scattered samples of sections Grecka, Agios Andreas and Pigadion. In the other sec-

tions frequent in many samples from clayey deposits, in association with *Ammonia perlucida*. Common in the basal part of section Kallidhea.

*Interpretation*: A shallow marine mud-dweller, which is able to stand some salinity decrease. Although it occurs often in associations with *Ammonia perlucida*, its tolerance for salinity deviations is distinctly lower than that of the *Ammonia* species.

### **Hanzawaia rhodiensis** (Terquem)

Plate 7, figs. 5a-c

*Truncatulina rhodiensis* Terquem, 1878, Mem. Soc. Géol. France, 3, 1, p. 21, pl. 1, fig. 26.

*Hanzawaia rhodiensis* (Terquem), Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 267, pl. 3, figs. 21-23.

*Occurrence*: Very rare to rare in sections Grecka and Katakolon, frequent in sample 301 M (Kallidhea), scattered occurrences in the other sections.

*Interpretation*: This species seems to have a preference for normal marine environments with a muddy substrate. Its absence in many associations that have other plano-convex species suggests that it is not a typical inhabitant of shallow marine, vegetated areas, although it may have an attached mode of life.

### **Melonis pompilioides** (Fichtel and Moll)

Plate 7, figs. 6a, b

*Nautilus pompilioides* Fichtel and Moll, 1798, Test. Micr., p. 31, pl. 2, figs. a-c.

not *Melonis pompilioides* (Fichtel and Moll), Frerichs, 1969, Contr. Geol., Univ. Wyoming, 8, p. 43, pl. 1, figs. 2, 3.

*Melonis pompilioides* (Fichtel and Moll), Murray, 1971, Atlas Brit. Rec. For., p. 199, pl. 84, figs. 1-7.

*Remarks*: The coarsely perforate, deep-water form, described as *M. pompilioides*, especially in the American literature (e.g. Frerichs, 1969), is almost certainly a species different from the form of Fichtel and Moll. The latter authors described *M. pompilioides* from Tertiary deposits near Siena, from an assemblage in which *Lenticulina* spp., *Planularia* spp., a plano-convex form and *Cancris auricula* are the accompanying faunal elements. This association points to deposition on a shelf, rather than to bathyal or abyssal environments.

*Occurrence*: Rare in the Grecka sections. Scattered occurrences in the other sections.

*Interpretation*: Probably an open marine species.

## Nonion boueanum (d'Orbigny)

Plate 7, figs. 7a, b

*Nonionina boueana* d'Orbigny, 1846, For. Foss. Vienne, p. 108, pl. 5, figs. 11, 12.

*Nonion boueanum* (d'Orbigny), Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 44, pl. 11, figs. 16a, b.

*Remarks:* This species shows variation in size, number of chambers in the last whorl, the degree in which the chambers increase in size as they are added, the degree of angularity of the periphery and the amount of granular material in the umbilical region. Specimens with a laterally compressed test and little or no granular material in the umbilical region resemble *Nonion scaphum* (Fichtel and Moll). This species has often been described as *Florilus asterizans*, which is also the genotype of *Florilus*. However, after the examination of the holotype of *Nautilus asterizans* Fichtel and Moll, by Hansen and Rögl, it is apparent that this specimen has to be assigned to *Hanzawaia* (pers. comm. F. Rögl).

*Occurrence:* Very rare to absent in sections Katakolon, Grecka, Grillos and Pigadion. Common in sections Lala, Agios Andreas and Kaiafas. Common to abundant in sections Kallidhea, Vounargon, Paleovarvaisena and Neraida.

*Interpretation:* A shallow water species with a preference for environments with relatively good connections with open marine waters and fairly normal marine salinities, although it can stand some salinity decrease.

## Nonion depressulum (Walker and Jacob)

Plate 7, figs. 8a, b

*Nautilus depressulus* Walker and Jacob, 1798, Kanmacher, p. 641, pl. 33.

*Nonion depressulus* (Walker and Jacob), Murray, 1965, Cush. Found. For. Res., Contr., 16, p. 148, pl. 25, figs. 6, 7, pl. 26, fig. 8.

*Occurrence:* Absent in sections Grecka, Katakolon, Lala and Grillos. Locally rare in clayey deposits of the other sections. Often found in association with *Ammonia beccarii tepida*, *A. perlucida*, *Fursenkoina schreibersiana* and *Reussella spinulosa*.

*Interpretation:* A shallow water species with a preference for a muddy substrate and salinities ranging from normal to slightly hyposaline.

## Nonion paraliium Tintant

Plate 7, figs. 9a, b

*Nonion paraliium* Tintant, 1954, Bull. Sci. Bourgogne, 14, p. 188, text. fig. 1, pl. 2, fig. 1.

*Nonion* cf. *depressulum* (Walker and Jacob), Kruit, 1955, Sed. Rhône delta, p. 112, pl. 2, fig. 6.

*Protelphidium anglicum* Murray, 1965, Cush. Found. For. Res., Contr., 16, p. 149, pl. 25, figs. 1–5, pl. 26, figs. 1–6.

*Remarks:* This species has often been confused with *Nonion depressulum* (Walker and Jacob), from which it differs in its wall characteristics; in polarized light it has a "radial" instead of a "granular" extinction pattern. Furthermore the wall is more hyaline, the test is laterally compressed, the sutures are limbate in the earlier part of the test, and the chamber arrangement is irregularly planispiral. Under the light microscope the umbilical side of *Ammonia perlucida* (Heron-Allen and Earland) resembles the spiral side of *N. paraliium*.

*Occurrence:* In both sands and silty clays of the sections Kallidhea and Pigadion this species is a rare to common constituent in *Ammonia beccarii*-dominated associations.

*Interpretation:* *N. paraliium* apparently is a species with a preference for somewhat hyposaline environments.

### *Nonionella* sp.

Plate 8, figs. 1a, b

*Description:* Test distinctly longer than broad, trochoid; ventral side completely involute; test laterally compressed; periphery broadly rounded; chambers slightly inflated, about 10 in the last formed convolution, increasing gradually in length and width; sutures distinct, slightly depressed and limbate; wall finely perforate; aperture a slit at the base of the apertural face.

*Remarks:* This form resembles *Nonionella limbato-striata* Cushman, 1931, (Cush. Lab. For. Res., Contr., 7, p. 30, pl. 4, figs. 4a-c), which has a much more compressed test and sutures which are not depressed.

*Occurrence:* Very rare in most sections; common in some of the silty clayey deposits of section Paleovarvaisena.

### *Oridorsalis stellatus* (Silvestri)

Plate 8, figs. 2a-c

*Truncatulina tenera?* Brady var. *stellata* Silvestri, 1878, Acc. Pont. Nuovi Lincei, Mem., 15, p. 297, pl. 6, figs. 9a-c.

*Oridorsalis stellatus* (Silvestri), Brolsma, 1978, Utr. Micropal. Bull., 18, pl. 3, fig. 2.

*Occurrence:* Rare to common in section Katakolon, locally frequent in the Grecka sections.

*Interpretation:* An open marine mud-dweller.

## *Planorbulina mediterraneensis* d'Orbigny

Plate 8, fig. 3

*Planorbulina mediterraneensis* d'Orbigny, 1826, Ann. Sci. Nat., 1, p. 280, pl. 14, figs. 4–6.

*Planorbulina mediterraneensis* d'Orbigny, Von Daniels, 1970, Göttinger Arb. Geol. Pal., 8, p. 89, pl. 8, fig. 4.

*Occurrence*: Scattered in most sections. Frequent in section Pigadion in assemblages dominated by other plano-convex species and miliolids.

*Interpretation*: A shallow water form, with an attached mode of life and a preference for normal marine salinities.

## *Pseudopolymorphina incerta* (Egger)

Plate 8, fig. 4

*Polymorphina incerta* Egger, 1857, Neues Jahrb. Min., p. 286, pl. 13, figs. 19–21.

*Pseudopolymorphina incerta* (Egger), Cushman and Ozawa, 1930, U.S. Nat. Mus., Proc., 77, p. 110, pl. 29, figs. 3–5.

*Remarks*: Some of our specimens are atypical in that they become uniserial in their final ontogenetic stage.

*Occurrence*: Predominantly in sandy deposits of the sections; very rare to rare in associations with *Ammonia beccarii beccarii* and plano-convex species.

*Interpretation*: Apparently a species with a preference for shallow, high energy environments with normal salinities.

## *Quinqueloculina aspera* d'Orbigny

Plate 8, figs. 5a, b

*Quinqueloculina aspera* d'Orbigny, 1826, Ann. Sci. Nat., 1, 7, p. 301.

*Quinqueloculina aspera* d'Orbigny, Fornasini, 1905, Acc. Sci. Bologna, 6, 2, pl. 3, figs. 1a-c.

non *Quinqueloculina aspera* d'Orbigny, Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., 35, p. 168, pl. 9, figs. 101, 102.

*Remarks*: Le Calvez and Le Calvez (1958) found in the collection of d'Orbigny a specimen which they considered to be the holotype of *Q. aspera*, but which is distinctly different from the form figured by Fornasini (1905), because of the absence of a neck and the presence of a simple tooth instead of a bifid one.

*Occurrence*: In section Vounargon common in a mollusc-bearing interval with abundant miliolids. In the other sections irregularly present in low frequencies.

## Quinqueloculina bradyana Cushman

Plate 8, figs. 6a, b

*Miliolina undosa* Brady (not Karrer), 1884, Challenger Rept., 9, p. 176, pl. 6, fig. 8.

*Quinqueloculina bradyana* Cushman, 1929, U.S. Nat. Mus., Bull., 104, 6, p. 23, pl. 1, figs. 3a-c.

*Quinqueloculina bradyana* Cushman, Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., 35, p. 172, pl. 11, figs. 129, 130.

**Occurrence:** Common in a mollusc bed of section Pigadion (sample 703 S) in an association dominated by plano-convex species and miliolids.

## Quinqueloculina duthiersi (Schlumberger)

Plate 8, fig. 7a, b

*Adelosina duthiersi* Schlumberger, 1886, Soc. Zool. Fr., 11, p. 100, pl. 16, figs. 16–18.

*Miliolina pulchella* Brady (not d'Orbigny), 1884, Challenger Rept., 9, p. 174, pl. 6, figs. 13, 14.

*Quinqueloculina duthiersi* (Schlumberger), Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., 35, p. 175, pl. 3, fig. 11.

**Remarks:** This species has often been confused with *Q. pulchella* d'Orbigny but unlike the latter it has a bifid tooth instead of a simple one.

**Occurrence:** Very rare in sections Grecka and Pigadion.

## Quinqueloculina elegans d'Orbigny

Plate 8, figs. 8a, b

*Quinqueloculina elegans* d'Orbigny, 1826, Ann. Sci. Nat., 1, 7, p. 135.

*Quinqueloculina elegans* d'Orbigny, Terquem, 1878, Soc. Geol. France, 3, p. 64, pl. 6, figs. 7–9.

*Quinqueloculina elegans* d'Orbigny, Fornasini, 1902, Mem. R. Accad. Sci. Inst. Bologna, 5, 10, p. 24, pl. 19.

**Occurrence:** Locally rare to common in associations dominated by plano-convex forms and miliolids in the sections Lala and Pigadion.

**Interpretation:** Probably a form with a preference for densely vegetated areas with normal marine salinities.

## Quinqueloculina elegans d'Orbigny var. A.

Plate 8, figs. 9a, b

**Remarks:** This form differs from *Q. elegans* in the complete absence of ornamentation.

**Occurrence:** Rare in silty clayey deposits of section Lala in associations dominated by miliolids and plano-convex forms.

**Interpretation:** This form is apparently an inhabitant of vegetated areas with a clayey substrate.

**Quinqueloculina excavata** Karrer

Plate 9, figs. 1a, b

*Quinqueloculina excavata* Karrer, 1868, Denkschr. K. Akad. Wiss., Wien, 58, p. 148, pl. 2, fig. 9.

**Occurrence:** Very rare to rare in silty clays of the sections Neraida, Paleovarvaisena and Lala.

**Interpretation:** A shallow, normal marine mud-dweller.

**Quinqueloculina jugosa** (Cushman)

Plate 9, figs. 2a, b

*Quinqueloculina seminula* (Linnaeus) var. *jugosa* Cushman, 1944, Cushm. Lab. For. Res., Spec. Publ., 12, p. 13, pl. 2, fig. 14.

*Quinqueloculina seminulum* (Linnaeus) var. *jugosa* Cushman, Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., 35, p. 178, pl. 4, figs. 20, 21.

**Occurrence:** In silty clayey sediments of sampling interval 2 G-I (Lala), rare to frequent. In the other sections practically absent.

**Interpretation:** A form with a preference for a muddy, vegetated environment and a tolerance or even preference for hypersalinity.

**Quinqueloculina longirostra** d'Orbigny

Plate 9, figs. 3a, b, 4a, b

*Quinqueloculina longirostra* d'Orbigny, 1826, Ann. Sci. Nat., Paris, 1, 7, p. 303.

*Quinqueloculina longirostra* d'Orbigny, Von Daniels, 1970, Göttinger Arb. Geol. Pal., 8, p. 73, pl. 2, fig. 15.

**Occurrence:** Frequent in a silty clay of section Lala (sample 2 I). In some of the other sections occasionally rare in clayey sediments.

**Interpretation:** A shallow marine mud-dweller with a tolerance or even preference for hypersaline conditions.

**Quinqueloculina seminula** (Linnaeus)

Plate 9, figs. 5a, b

*Serpula seminulum* Linnaeus, 1767, Syst. Nat., Ed. 12, p. 786.

*Quinqueloculina seminulum* (Linnaeus), Loeblich and Tappan, 1964, Treat. Invert. Pal., C, 2, p. 458, pl. 349, figs. 1a-c.

*Quinqueloculina seminulum* (Linnaeus), Von Daniels, 1970, Göttinger Arb. Geol. Pal., 8, p. 75, pl. 3, fig. 4.

**Remarks:** Because of the wide variety of forms included in *Q. seminula* by various authors, the inadequate description and figures, and the loss of the original type, Loeblich and Tappan (1964) designated a neotype. The tooth

of this type specimen has a somewhat aberrant shape, but it probably represents a broken-off bifid tooth. Therefore, although some doubt remains concerning the tooth-shape of this species, only specimens with a bifid tooth have been assigned to *Q. seminula*.

*Occurrence*: Very rare to rare in almost all sections; occurring especially in silty clays.

*Interpretation*: A mud-dweller to be found both in open, normal marine environments and in somewhat restricted, slightly hyposaline environments.

### *Quinqueloculina ungeriana* d'Orbigny

Plate 9, figs. 6a, b

*Quinqueloculina ungeriana* d'Orbigny, 1846, For. Foss. Vienne, p. 291, pl. 18, figs. 22–24.

*Quinqueloculina ungeriana* d'Orbigny, Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., p. 185, pl. 13, figs. 155–157.

*Occurrence*: Very rare in section Katakolon and in the basal part of section Kallidhea. Scattered in section Neraida.

*Interpretation*: A mud-dweller with a preference for normal open marine environments.

### *Quinqueloculina vulgaris* d'Orbigny

Plate 9, figs. 7a, b

*Quinqueloculina vulgaris* d'Orbigny, 1826, Ann. Sci. Nat. 1, 7, p. 302.

*Quinqueloculina vulgaris* d'Orbigny, Fornasini, 1902, Mem. R. Accad. Sci. Bologna, 5, 10, p. 23, pl. 13.

*Quinqueloculina vulgaris* d'Orbigny, Von Daniels, 1970, Göttinger Arb. Geol. Pal., 8, p. 75, pl. 3, fig. 7.

*Occurrence*: Absent in sections Katakolon, Grecka and Grillos. Especially in the silty clays of the other sections occasionally very rare to rare.

*Interpretation*: Probably a shallow water species with a preference for muddy environments with normal marine salinities.

### *Reussella spinulosa* (Reuss)

Plate 9, fig. 8

*Verneuilina spinulosa* Reuss, 1850, Denkschr. K. Akad. Wiss., Wien, 1, p. 374, pl. 47, fig. 12.

*Reussella spinulosa* (Reuss), Loeblich and Tappan, 1964, Treat. Invert. Pal., C, 2, p. 563, pl. 445, figs. 3–5.

*Remarks*: Some of our specimens with poorly developed spines resemble *R. spinulosa* var. *laevigata* Cushman, 1945. Included in our countings were also individuals with robust spines and a somewhat twisted test, which show

an affinity with *R. checchia-rispolii* Kicinski, 1952.

*Occurrence*: Very rare to rare in sections Grecka and Katakolon and in the basal part of section Kallidhea. Locally common in sections Vounargon, Kaiafas and the upper part of section Kallidhea. Very rare to rare in the other sections.

*Interpretation*: A shallow water species with a slight preference for environments with a silty clayey substrate. Its tolerance for hyposaline conditions seems to be somewhat higher than that of *Fursenkoina schreibersiana* and somewhat lower than that of *Ammonia perlucida*.

### *Rosalina globularis* d'Orbigny

Plate 9, figs. 9a, b

*Rosalina globularis* d'Orbigny, 1826, Ann. Sci. Nat., 1, 7, p. 271, pl. 13, figs. 1–4.

*Rosalina globularis* d'Orbigny, Murray, 1971, Atlas Brit. Rec. For., p. 135, pl. 56, figs. 1–6.

*Occurrence*: Common to frequent in section Pigadion in assemblages with miliolids and other plano-convex species. Absent in sections Grillos and Agios Andreas, occasionally very rare in the other sections.

*Interpretation*: An attached living form with a preference for normal marine salinities.

### *Sphaeroidina bulloides* d'Orbigny

Plate 10, figs. 1a, b

*Sphaeroidina bulloides* d'Orbigny, 1826, Ann. Sci. Nat., 1, 7, p. 267.

*Sphaeroidina bulloides* d'Orbigny, Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 77, pl. 10, fig. 1.

*Occurrence*: Common in section Katakolon, very rare in the Grecka sections.

*Interpretation*: A stenohaline, open marine mud-dweller.

### *Textularia agglutinans* d'Orbigny

Plate 10, figs. 2a, b

*Textularia agglutinans* d'Orbigny, 1839, Foram. Cuba, p. 136, pl. 1, figs. 17, 18, 32–34.

*Textularia agglutinans* d'Orbigny, Von Daniels, 1970, Göttinger Arb. Geol. Pal., p. 69, pl. 2, figs. 1, 2.

*Remarks*: In our countings this specific name was used for a large, variable group of *Textularia* specimens in which there is continuous gradation from specimens with almost parallel sides to others which are distinctly conical. The characteristics for this species are considered to be the laterally compressed test with straight sutures, the rounded periphery and the slightly inflated chambers. The wall is made up exclusively of calcareous grains.

*Occurrence*: Present especially in silty clayey sediments of all sections.

Occasionally common to frequent in single samples of sections Lala, Neraida, and Pigadion. In section Agios Andreas rare to frequent.

*Interpretation*: A mud-dweller probably with a tolerance for slightly hypersaline conditions. The occasionally strongly fluctuating frequencies of this species are not fully understood, but they may be connected with pH deviations near the substrate during the sedimentation.

### ***Textularia silvestrii* nov. nom.**

Plate 10, figs. 3a, b

*Textularia concava* (Karrer) var. *jugosa* Silvestri, 1920, Dim. Text. conc. K., p. 222, figs. 1, 2.

*Textularia concava* (Karrer) var. *jugosa* Silvestri, Longinelli, 1956, Paleontogr. Ital., nov. ser., 19, p. 4, pl. 1, figs. 10, 11.

*Remarks*: This species cannot be considered as a variety of *Siphotextularia concava* (Karrer), which belongs to a different genus than Silvestri's form, because of the presence of a short apertural neck. The name *Textularia jugosa* was already used by Brady (1884) for a different species.

The grain-size of the agglutinated particles ranges from silt to sand. In individuals with a wall containing very coarse particles, the specific features may become indistinct.

*Occurrence*: Locally very rare in the sections Katakolon, Grecka, Neraida and Kaiafas.

*Interpretation*: Probably a stenohaline mud-dweller.

### ***Triloculina trigonula* (Lamarck)**

Plate 10, figs. 4a, b

*Miliolites trigonula* Lamarck, 1804, Ann. Mus. Hist. Nat., 5, p. 351; 1807, *ibid.*, 9, pl. 17, fig. 7.

*Triloculina trigonula* (Lamarck), Le Calvez and Le Calvez, 1958, Ann. Inst. Oceanogr., 35, p. 190, pl. 6, figs. 49, 50.

*Occurrence*: Rare in sections Lala and Pigadion in assemblages dominated by plano-convex species and miliolids.

*Interpretation*: A species with a preference for normal saline, vegetated areas.

### ***Uvigerina peregrina* Cushman**

Plate 10, fig. 5

*Uvigerina peregrina* Cushman, 1923, U.S. Nat. Mus., Bull. 104, p. 166, pl. 42, figs. 7–10.

*Uvigerina peregrina* Cushman, Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 263, pl. 2, figs. 37, 38.

*Occurrence*: Common in section Katakolon and in the upper part of section Grecka 300.

*Interpretation*: An open marine mud-dweller.

**Valvulineria complanata (d'Orbigny)**

Plate 10, figs. 6a-c

*Rosalina complanata* d'Orbigny, 1846, For. Foss. Vienne, p. 175, pl. 10, figs. 13–15.

*Discorbina bradyana* Fornasini, 1900, Mem. R. Accad. Sci. Ist. Bologna, 5, 8, p. 393, text. fig. 43.

*Valvulineria complanata* (d'Orbigny), Parker, 1958, Rep. Swed. Deep Sea Exped., 8, p. 268, pl. 3, figs. 42–44.

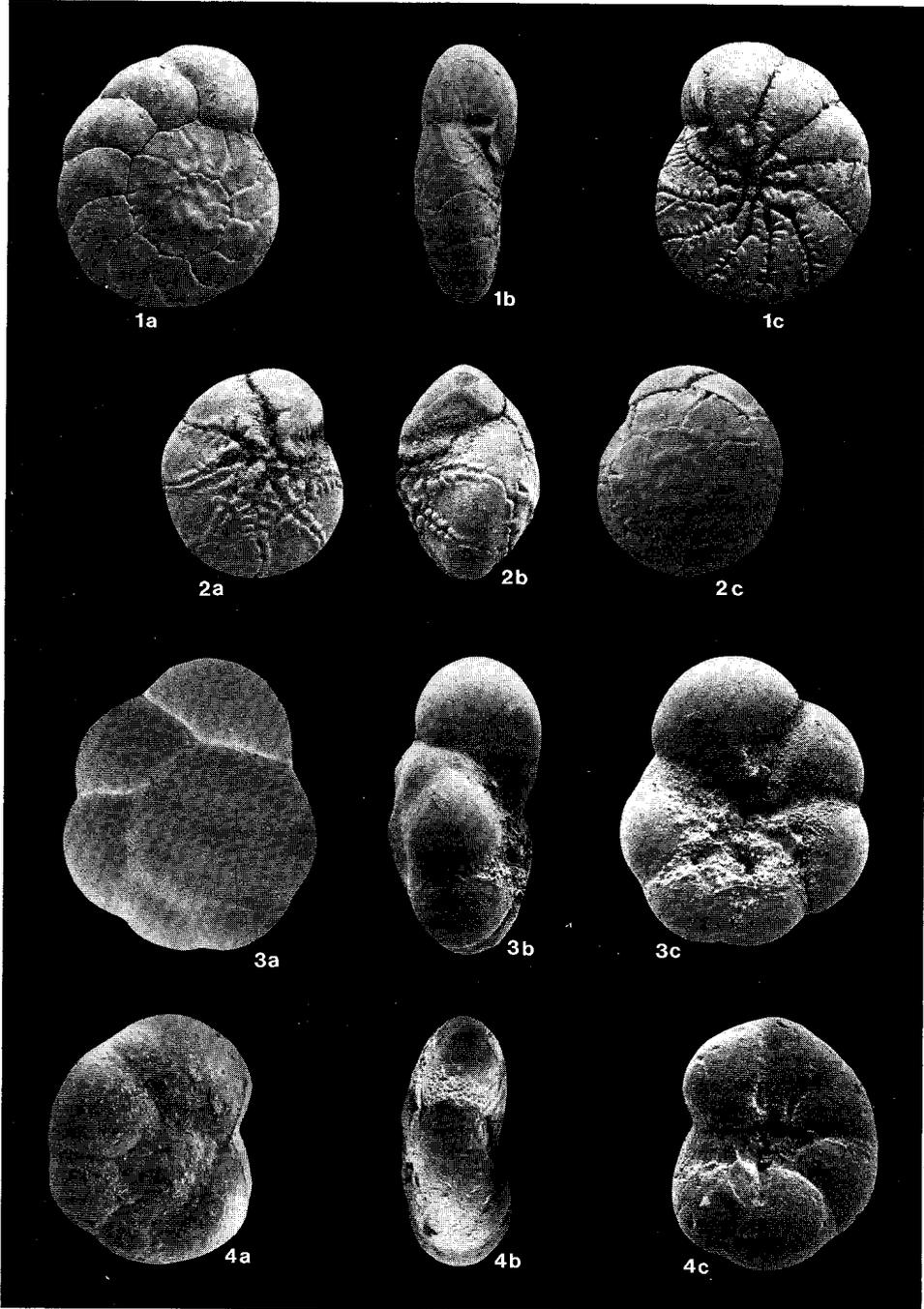
*Remarks*: Recent Mediterranean specimens have often been assigned to *V. bradyana* (Fornasini). We agree with Parker (1958) that this species is probably a junior synonym of *V. complanata* (d'Orbigny) from the Miocene of Austria.

*Occurrence*: In the basal part of section Kallidhea and the basal part of section Vounargon, common; in the Grecka sections common to rare; in sections Katakolon and Neraida, rare; scattered in the other sections.

*Interpretation*: A mud-dweller with a preference for shallow marine environments with normal salinities and relatively good connections with open marine waters.

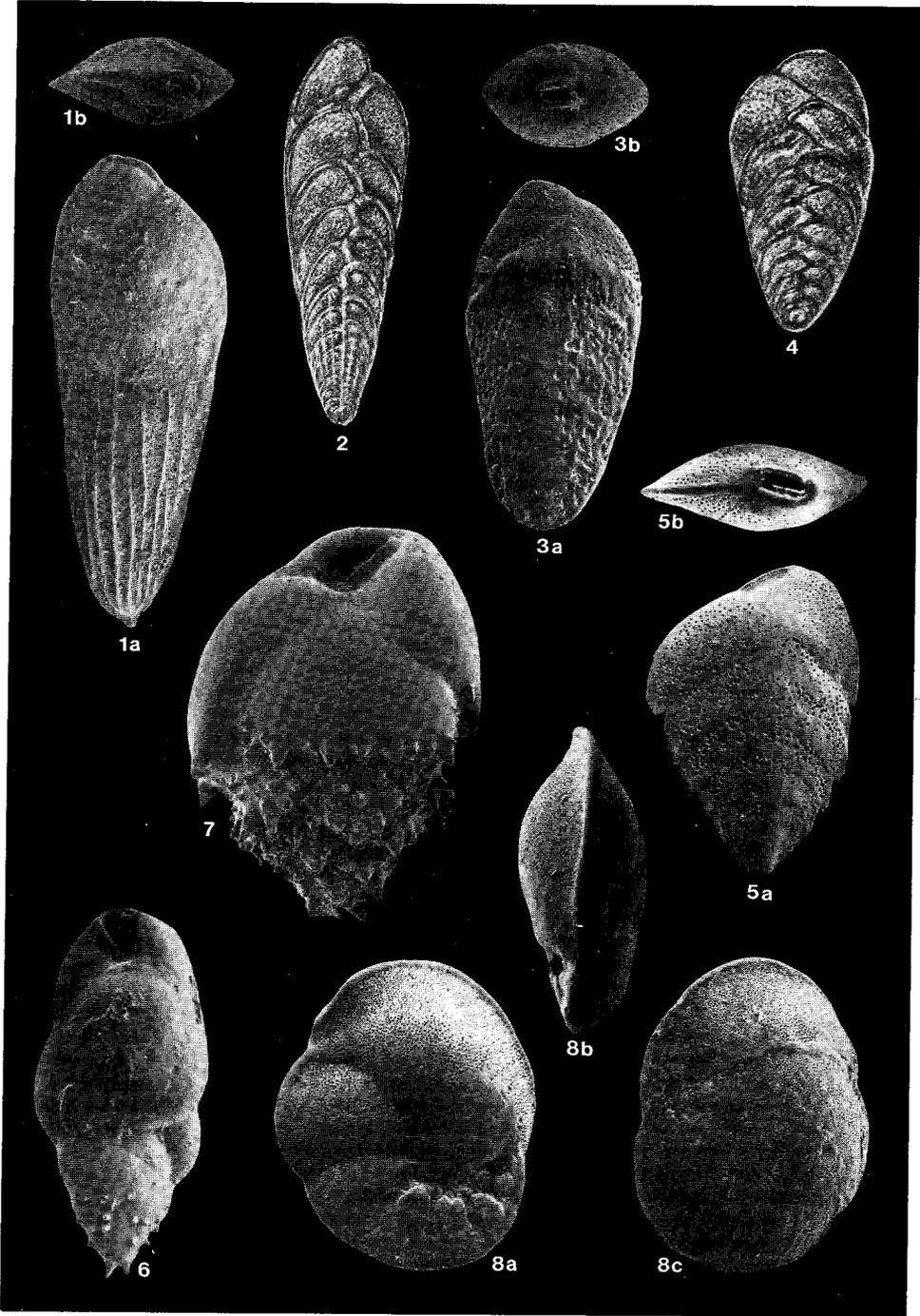
## Plate 1

- Figs. 1a-c      *Ammonia beccarii* (Linnaeus) var. *beccarii* (Linnaeus), sample 2 A, × 50.  
Figs. 2a-c      *Ammonia beccarii* (Linnaeus) var. *inflata* (Seguenza), sample 703 T, × 50.  
Figs. 3a-c      *Ammonia beccarii* (Linnaeus) var. *tepida* (Cushman), sample 703 C, × 200.  
Figs. 4a-c      *Ammonia perlucida* (Heron-Allen and Earland), sample 313 F, × 200.



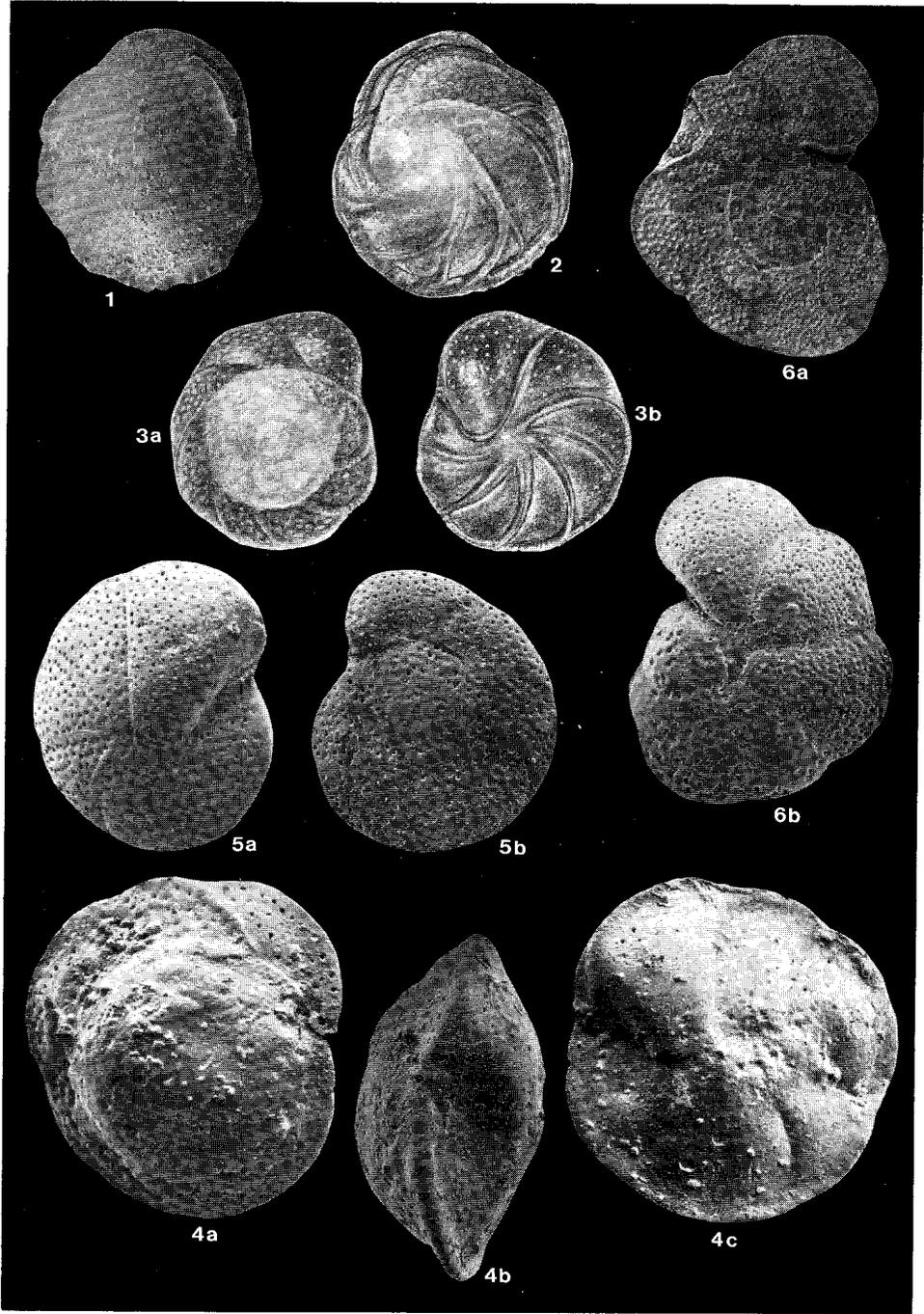
## Plate 2

- Figs. 1a, b      *Brizalina aenariensis* Costa, sample 305 A, X 200.  
Fig. 2            *Brizalina aenariensis* Costa, sample 305 A, X 160.  
Figs. 3a, b      *Brizalina dilatata* (Reuss), sample 315 B, X 200.  
Fig. 4            *Brizalina dilatata* (Reuss), sample 315 B, X 160.  
Figs. 5a, b      *Brizalina spathulata* (Williamson), sample 305 A, X 200.  
Fig. 6            *Bulimina elongata* d'Orbigny subsp. *subulata* Cushman and Parker, sample 305 A,  
                         X 250.  
Fig. 7            *Bulimina marginata* d'Orbigny, sample 315 B, X 200.  
Figs. 8a-c       *Cancris auricula* (Fichtel and Moll), sample 310 G, X 125.



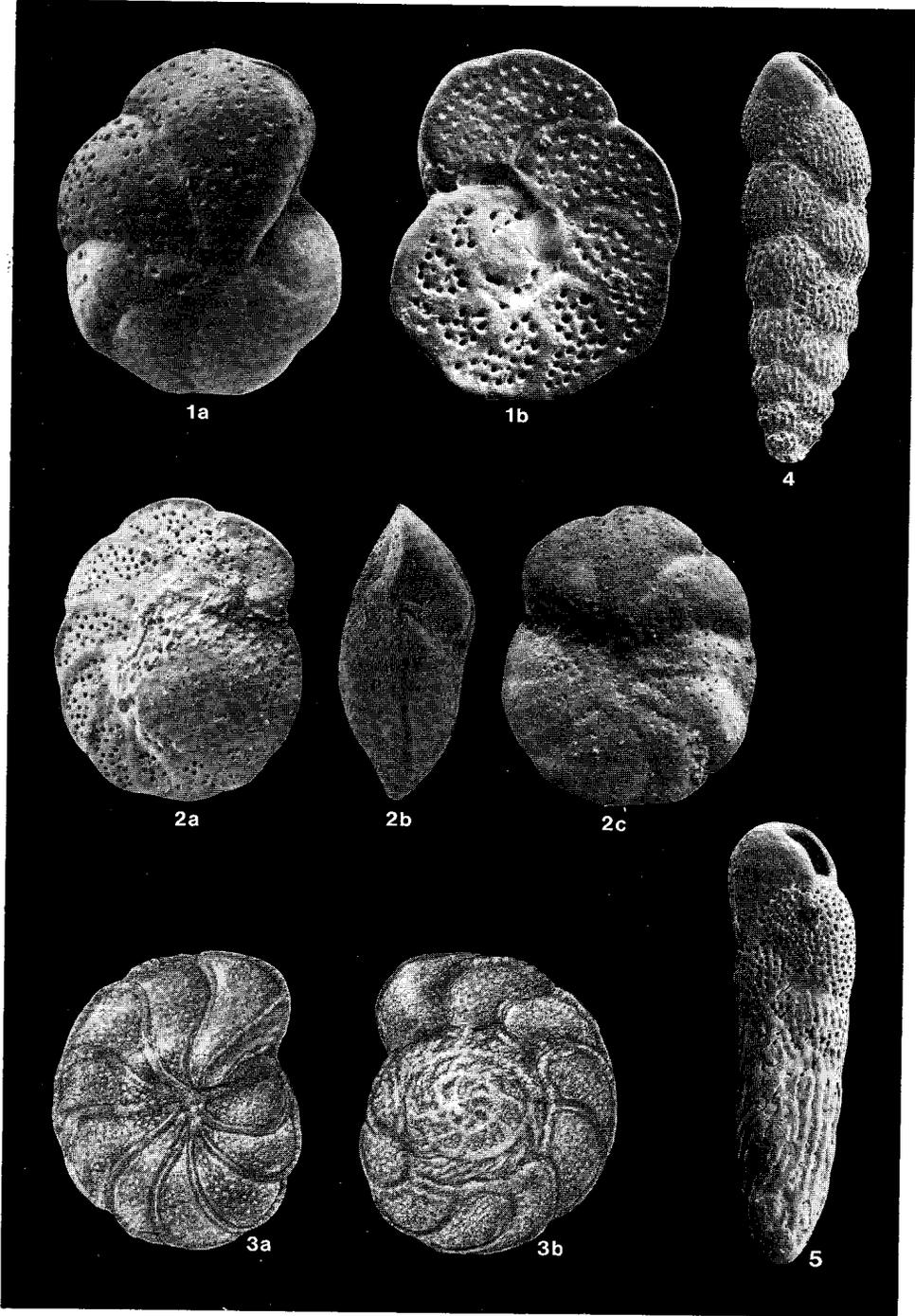
### Plate 3

- Fig. 1            *Cassidulina carinata* Silvestri, sample 315 C, X 200.  
Fig. 2            *Cassidulina carinata* Silvestri, sample 315 C, X 200.  
Figs. 3a, b        *Cibicides burdigalensis* Colom, sample 315 C, X 175.  
Figs. 4a-c        *Cibicides burdigalensis* Colom, sample 315 C, X 225.  
Figs. 5a, b        *Cibicides dutemplei* (d'Orbigny), sample 313 B, X 115.  
Figs. 6a, b        *Cibicides lobatulus* (Walker and Jacob) var. 1, sample 2 G, X 80.



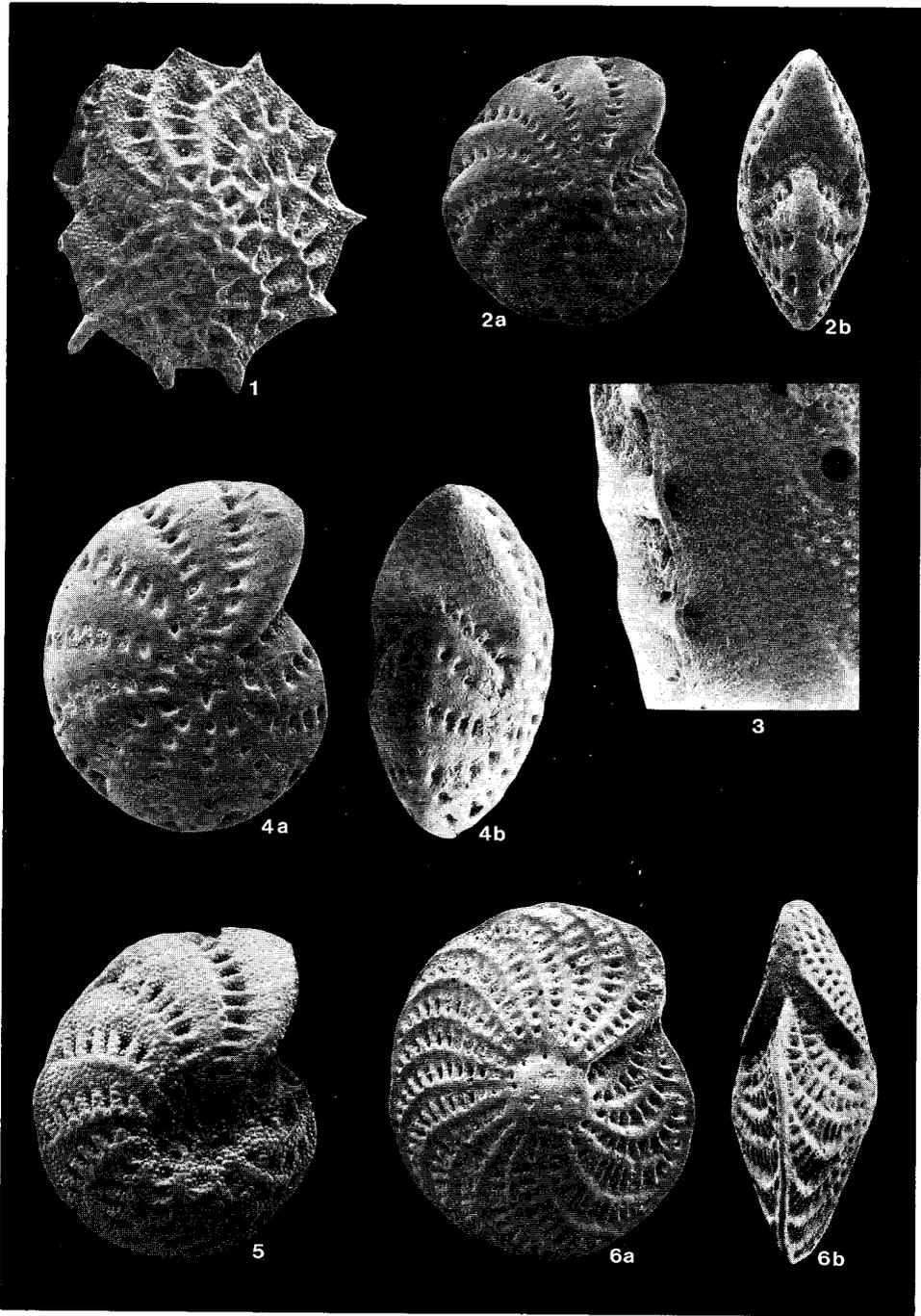
## Plate 4

- Figs. 1a, b      *Cibicides lobatulus* (Walker and Jacob) var. 2, sample 313 A, × 200.  
Figs. 2a-c      *Cibicides ungerianus* (d'Orbigny), sample 315 C, × 125.  
Figs. 3a, b      *Cibicides ungerianus* (d'Orbigny), sample 315 C, × 100.  
Fig. 4            *Coryphostoma silvestrina* (Cushman), sample 700 T, × 150.  
Fig. 5            *Coryphostoma* sp., sample 700 T, × 150.



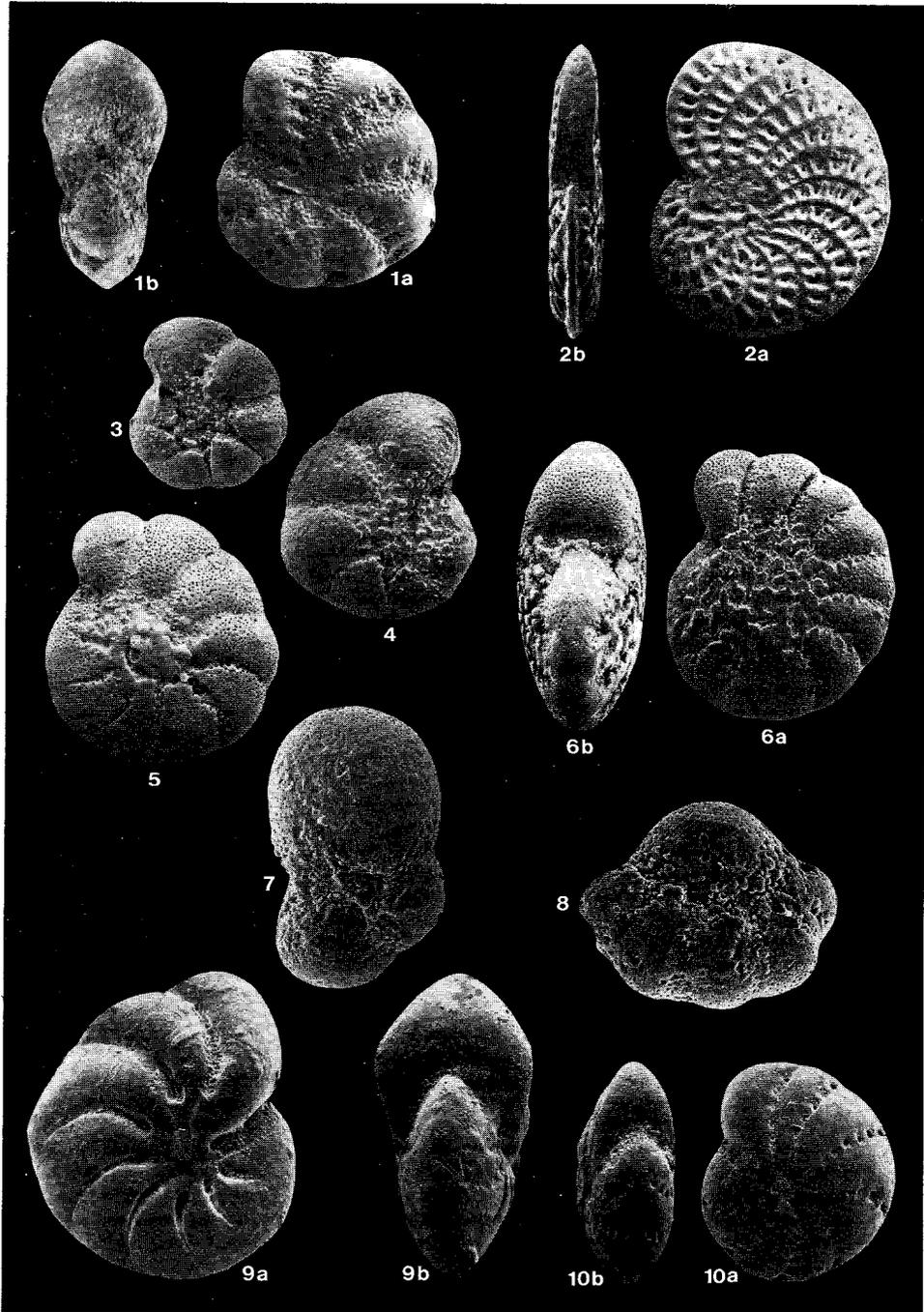
## Plate 5

- Fig. 1 *Elphidium aculeatum* (d'Orbigny), sample 703 X, × 200.
- Figs. 2a, b *Elphidium advenum* (Cushman), sample 301 Q, × 100.
- Fig. 3 *Elphidium advenum* (Cushman); detail of a hollow sutural bridge, sample 301 Q, × 500.
- Figs. 4a, b *Elphidium articulatum* (d'Orbigny), sample 310 M, × 200.
- Fig. 5 *Elphidium complanatum* (d'Orbigny) subsp. *tyrrhenianum* Accordi, sample 703 T, × 125.
- Figs. 6a, b *Elphidium crispum* (Linnaeus), sample 310 K, × 100.



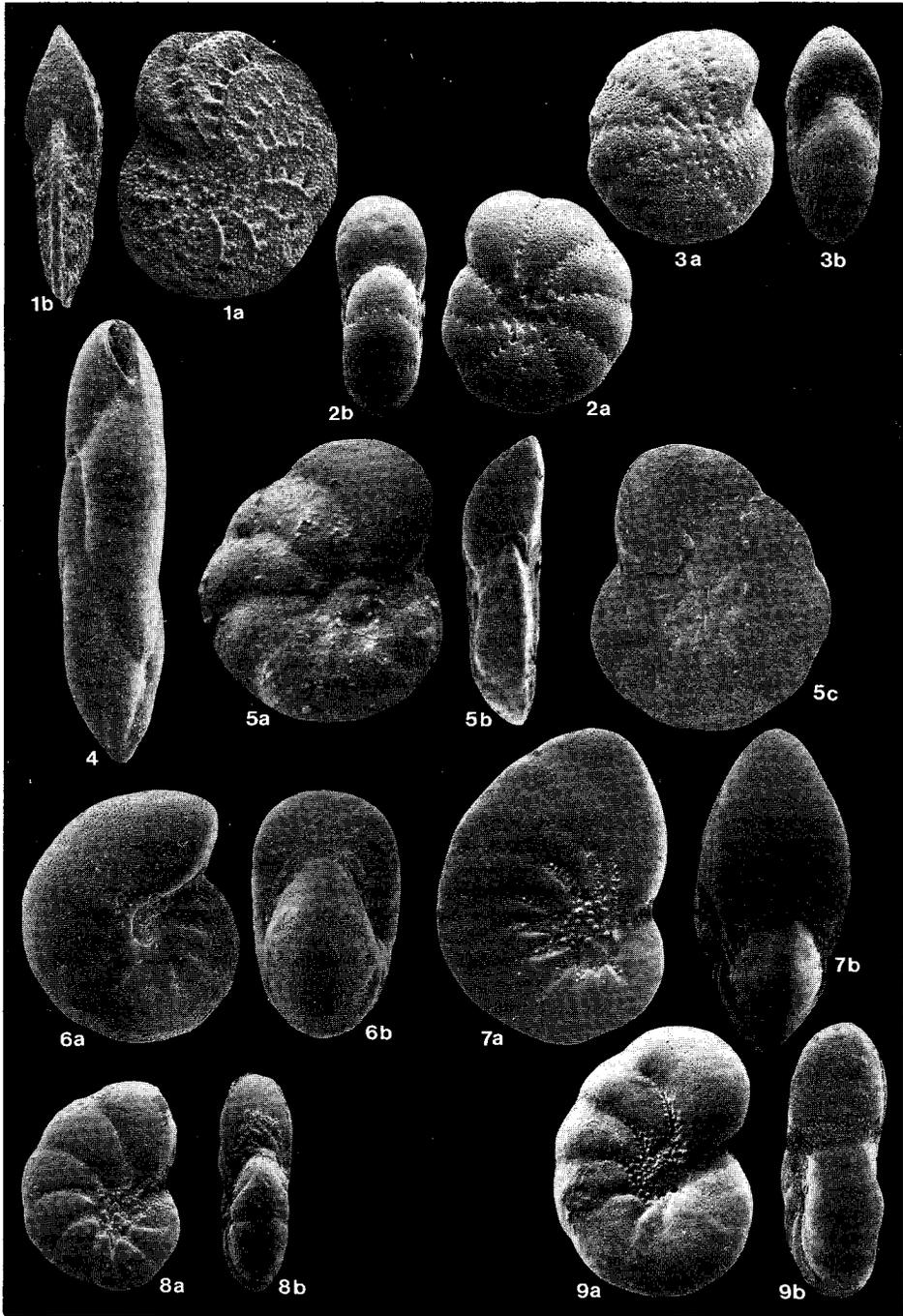
## Plate 6

- Figs. 1a, b      *Elphidium excavatum* (Terquem), sample 310 B, × 200.  
Figs. 2a, b      *Elphidium fichtelianum* (d'Orbigny), sample 301 M, × 100.  
Fig. 3            *Elphidium granosum* (d'Orbigny), juvenile specimen, sample 2 C, × 200.  
Fig. 4            *Elphidium granosum* (d'Orbigny), "Nonion granosum"-type, sample 2 C, × 200.  
Fig. 5            *Elphidium granosum* (d'Orbigny), "Elphidium lidoense"-type, sample 2 C, × 100.  
Figs. 6a, b      *Elphidium granosum* (d'Orbigny), "Elphidium lidoense"-type, sample 2 C, × 100.  
Fig. 7            *Elphidium granosum* (d'Orbigny) var. *demens* (Arnold Bik), sample 723 C, × 375.  
Fig. 8            *Elphidium granosum* (d'Orbigny) var. *demens* (Arnold Bik), sample 723 C, × 375.  
Figs. 9a, b      *Elphidium incertum* (Williamson), sample 2 L, × 200.  
Figs. 10a, b     *Elphidium minutum* (Reuss), sample 2 D, × 200.



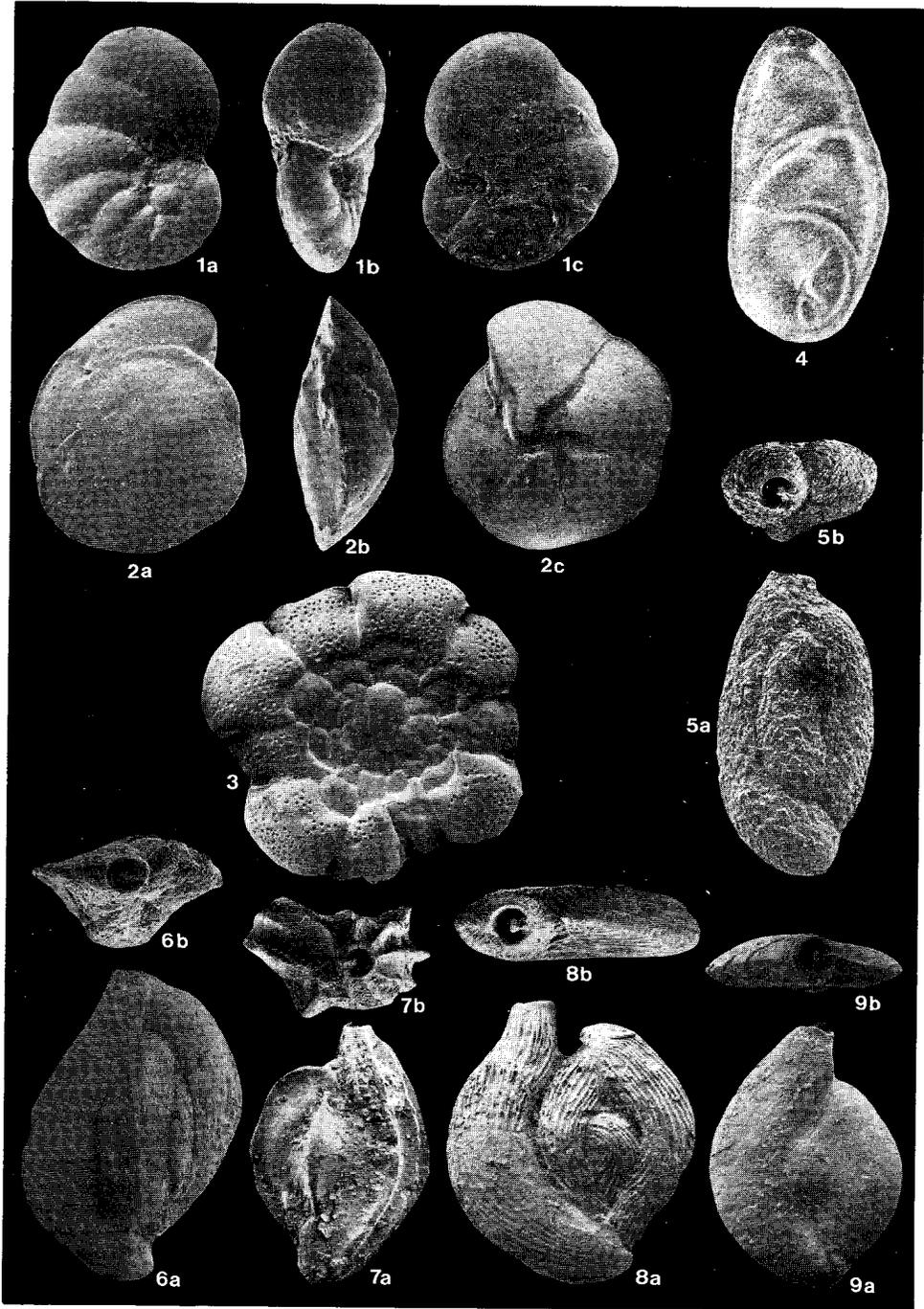
## Plate 7

- Figs. 1a, b      *Elphidium pulvereum* Todd, sample 301 E, × 200.  
Figs. 2a, b      *Elphidium semistriatum* (d'Orbigny), sample 2 D, × 100.  
Figs. 3a, b      *Elphidium semistriatum* (d'Orbigny) var. *minimum* (Seguenza), sample 2 D, × 100.  
Fig. 4            *Fursenkoina schreibersiana* (Czjzek), sample 2 C, × 200.  
Figs. 5a-c       *Hanzawaia rhodiensis* (Terquem), sample 301 M, × 160.  
Figs. 6a, b       *Melonis pompilioides* (Fichtel and Moll), sample 300 E, × 225.  
Figs. 7a, b       *Nonion boueanum* (d'Orbigny), sample 2 C, × 225.  
Figs. 8a, b       *Nonion depressulum* (Walker and Jacob), sample 301 N, × 225.  
Figs. 9a, b       *Nonion paraliium* Tintant, sample 703 R, × 185.



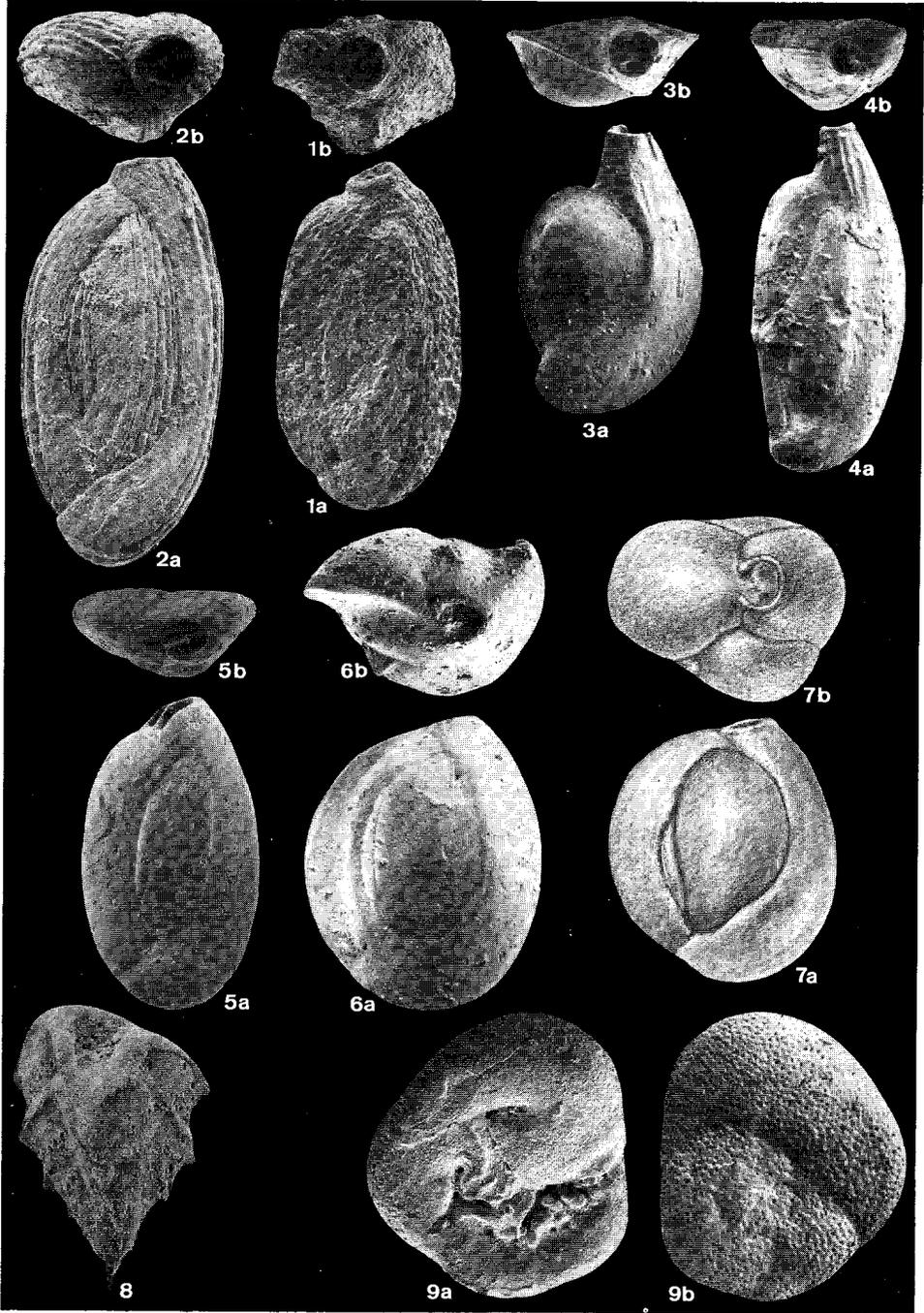
## Plate 8

- Figs. 1a, b      *Nonionella* sp., sample 301 G, × 200.  
Figs. 2a-c      *Oridorsalis stellatus* (Silvestri), sample 315 C, × 150.  
Fig. 3          *Planorbulina mediterranensis* d'Orbigny, sample 703 Y, × 100.  
Fig. 4          *Pseudopolymorphina incerta* (Egger), sample 310 A, × 150.  
Figs. 5a, b      *Quinqueloculina aspera* d'Orbigny, sample 700 R, × 250.  
Figs. 6a, b      *Quinqueloculina bradyana* Cushman, sample 703 S, × 150.  
Figs. 7a, b      *Quinqueloculina duthiersi* (Schlumberger), 703 Y, × 100.  
Figs. 8a, b      *Quinqueloculina elegans* d'Orbigny, sample 2 G, × 50.  
Figs. 9a, b      *Quinqueloculina elegans* d'Orbigny var. A, sample 2 G, × 50.



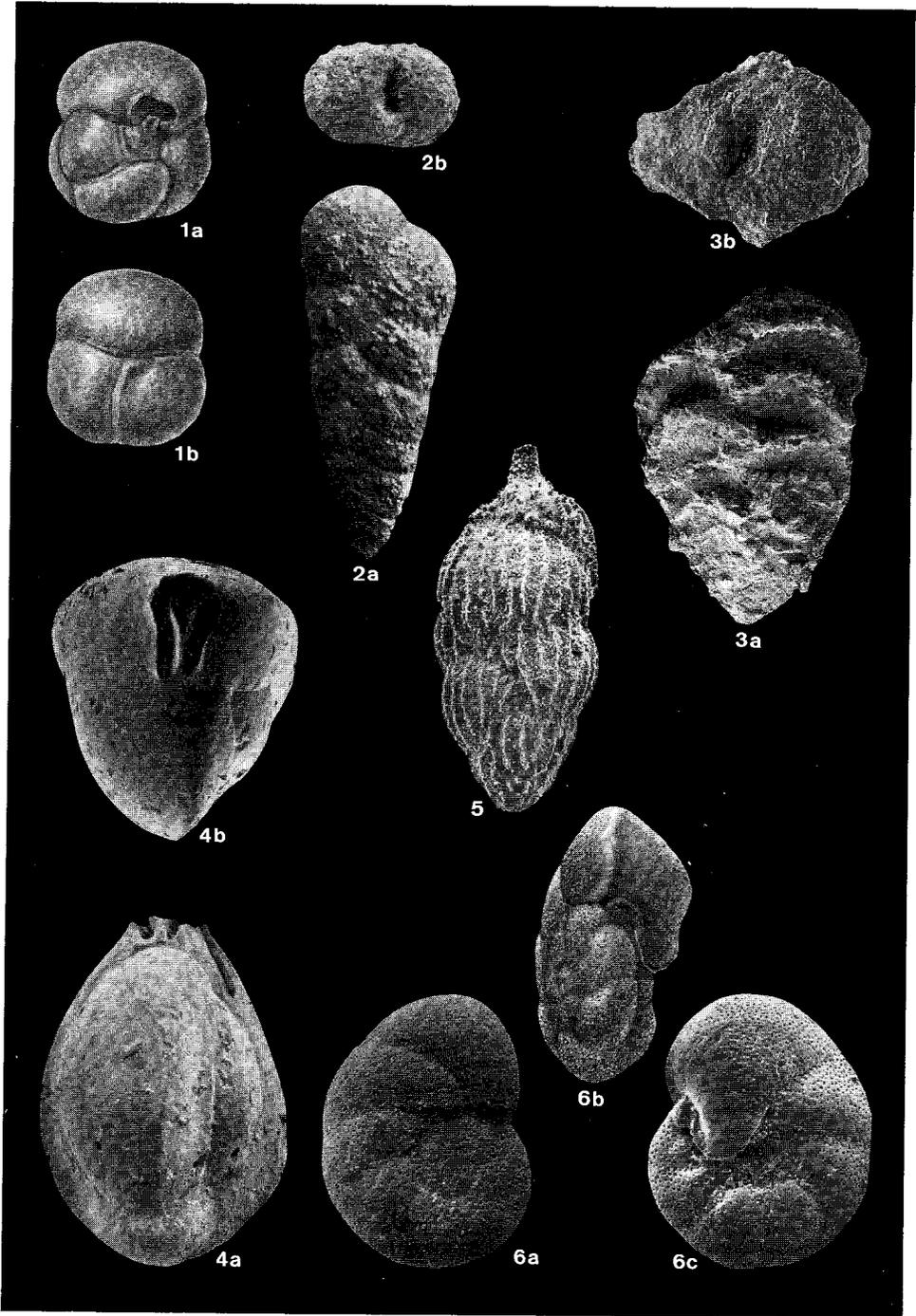
## Plate 9

- Figs. 1a, b      *Quinqueloculina excavata* Karrer, sample 2 F, × 150.  
Figs. 2a, b      *Quinqueloculina jugosa* (Cushman), sample 2 G, × 115.  
Figs. 3a, b      *Quinqueloculina longirostra* d'Orbigny, macrospheric, "Adelosina-like" specimen,  
sample 2 I, × 100.  
Figs. 4a, b      *Quinqueloculina longirostra* d'Orbigny, microspheric specimen, sample 2 I, × 100.  
Figs. 5a, b      *Quinqueloculina seminula* (Linnaeus), sample 109 F, × 50.  
Figs. 6a, b      *Quinqueloculina ungeriana* d'Orbigny, sample 301 A, × 175.  
Figs. 7a, b      *Quinqueloculina vulgaris* d'Orbigny, sample 310 B, × 100.  
Fig. 8            *Reussella spinulosa* (Reuss), sample 313 E, × 250.  
Figs. 9a, b      *Rosalina globularis* d'Orbigny, sample 703 S, × 100.



## Plate 10

- Figs. 1a, b      *Sphaeroidina bulloides* d'Orbigny, sample 315 C, × 100.  
Figs. 2a, b      *Textularia agglutinans* d'Orbigny, sample 2 D, × 100.  
Figs. 3a, b      *Textularia silvestrii* nov. nom., sample 315 I, × 100.  
Figs. 4a, b      *Triloculina trigonula* (Lamarck), sample 2 G, × 125.  
Fig. 5            *Uvigerina peregrina* Cushman, sample 315 B, × 165.  
Figs. 6a-c       *Valvulineria complanata* (d'Orbigny), sample 301 C, × 150.



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## Appendix

### COMPUTER ANALYSIS OF THE FORAMINIFERAL FREQUENCY DATA FROM THE PYRGOS SEDIMENTS

M. M. DROOGER and J. HAGEMAN

The relative frequency data for the 18 taxonomic groups, in all samples from which more than 80 individuals had been counted, were submitted to an R-mode analysis (species comparisons). These 142 samples were treated as equal, i.e. all differences in stratigraphic position within the sections and in geographic location (except North versus South) were ignored. Correlation coefficient values were calculated from the frequencies of each pair of taxonomic groups; this means that we checked  $(18 \times 17) / 2 = 153$  combinations. We used a method which to a great extent eliminates the closed sum effect. Since we suspected that squeezing effects were caused by the irregular pattern of highly fluctuating frequencies of *A. beccarii beccarii* and *A. beccarii tepida*, we analysed the data a second time deleting the frequencies of these two forms. There appeared to be little difference between the results of both tests.

Although the closed sum effect was eliminated, the correlation coefficient values derived from the relative frequency data still have to be interpreted with care because of other obscuring effects which we will not dwell on in this paper. In general high absolute values express a greater intensity of the relation than lower values. As far as the statistical significance is concerned,  $|r| \geq 0.21$  corresponds to the 1% level of significance and  $|r| \geq 0.16$  corresponds to the 5% level of significance (two-sided). Generally we shall take  $|r| \geq 0.21$  as the critical region.

In addition to comparing these taxon-taxon frequencies we also compared the taxa group frequencies to some non-taxonomic parameters: P/B ratio, Fisher  $\alpha$  index for diversity, benthos density, sediment type as a measure of hydrodynamic energy, and geographic location in two classes, North and South. The latter intraregional difference may have a stratigraphic time significance. In comparing the taxa group frequencies to the non-taxonomic parameters, we used the relative frequencies of each taxon after deleting the numbers of the "squeezing" taxa *A. beccarii beccarii* and *A. beccarii tepida*, with the obvious exceptions of both taxa themselves.

The authors greatly appreciate the discussions with C. W. Drooger about the interpretation of the computer-derived data.

### The faunal groups

On the basis of the significantly positive links between the eighteen taxonomic units (fig. 26), four groups of taxa become apparent, which can be brought in connection with major environments.

1. The group consisting of *Cassidulina*, *Brizalina*, *Bulimina*, *Valvulineria* and the trochoid-biconvex taxa, which is evidently the open marine, offshore association on the clastic substrate without prolific vegetation. The category Miscellaneous also fits into this group.

2. The group of the plano-convex taxa and the Miliolids, which is thought to reflect open marine vegetated habitats. The only species having a connection with this group is *A. beccarii inflata*.

3. The group of *Nonion boueanum*, *Cancris*, *Reussella*, *Fursenkoina*, *Elphidium* and *Ammonia perlucida*. The arenaceous species show ties with some of these forms. This group is thought to have lived in shallow marine habitats closer to the shoreline or shoals. Its various elements may have variable but slight tolerances for salinity deviations.

4. The group of *A. beccarii tepida* and *A. beccarii beccarii*, each of which variants appears to have positive correlations with *Elphidium* and *A. perlucida* of the previous group as well. This group of four taxa is the one with the greatest tolerance for ecological stress which is thought to be mainly caused by salinity fluctuations.

Before dwelling on the more subtle differences in strength of correlation within each of the groups, we shall discuss the non-taxonomic parameters.

### Benthos density

This density, given as a calculated number of benthic foraminifera per cc, is found to have a negative correlation with all four faunal components of group 4. This means that the faunas of this so-called ecological stress group have lower average density values. This can be explained by lower productivity as well as by high sedimentation rates. Rapid sedimentation may account for the negative correlation with *A. beccarii beccarii* (see paragraph on energy), low productivity is thought to account for the correlation with *A. beccarii tepida*, but it must be admitted that there are no other clues in the analysis to support this assumption. We shall not attempt to explain the negative correlation with *Elphidium* and *A. perlucida*. The reaction of

the group as a whole is interesting; freshwater input in a shallow habitat evidently leads to low foraminiferal densities.

In contrast we find that the density has a positive correlation with both major elements of group 2, the Miliolids and the plano-convex taxa of the assumedly vegetated habitats. We are inclined to believe that the sedimentation rate was below the average in the subaquatic meadows; this assumption seems plausible. There may be a hidden snag, however, if one notes the position of the assumedly epiphytic taxa in the energy scale (see below).

Finally, the benthos density appears to have a high positive correlation coefficient value of 0.53, with the diversity expressed on the Fisher  $\alpha$  scale, but again the explanation does not seem to be a simple one, since there are no markedly positive correlations between the density and the individual elements of the most diverse offshore group 1.

### Diversity

The Fisher  $\alpha$  values show consistent, though fairly low positive correlation (0.14 to 0.37) with all five elements of the open marine *Cassidulina* group. Evidently the offshore faunas tend to be most diverse; this conclusion is supported by the positive link of these faunas with the varied group Miscellaneous. The +0.19 correlation coefficient of the diversity with the P/B ratio also fits in with this picture.

Another confirmation of our knowledge of Recent foraminiferal associations is found in the taxa of the so-called stress association of group 4 which show a distinct negative correlation (-0.31 to -0.58) with the diversity. The highly significant value of -0.58 fits to *A. beccarii tepida*, which evidently is the form most tolerant to the stress of salinity fluctuations.

The negative values of the *A. beccarii* group deviate more from zero than the positive values of the *Cassidulina* group. It can thus be assumed that the positive correlation between the  $\alpha$ -index and the density was caused mainly by the effect of the *Ammonia* group. The weaker link of the *Cassidulina* group with diversity does not need to be expressed in distinct positive values of the correlation between the elements of this group and the density.

Another remarkable positive correlation was found between the diversity and the Miliolids. There is no obvious environmental explanation for this. The correlation might be the consequence of the proliferation of species names in the Miliolidae. When the number of miliolid individuals in the samples rises, authors tend to distinguish more and more species.

## Plankton/benthos ratio

The results of the computer analysis are not impressive as far as the P/B ratios are concerned. In addition to the positive correlation with the diversity there are fairly low positive values (0.23 to 0.35) with some of the elements of the *Cassidulina* group; this result fits in with the assumed increase of the P/B ratio in the offshore direction. It is surprising, and difficult to understand why there are no clear negative correlations, even with *A. beccarii tepida*, the most extreme element of the salinity fluctuation group of taxa. It could be assumed that reworking and currents were of such importance that the rare floating planktonics were spread fairly evenly over all shallower environments including the more or less protected lagoons.

## Energy

A hydrodynamic energy scale of six classes in linear connection (0 to 5) was constructed on the basis of the lithology types given in the lithostratigraphic columns (coarse sand (= 0), fine sand, silt, silty clay, clay, and limestone).

No significant correlations with any of the other four non-taxonomic items were found, and there were only three significant correlation coefficient values with the taxa groups.

*Cassidulina* is the only species group that has a distinct link with low energy sediments. None of its usual companions or other species suspected of having a preference for muddy substrates show a correlation of this kind. This unexpected lack of ties may be a trick of our lithology parameter however. The ranking of the six sediment types places the rare limestones at the end of the numerical scale, whereas a possible preference of taxa for the very common silty clays might give a non-significant correlation value that is indistinguishable from the values obtained for taxa which have no preference for any of the sediment types. In an attempt to avoid this deficiency another computer run was made, this time with only four energy classes, the number being reduced by putting silty clay, clay and limestone in one class (= 3). The result of this second analysis shows that in the low energy quarter *Cassidulina* is distinctly joined by *Bulimina*, while at about the 5–10% significance level Arenaceous, *Fursenkoina*, *Valvulineria*, Miscellaneous and *Brizalina* complete the group.

At the other end of the scale *A. beccarii beccarii* is found to have a clear preference (r-value  $-0.53$ ) for the coarser sediments, i.e. high energy. As concluded before, the position of this *Ammonia beccarii* variant in the so-

called stress group certainly has something to do with high energy conditions, but in our analysis the effect of this connection cannot be separated from the possible influence of salinity fluctuations.

At first sight the distinct correlation ( $-0.39$ ) between the plano-convex or epiphytic taxa and high hydrodynamic energy conditions is very remarkable. It seems to contradict the conclusion that there was a low sedimentation rate in the subaquatic meadows, in which these epiphytic taxa were linked with high benthos density values. Slow sedimentation is not expected to find its expression in the deposition of the coarser sediments, i.e. the sands. Possibly we are dealing with two different depositional environments for the epiphytic taxa in the Pyrgos area. One environment is in the slow sedimentation realm of the vegetation, in which the Miliolids seem to be more closely linked with density (0.41) than the epiphytic taxa (0.25). For both groups these meadows must be considered to be the preferential habitat. It is likely, however, that currents removed some of the plants with the adhering plano-convex forms from their original habitat and washed them ashore in high energy environments. The absence of any clear positive correlation between *A. beccarii beccarii* and the plano-convex taxa may mean that their high energy environments were not the same. *A. beccarii beccarii* may have had a preference for areas with some freshwater run-off, whereas the epiphytic forms of the *Asterigerina-Cibicides-Rosalina* group were brought ashore in all kinds of shoal areas, also in the fully marine realm.

Both computer runs showed that *Nonion boueanum* might have some preference for sands ( $r = -0.15$ ).

### North-South

In the computer analysis "North" has been labelled as 1, "South" as 2. Some brackish elements of group 4 (*A. beccarii tepida* and *A. perlucida*) and the Miscellaneous group are more frequent in the North, whereas some shallow marine forms of the third group (*Nonion boueanum*, *Fursenkoina*) and *Valvulineria* have a preferential distribution in the South. Although it is not certain whether the selection of the sections is sufficiently random, there may well be a difference in the predominance of these two vaguely defined habitats. Brackish environments would have been relatively more common in the North, the shallow-marine environments more common in the South. A similar conclusion was arrived at already from the qualitative assessment of the data, especially from the relative frequencies of *N. boueanum*. A relative time factor may be involved in the explanation of the difference. Hageman concluded from the field data that the northern sections might be

somewhat younger than the bulk of the southern sediments. It is remarkable in this context that *A. beccarii inflata*, which is frequent only in the northern section Pigadion, cannot be shown to have a special connection with the North. The high frequencies in the North are evidently sufficiently balanced by low frequency occurrences in the South.

### The four major taxa groups

Looking for more subtle environmental differences among the elements of the four major groups of species on the basis of the computer-derived results is quite a tricky business. Before discussing possible explanations for the correlations between the taxa frequencies within the four groups we must make some remarks about the meaning of the correlation coefficient values.

Matching of the relative frequencies seems to give comprehensible results about positive and negative links, but the type of the total set of data as well as the details of the method may influence the correlation coefficient values.

We present the results obtained with only one of the available methods which eliminate closed-sum effects and possible squeezing effects (fig. 26). Another method gave fewer but similar results. Since it is not yet clear whether the second method is the better one we have preferred to base our conclusions on the first one.

As to the type of data-set our frequencies come from a wide array of habitats, from offshore open marine to brackish lagoonal. This has a large impact on the correlation coefficient values.

The mutual correlations express the character of the frequency trends of pairs of taxa. Positive correlation means that the frequencies of both taxa tend to rise together and to go down together, whereas negative correlation means that the frequency trends of both taxa are opposed. However, if there is a large number of samples in which both taxa are absent or represented with very few specimens only, a dense cluster of points (if visualized in a scatter diagram) near the origin starts to affect the correlation coefficient; positive links may be unduly strengthened and negative links may dwindle to insignificant values. The latter effect must be taken seriously in our example. The question whether the correlation coefficient is the best statistic in such cases will be considered elsewhere.

The most plausible explanation for positive correlation is that both taxa had similar habitat preferences or tolerances. A high positive correlation value may mean a closer habitat correspondence than a low value. However,

a similar preference combined with a certain tolerance of both taxa for other environments may cause the paradox of a positive value, that is lower than the value obtained for less perfect preference correspondence combined with the near-absence in most other habitats.

Negative correlation may mean that both taxa had some biotope overlap but that their preferences or tolerances were well apart on the environmental cline. Also when there is no overlap at all in the preferential environment we may expect a distinct negative correlation coefficient, provided that one or the other is present in most of the samples from the other habitats. If both taxa seem to be mutually exclusive as to habitat, but one occurs in a few samples only, the negative correlation may also become obscured. This is demonstrated in figure 27, which shows the numerous occurrences of *A. beccarii tepida* versus the low number of samples with occurrences of abundant *A. beccarii inflata*. The high frequencies of the latter in the absence of the former in a number of samples from the Pigadion section are almost entirely overruled in the calculation of the correlation coefficient by the numerous data of the *tepida* variant alone along the horizontal axis ( $r = -0.12$ ).

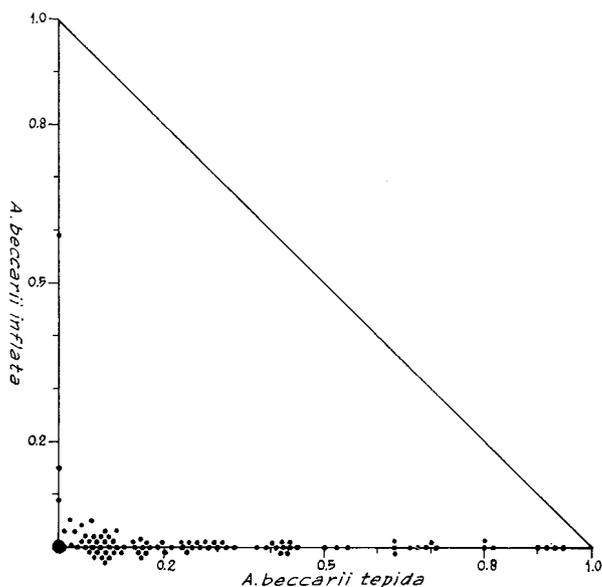


fig. 27 Scatter diagram showing the interrelation between the percentages of *Ammonia beccarii tepida* and the percentages of *A. beccarii inflata* in the 142 samples from the Pyrgos region considered in the computer analysis.

No correlation, or insignificant positive or negative correlation values may have diverse meanings. We have seen already that the (near-) absence of both taxa in many of the samples may obscure the effect of opposed frequency trends in the other samples. A similar effect is obtained if one of these taxa occurs in too few samples. Furthermore, a low correlation coefficient value may be brought about by the indifference of one of the taxa to the various habitats. This could be due to the fact that a taxon likes all the environments equally well (no clear example in the Pyrgos area), but a similar indifference is suggested when too many species with different environmental preferences along the entire cline have been lumped together in a single group (e.g. the arenaceous species). The suggestion that there is no correlation may also mean that although the preferential habitats of both taxa are different, one taxon is transported so regularly into the realm of the other that there is no expression in the correlation coefficient any more.

The following paragraphs will show that it is sometimes difficult, if not impossible, to choose between various explanations.

### The open marine, offshore association

The five components of the *Cassidulina* group form a tight cluster. *Bulimina* seems to be the central taxon since it has the strongest ties with *Cassidulina* and *Brizalina*. This central three-taxon group shows consistent, negative correlation values with all six elements of the so-called shallow marine group (group 3). There is probably little or no overlap between both groups along the environmental cline (probably depth), and the preferential centres of both groups on this cline are likely to be well apart.

All five elements of the *Cassidulina* group show regular negative correlations with both group 4 variants of *A. beccarii* and (with the exception of *Valvulineria*) with *A. perlucida* and *Elphidium*, the other components of group 4. There seems to be hardly any or no overlap in the environment of these two groups. The above correlations suggest that *Valvulineria* is the shallowest element in the offshore association. This taxon seems to be the element most loosely attached to the other taxa of the *Cassidulina* group, as judged from the somewhat lower positive correlation coefficient values; it shows no clear correlation with the trochoid-biconvex group.

Also the Miscellaneous category has to be placed in the offshore group, because it has distinct positive correlations with some members of the group. Its presence may account for some of the high average diversity values of the group.

The entire group can be placed in a muddy environment, but on the basis of the correlation coefficient between the separate taxa and the energy scale

this connection is confirmed for only four of the elements with decreasing emphasis: *Cassidulina*, *Bulimina*, *Valvulineria* and *Brizalina*. The slight differences between the elements of the group cannot be explained so easily. One might suggest that the trochoid-biconvex group and *Valvulineria* were more tolerant for the conditions of the shallow marine group, whatever these may have been. It is remarkable that these two groups show no mutual preference. Differences in substrate or energy level may account for this lack of correlation; the trochoid-biconvex group is the only one in the *Cassidulina* association to have no link with clayey sediments.

The relative numbers of some *Brizalina* species and especially of *Bulimina* are known to rise strongly when bottom waters become stagnant. The relation between these taxa and the diversity in the Pyrgos area seems to indicate that stagnation, if it occurred, played only a subordinate role ( $r = +0.14$  and  $r = +0.27$  respectively).

### The vegetation-bound association

The small group of three taxa in the assumedly vegetated habitats shows only a clear positive correlation (0.31) between the Miliolids and the plano-convex taxa, which are considered to have lived between and on the plants respectively. *A. beccarii inflata* is placed in this group, although it has a positive link with the epiphytic taxa only.

It has been argued already that the plants with the adhering plano-convex forms were repeatedly displaced by currents. They may have drifted into the shallow marine environments. Sinking to the deeper marine habitats seems unlikely, as can be deduced from the negative correlation between the plano-convex species group and some of the components of the offshore association.

The absence of distinct negative values of the correlation coefficient between the Miliolidae and all other taxa, with the exception of *A. beccarii tepida*, is not so easily explained by widespread transport from the bottom of the original low-sedimentation-rate environment in which they thrived. It indicates rather that miliolid species may be found in all habitats; probably the individual species that were lumped together in this group had a varied preference. We may find miliolid species from the shallow sands to the offshore (e.g. *Pyrgo*, *Sigmoilina*); the group probably had no species in the preferential environment of *A. beccarii tepida* where there was a considerable freshwater input. The fact that the epiphytic taxa have an  $-0.18$  correlation with the latter *Ammonia* variant may mean that the lagoons were generally well-sheltered from the shoreward currents that carried the plants with their attached foraminifera.

## The shallow marine association

In our qualitative appreciation of the frequency data of the components of this so-called shallow marine group we seemed to be able to make a considerable differentiation in preferential habitats. It is not so easy to make such a differentiation on the basis of the computer analysis.

The largest positive tie of 0.54 between *Elphidium* and *Nonion boueanum* seems to form a kind of centre in the association, to which *Cancris*, *Reussella* and *Fursenkoina* may be added with somewhat lower positive correlation coefficient values. These five taxa all have a negative correlation with the three central elements of the offshore group (*Bulimina*, *Brizalina* and *Cassidulina*). From *Elphidium* to *Fursenkoina* the absolute values of the coefficients diminish rapidly. Increasing overlap in habitat may provide an explanation.

*Elphidium* is furthest away from the offshore group, possibly because it enters shallower environments than the others, but it shows quite a number of additional positive links. In addition to the distinct positive ties with *A. perlucida*, it also has a positive correlation with *A. beccarii beccarii* and especially with *A. beccarii tepida*. This wide array of habitats seems to indicate that we lumped in *Elphidium* several species with clearly different preferences or tolerances, including distinctly brackish (e.g. *E. granosum*) and normal saline forms (e.g. *E. minutum*).

Together with *Cancris*, *Elphidium* is the only group which has a positive, though not stringent correlation (0.23) with the arenaceous species. In the Pyrgos area the agglutinants seem to have few preferences; their presence in low numbers throughout practically the entire area may mean that we lumped too many species together in one category.

The *Elphidium* group as a whole appears to show no correlation with the taxa of the assumedly vegetated habitats although such a relation was expected for several of its species. If any of the species really has such a preference, the numerical effects of these species are completely obscured by those of the others which have not.

*Ammonia perlucida* is another taxon which has positive correlation ties with some elements of the shallow marine group (*Elphidium* and *Fursenkoina*) as well as with the "brackish" taxa *A. beccarii beccarii* and especially *A. beccarii tepida*. It seems safe to assume that *A. perlucida* has a fair tolerance for salinity deviations, although its habitat extends into the shallow marine realm where there is little or no freshwater influence. Its negative correlation coefficient values with the major elements of the offshore marine group may be due to the absence of overlap of the habitats. The positive

correlation of 0.36 between *A. perlucida* and the group Miscellaneous may be caused by the incorporation of *Nonion depressulum* and *N. paraliun* in the latter group.

*Reussella* and *Cancris* are clearly associated with *N. boueanum* and *Elphidium*, but without the tendency to follow the latter group into the more brackish environments because there is no correlation with any *Ammonia* type, not even with *A. perlucida*. Their habitat seems to be restricted to the open marine side because of negative values of the correlation coefficient with the central elements of the offshore group with which they probably have only slight habitat overlap, or none at all.

*Fursenkoina* shows a special behaviour within the shallow marine group. It has fairly high positive correlation coefficient values with *Elphidium*, *Nonion boueanum* and *A. perlucida* which seems to point to the "brackish" side of the shallow realm. This seems to fit in with the fact that the positive correlation coefficient values with *Cancris* and *Reussella* are hardly significant (0.13 and 0.17). *Fursenkoina* shows negative correlations with the offshore group. One might wonder whether *Fursenkoina* has a geographically restricted preferential biotope in the shallow marine realm. A preference for a shallow and muddy environment and a certain tolerance for salinity deviations may have caused the habitat limitation.

Finally *Nonion boueanum* may be seen as the most typical element in the group with again only slight tolerance to the brackish side as is concluded from its positive correlation with *Elphidium* only. Its weak positive correlation with the sandy side of the sediment spectrum is not accompanied by a positive correlation with *A. beccarii beccarii*; the species evidently prefers near-normal salinities.

### The brackish water association

In the nearshore, protected environments we have a distinct group of four taxa: *A. beccarii beccarii*, *A. beccarii tepida*, *Elphidium* and *A. perlucida*. We have concluded already that the latter two must be situated in an area that overlaps with the shallow marine biotopes, but they extend more towards *A. beccarii tepida* ( $r = 0.42$  twice) than towards *A. beccarii beccarii* ( $r = 0.25$  and  $r = 0.22$  respectively). Possibly they are less tolerant of the higher energy conditions in which *A. beccarii beccarii* is found than of the assumedly greater salinity fluctuations of the environment of *A. beccarii tepida*.

The negative correlation coefficient values of the *A. beccarii* variants with the entire offshore group and the absence of such links with the more marine elements in the shallow marine association are logical. Synsedimentary re-

working and washing down the slope may have been a regular phenomenon which added to the lack of opposite frequency trends concerning the species in the shallower habitats.

Habitat separation may account for the negative correlation of only *A. beccarii tepida* with the major elements of the vegetated zone. Addition of *A. beccarii beccarii* from its high energy environment to the vegetated area may have been a much more frequent happening.

The fairly low positive correlation coefficient value 0.23 between both brackish *A. beccarii* variants may be due entirely to differences in tolerance for high hydrodynamic energy. Apart from the  $-0.31$  value for the correlation of *A. beccarii beccarii* with the diversity (versus  $-0.38$  for *A. beccarii tepida*) the analysis gives little support to the earlier assumption that *A. beccarii beccarii* is a more marine variant with less tolerance for salinity deviations.

### Cluster analysis of the eighteen taxa

The four taxa groups considered in the foregoing might also emerge if we perform a cluster analysis of the 18 taxa on the basis of the correlation coefficients. The clustering technique we used is the so-called unweighted pair group method. Essentially, this technique consists of repeatedly joining the two clusters of taxa that have the highest correlation coefficient value, until all taxa have been united in one cluster. The somewhat confusing term "unweighted" means that if in a clustering step the clusters P and Q consisting of p and q taxa respectively are joined to  $(P \cup Q)$  having  $(p + q)$  taxa, then the correlation coefficient value of the new cluster with any other cluster R is calculated as

$$r((P \cup Q), R) = \frac{p}{p + q} \cdot r(P, R) + \frac{q}{p + q} \cdot r(Q, R)$$

which can be seen as a weighted rather than an unweighted average of  $r(P, R)$  and  $r(Q, R)$ .

The result of the cluster analysis of the 18 taxa of the Pyrgos region is visualized in a dendrogram (fig. 28). The off-shore association and the vegetation-bound association are clearly visible in the dendrogram. The shallow marine association and the brackish water association, as indicated in previous paragraphs, are reflected less clearly. At the level  $r = 0.20$  the group of *A. beccarii beccarii*, *A. beccarii tepida* and *A. perlucida* is separated in the dendrogram from the group containing *Elphidium*, *Nonion boueanum*, *Canceris*, *Reussella* and *Fursenkoina*.

A severe criticism of this cluster analysis and of such analyses in general, is that information about details present in the correlation coefficient matrix (fig. 26) cannot be retraced from the dendrogram, so that this picture is a poor source of information. The use of the correlation coefficient which is a "two-sided" statistic (positive versus negative) strengthens this objection, because all information about negative correlations between certain pairs of taxa is bound to be destroyed in the dendrogram. This last statement is of course not valid if similarity coefficients and distance coefficients are used because they are "one-sided".

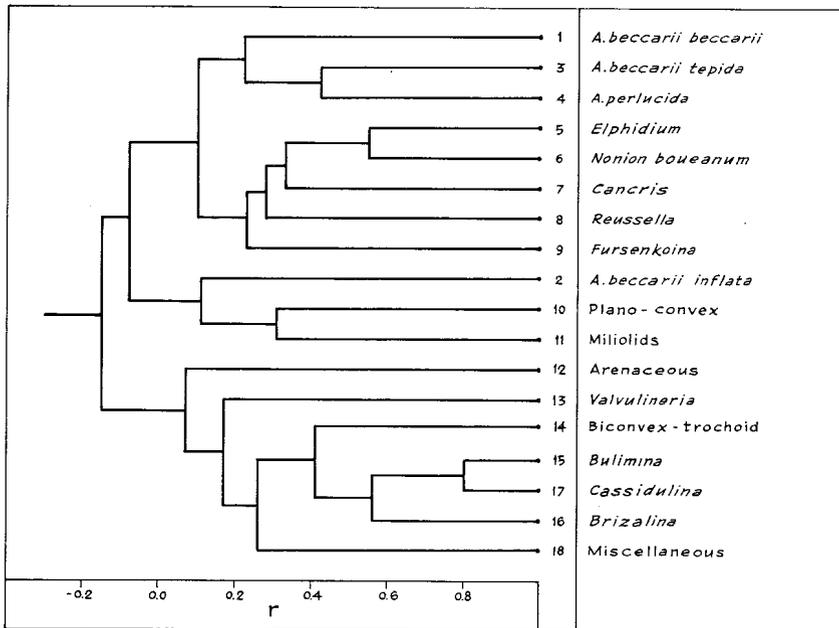


fig. 28 Dendrogram of the 18 taxa, visualizing the result of a clustering technique (unweighted pair group method), and based on the correlation coefficient values given in fig. 26.

**Tables I–XIV**

The order of the tables has been changed

Table I Distribution chart of benthic species at Katakolon, exp. 315.

Species	Samples 315	A	B	C	D	E	F	G	H	I	K
<i>Ammonia beccarii</i> var. <i>inflata</i>	--	--	--	--	--	--	--	--	--	--	1
<i>A. beccarii</i> var. <i>tepida</i>	--	2	--	1	1	1	1	1	--	--	--
<i>Ammonia perlucida</i>	--	--	--	1	1	--	1	1	--	1	--
<i>Elphidium granosum</i>	--	--	--	--	--	--	1	1	--	1	--
<i>E. minutum</i>	--	--	--	--	--	--	--	--	--	--	1
<i>E. semistriatum</i>	--	--	--	--	--	1	--	--	--	--	--
<i>Reussella spinulosa</i>	--	--	--	1	--	--	2	--	2	--	--
<i>Cibicides lobatulus</i> var. 1	--	1	--	--	--	--	--	--	1	1	--
<i>C. lobatulus</i> var. 2	--	2	1	1	3	--	1	2	1	2	--
<i>Discorbinella bertheloti</i>	--	--	--	--	--	1	1	2	2	1	--
<i>Gavelinopsis praeegeri</i>	--	1	--	--	--	--	--	2	1	--	--
<i>Hanzawaia rhodiensis</i>	14	9	7	4	10	5	9	1	4	4	--
<i>Neoconorbina milletti</i>	--	--	--	3	1	4	7	3	2	5	--
<i>Planorbulina mediterraneensis</i>	--	1	--	--	--	--	1	--	--	--	--
<i>Rosalina globularis</i>	--	1	--	--	--	2	2	1	--	1	--
Miliolidae indet.	2	3	7	8	3	1	7	3	3	7	--
<i>Miliolinella circularis</i>	--	--	--	--	--	--	3	3	--	--	--
<i>Pyrgo oblongus</i>	--	--	--	1	--	--	--	--	--	--	--
<i>P. simplex</i>	--	1	--	--	--	--	--	--	--	--	--
<i>Quinqueloculina aspera</i>	--	--	--	--	1	1	1	--	--	1	--
<i>Q. bradyana</i>	--	--	--	--	1	--	--	--	--	--	--
<i>Q. excavata</i>	--	--	--	--	1	--	2	--	--	--	--
<i>Q. seminula</i>	--	1	--	2	--	--	--	--	--	--	--
<i>Q. ungeriana</i>	--	--	--	5	3	1	3	--	--	3	--
<i>Sigmoilina edwardsii</i>	3	2	2	3	2	5	15	3	1	1	--
<i>S. tenuis</i>	--	1	--	--	--	3	2	2	--	2	--
<i>Sigmoilopsis celata</i>	--	3	1	6	--	4	2	5	--	5	--
<i>Spiroloculina canaliculata</i>	--	1	--	--	--	1	1	--	--	--	--
<i>Triloculina trigonula</i>	--	--	--	--	--	--	--	--	--	1	--
<i>Bigenerina nodosaria</i>	--	3	2	2	8	5	2	3	1	--	--
<i>Cylindroclavulina rudis</i>	1	--	1	--	1	--	2	--	--	--	--
<i>Dorothia gibbosa</i>	--	14	--	1	3	--	2	--	--	--	--
<i>Martinottiella communis</i>	--	2	--	--	1	1	--	--	--	--	--
<i>Rheophax?</i> sp.	--	1	--	1	2	1	1	--	--	--	--
<i>Textularia agglutinans</i>	1	5	3	6	4	1	5	3	3	3	--
<i>T. deperdita</i>	--	2	4	2	5	4	7	4	2	3	--
<i>T. soldanii</i>	--	2	--	--	1	1	--	--	--	--	--
<i>T. sp.</i>	1	1	--	--	--	--	--	--	3	--	--
<i>Valvulineria complanata</i>	2	1	8	12	1	4	1	1	3	3	--
<i>Cibicides burdigalensis</i>	41	24	22	21	31	42	40	16	32	20	--
<i>C. dutemplei</i>	--	2	--	--	--	3	1	--	1	--	--
<i>C. ungerianus</i>	16	7	--	1	3	3	1	1	8	3	--
<i>Oridorsalis stellatus</i>	1	3	3	3	3	11	3	5	5	4	--
<i>Bulimina marginata</i>	45	21	52	43	34	32	27	30	22	19	--
<i>Globobulimina ovata</i>	7	6	3	3	--	9	2	21	7	8	--
<i>Stainforthia complanata</i>	--	1	--	--	--	--	--	1	--	--	--
<i>Trifarina angulosa</i>	--	--	1	--	--	--	--	--	1	--	--

continued table I.

Species	Samples 315	A	B	C	D	E	F	G	H	I	K
<i>Uvigerina peregrina</i>		33	31	6	14	23	23	12	1	15	15
<i>U. peregrina</i> var. <i>pygmaea</i>		1	2	—	—	—	17	—	—	—	—
<i>Bolivina pseudoplicata</i>		1	—	—	—	2	—	—	—	—	—
<i>Brizalina dilatata</i>		18	36	3	25	35	16	34	11	35	25
<i>B. spathulata</i>		—	5	—	4	—	—	1	3	1	—
<i>Coryphostoma</i> sp.		—	2	2	1	1	—	1	2	2	1
<i>Loxostomum alatum</i>		—	—	—	—	—	—	3	2	—	—
<i>Cassidulina carinata</i>		66	60	95	91	64	50	49	102	93	110
<i>Globocassidulina oblonga</i>		5	10	15	8	—	3	3	17	—	1
<i>Fissurina</i> spp.		—	1	2	—	2	—	1	4	—	—
<i>Glandulina laevigata</i>		—	1	2	1	1	—	2	1	1	—
<i>Gyroidina soldanii</i>		8	1	1	3	1	15	1	10	15	15
<i>Gyroidinoides delicatus</i>		12	3	21	13	14	11	13	10	2	3
<i>Lagena hexagona</i>		2	1	—	1	—	—	—	—	—	—
<i>Lenticulina</i> sp.		—	—	—	—	—	—	1	—	1	1
<i>Melonis barleeanus</i>		2	2	25	3	4	7	2	12	13	5
<i>M. pompilioides</i>		—	—	—	—	—	—	1	1	—	1
<i>Nodosaria</i> spp.		—	2	—	1	1	1	1	1	—	1
<i>Nonionella opima</i>		—	—	—	—	—	1	—	—	—	—
<i>Oolina</i> spp.		—	—	1	—	—	—	—	—	1	3
<i>Planulina ariminensis</i>		7	5	6	2	2	3	6	2	4	5
<i>Pullenia bulloides</i>		—	—	—	—	5	2	—	2	1	2
<i>P. quinqueloba</i>		—	—	—	—	1	—	2	—	3	—
<i>Rotalia granulata</i>		—	—	—	—	1	—	—	—	—	—
<i>Sphaeroidina bulloides</i>		11	14	4	2	19	4	11	5	8	11
Total number of counted specimens		300	300	300	300	300	300	300	300	300	300
Total number of counted species		24	46	28	37	40	39	50	40	36	40
Fisher $\alpha$ -index		6	15	7 $\frac{1}{2}$	11	12	12	17	12	11	12
Number of specimens per cc sediment		22.7	48.3	32.5	51.1	47.0	28.1	47.4	31.2	52.3	40.5
Number of planktonics per counted number of benthic forams		112	57	59	39	56	29	40	50	174	126

Table II Distribution chart of benthic species at Grecka, exp. 300.

Species	Samples 300	A	B	C	D	E	F
<i>Ammonia beccarii</i> var. <i>tepida</i>		—	—	—	—	1	—
<i>Elphidium aculeatum</i>		1	—	—	—	—	—
<i>E. minutum</i>		—	1	—	—	—	3
<i>Nonion boueanum</i>		2	1	8	4	1	—
<i>Asterigerinata mamilla</i>		1	—	—	—	—	—
<i>Cibicides lobatulus</i> var. 1		2	—	—	—	—	—
<i>C. lobatulus</i> var. 2		2	1	—	2	—	—
<i>Gavelinopsis praegeri</i>		—	—	—	—	—	2
<i>Hanzawaia rhodiensis</i>		10	7	2	2	1	1
<i>Planorbulina mediterraneensis</i>		—	1	—	—	—	—
<i>Rosalina globularis</i>		—	—	—	2	—	—
Miliolidae indet.		5	—	—	1	—	—
<i>Miliolinella circularis</i>		1	—	—	—	—	2
<i>Quinqueloculina seminula</i>		2	3	2	—	—	6
<i>Sigmoilina tenuis</i>		—	1	—	—	—	—
<i>Sigmoilopsis celata</i>		6	—	1	—	1	—
<i>Triloculina oblonga</i>		3	—	—	—	1	—
<i>T. trigonula</i> var. <i>adriatica</i>		1	—	—	—	—	—
<i>Bigenerina nodosaria</i>		—	—	—	—	1	3
<i>Dorothia gibbosa</i>		—	—	—	—	9	6
<i>Rheophax?</i> sp.		1	1	—	—	—	—
<i>Textularia agglutinans</i>		2	2	—	2	1	—
<i>T. pseudotrochus</i>		—	—	—	—	9	—
<i>T.</i> sp.		6	2	—	3	5	—
<i>Valvulineria complanata</i>		9	22	—	4	1	—
<i>Cibicides dutemplei</i>		—	1	—	—	1	—
<i>C. ungerianus</i>		1	1	—	2	2	12
<i>Oridorsalis stellatus</i>		1	21	1	—	—	22
<i>Bulimina elongata</i> subsp. <i>subulata</i>		8	57	151	22	6	12
<i>B. marginata</i>		—	—	—	1	10	2
<i>Globobulimina ovata</i>		2	—	—	—	2	3
<i>Hopkinsina bononiensis</i>		3	—	1	—	—	—
<i>Trifarina angulosa</i>		—	—	—	1	—	—
<i>Uvigerina peregrina</i>		—	—	1	—	24	27
<i>Bolivina pseudoplicata</i>		—	1	—	—	—	1
<i>Brizalina aenariensis</i>		91	72	48	63	30	46
<i>B. dilatata</i>		4	5	1	—	—	6
<i>B. spathulata</i>		110	46	—	151	75	38
<i>Coryphostoma silvestrina</i>		—	1	—	—	—	—
<i>C.</i> sp.		—	—	2	—	—	1
<i>Loxostomum alatum</i>		—	—	—	—	—	1
<i>Cassidulina carinata</i>		23	48	62	36	112	96
<i>Globocassidulina oblonga</i>		2	1	—	—	1	—
<i>Fissurina</i> sp.		1	—	—	—	—	—
<i>Glandulina laevigata</i>		—	—	—	—	—	1
<i>Gyroidinoides delicatus</i>		—	—	20	—	2	—
<i>Lagena</i> spp.		—	—	—	1	—	1

continued table II.

Species	Samples 300	A	B	C	D	E	F
<i>Melonis barleeanus</i>		—	4	—	—	1	5
<i>M. pompilioides</i>		—	—	—	—	3	2
<i>Pullenia bulloides</i>		—	—	—	3	—	—
<i>Sphaeroidina bulloides</i>		—	—	—	—	—	1
Total number of counted specimens		300	300	300	300	300	300
Total number of counted species		27	23	13	17	24	25
Fisher $\alpha$ -index		7	6	3	4	6	$6\frac{1}{2}$
Number of specimens per cc sediment		28.8	29.9	18.2	32.5	29.8	27.0
Number of planktonics per counted number of benthic forams		32	29	101	21	36	28



continued table IV.

Species	Samples 301	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V
<i>T. sp.</i>		3	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Valvulineria complanata</i>		32	28	12	6	--	--	--	--	--	--	--	4	--	1	1	--	--	--	--	--	--
<i>Cibicides dutemplei</i>		1	--	--	--	--	--	--	--	--	4	--	16	--	--	1	--	--	--	--	--	--
<i>Bulimina elongata</i> subsp. <i>subulata</i>		9	40	6	1	--	--	4	6	--	1	--	--	11	2	2	--	--	--	--	--	--
<i>B. marginata</i>		19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
<i>Globobulimina ovata</i>		5	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Stainforthia complanata</i>		--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Uvigerina peregrina</i>		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5
<i>Brizalina dilatata</i>		2	--	--	--	--	--	--	2	--	1	--	--	--	--	--	--	--	--	--	--	--
<i>B. spathulata</i>		7	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
<i>Coryphostoma</i> sp.		8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Loxostomum alatum</i>		3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Cassidulina carinata</i>		75	73	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
<i>Fissurina</i> sp.		1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Glandulina laevigata</i>		1	2	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Lagena</i> sp.		2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Lenticulina</i> sp.		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--
<i>Melonis barleeanus</i>		3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Nonion depressulum</i>		--	1	4	--	10	3	--	3	3	--	--	9	23	1	9	--	15	21	15	6	5
<i>N. paraliium</i>		--	--	--	2	1	--	--	27	--	--	--	--	9	1	--	--	--	6	--	--	--
<i>Nonion/Elphidium</i> spp. indet		--	--	--	--	--	--	--	2	1	--	--	--	--	1	--	1	--	1	--	--	--
<i>Nonionella opima</i>		1	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>N. sp.</i>		1	3	1	--	--	--	1	--	--	--	--	--	1	--	4	--	7	6	--	--	1
<i>Pseudopolymorphina incerta</i>		--	--	--	--	--	--	--	--	--	--	--	1	--	--	2	7	--	--	--	--	--
<i>Pullenia quinqueloba</i>		1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Rotalia granulata</i>		--	--	--	--	3	--	--	--	3	1	--	4	--	--	--	--	1	--	--	--	--
Total number of counted specimens		300	300	300	300	300	300	300	300	300	90	41	300	300	300	300	300	300	300	300	300	300
Total number of counted species		40	21	21	21	16	11	20	17	18	10	5	27	22	23	25	18	16	13	13	13	15
Fisher $\alpha$ -index		12	5	5	5	4	2	5	4	4	2	--	7	5	6	6 $\frac{1}{2}$	4	4	3	3	3	3
Number of specimens per cc sediment		35.2	26.4	25.0	8.3	16.9	2.2	19.8	30.0	0.8	<0.1	<0.1	33.7	28.2	17.0	3.4	4.5	22.4	6.8	0.6	4.3	0.9
Number of planktonics per counted number of benthic forams		114	90	18	12	13	5	14	9	69	34	2	15	21	21	20	18	5	15	9	5	12

Table V Distribution chart of benthic species at Vounargon, exp. 700.

Species	Samples 700	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
<i>Ammonia beccarii</i> var. <i>beccarii</i>	—	9	13	17	30	8	21	18	18	1	—	—	—	—	18	29	7	—	13	134	—	3	
<i>A. beccarii</i> var. <i>tepida</i>	15	5	29	13	20	76	30	22	—	—	—	—	—	9	34	13	20	30	26	19	—	—	
<i>Ammonia perlucida</i>	23	3	11	10	3	2	—	—	—	—	—	—	—	—	12	10	18	—	78	9	—	—	
<i>Elphidium advenum</i>	2	11	3	26	42	—	10	6	7	—	—	—	—	—	3	2	—	—	—	44	—	—	
<i>E. articulatum</i>	1	1	—	—	—	—	—	3	—	—	—	—	—	—	—	1	—	—	—	—	—	—	
<i>E. crispum</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	2	1	—	1	—	—	
<i>E. granosum</i>	8	19	12	38	22	28	39	29	25	—	—	—	—	—	29	32	29	2	39	6	—	—	
<i>E. incertum</i>	—	5	18	3	4	10	12	1	—	—	—	—	—	—	—	—	14	—	—	—	—	—	
<i>E. minutum</i>	—	—	—	—	—	—	3	—	3	—	—	—	—	—	6	2	18	2	5	—	—	—	
<i>E. semistriatum</i>	—	4	5	—	—	4	4	2	2	—	—	—	—	—	5	9	4	—	22	—	—	—	
<i>E. semistriatum</i> var. <i>minimum</i>	78	13	69	51	38	18	20	3	45	—	—	—	—	—	17	9	39	15	28	13	—	—	
<i>Nonion boueanum</i>	51	103	49	27	65	52	51	66	81	—	—	—	—	1	124	40	32	4	36	33	—	—	
<i>Cancris auricula</i>	11	16	19	—	19	34	60	59	56	—	—	1	—	—	9	3	—	—	—	—	—	—	
<i>Reussella spinulosa</i>	21	12	26	7	1	36	9	15	8	—	—	—	—	—	6	8	47	—	—	—	—	—	
<i>Fursenkoina schreibersiana</i>	32	3	20	3	12	5	3	6	14	—	—	—	—	—	7	—	3	—	3	—	—	—	
<i>Asterigerinata mamilla</i>	—	6	2	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	1	3	—	—	
<i>Cibicides lobatulus</i> var. 2	1	3	—	34	9	—	1	—	8	—	—	—	—	—	—	2	—	5	—	2	—	—	
<i>Discorbinella bertheloti</i>	—	—	1	—	—	—	—	—	1	—	—	—	—	—	1	—	—	1	—	—	—	—	
<i>Gavelinopsis praegeri</i>	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	
<i>Rosalina globularis</i>	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
<i>Quinqueloculina aspera</i>	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	22	—	—	—	—	—	—	
<i>Q. excavata</i>	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	
<i>Q. longirostra</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	—	—	—	—	—	—	
<i>Q. parvula</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	
<i>Q. seminula</i>	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29	—	—	—	—	—	—	
<i>Q. vulgaris</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16	—	—	—	—	—	—	
<i>Q. spp. indet.</i>	—	—	2	3	1	1	—	1	—	—	—	—	—	—	1	—	—	1	4	—	1	—	
<i>Triloculina oblonga</i>	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
<i>T. trigonula</i> var. <i>adriatica</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	—	—	—	—	—	—	
Agglutinated spp. indet.	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	
<i>Dorothia gibbosa</i>	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	3	—	—	—	—	—	
<i>Textularia agglutinans</i>	7	8	2	18	13	1	9	35	12	—	—	—	—	—	12	—	15	—	3	16	—	—	
<i>T. deperdita</i>	—	—	—	—	4	—	2	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	
<i>Valvulineria complanata</i>	21	—	1	10	—	—	—	—	—	—	—	—	—	—	3	—	16	2	7	3	—	—	
<i>Cibicides dutemplei</i>	2	62	1	1	9	—	2	1	12	—	—	—	—	—	—	18	2	—	—	1	—	—	
<i>Bulimina elongata</i> subsp. <i>subulata</i>	—	6	1	5	3	—	3	6	1	—	—	—	—	—	4	—	—	3	8	—	—	—	

continued table V.

Species	Samples 700	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
<i>B. marginata</i>	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	2	--	--	--	--
<i>Globobulimina ovata</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
<i>Stainforthia complanata</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
<i>Trifarina angulosa</i>	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1	3	1	1	--	1	--
<i>Uvigerina peregrina</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--
<i>Bolivina pseudoplicata</i>	--	--	1	--	--	--	1	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--
<i>Brizalina dilatata</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	--	1	--	--
<i>Coryphostoma silvestrina</i>	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	1	4	1	6	4	--	--	--
<i>C. sp.</i>	--	1	2	3	--	1	2	2	1	--	--	--	--	--	1	--	--	--	4	--	--	--	--
<i>Cassidulina carinata</i>	--	--	--	18	--	--	--	--	--	--	--	--	--	--	3	--	1	2	4	--	--	--	--
<i>Globocassidulina oblonga</i>	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	2	--	--	--	--	--
<i>Glandulina laevigata</i>	2	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
<i>Lagena sp.</i>	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--
<i>Lenticulina sp.</i>	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Melonis barleeanus</i>	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<i>Nodosaria sp.</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
<i>Nonion depressulum</i>	5	1	3	--	--	17	15	11	3	--	--	1	--	--	--	--	--	--	--	--	--	--	--
<i>Nonion/Elphidium spp. indet.</i>	8	5	2	3	3	5	1	10	--	3	--	--	--	--	5	--	2	14	5	7	7	--	--
<i>Nonionella opima</i>	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	1	1	3	--	--	--	--	--
<i>N. sp.</i>	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--
<i>Pseudopolymorphina incerta</i>	--	3	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	1	--	--	--	--	--
<i>Pullenia bulloides</i>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
<i>Rotalia granulata</i>	1	1	2	4	1	--	3	--	--	--	--	--	--	--	1	5	--	--	--	--	--	--	--
Total number of counted specimens	300	300	300	300	300	300	300	300	300	300	5	--	3	--	19	300	300	300	92	300	300	2	3
Total number of counted species	20	23	28	26	20	18	21	22	20	3	--	3	--	4	24	28	25	22	23	17	2	1	--
Fisher $\alpha$ -index	5	6	7 $\frac{1}{2}$	7	5	4	5	5	5	--	--	--	--	--	6	7 $\frac{1}{2}$	6 $\frac{1}{2}$	8	6	4	--	--	--
Number of specimens per cc sediment	37.3	2.2	13.8	23.5	12.1	33.0	9.9	18.2	0.8	<0.1	0	<0.1	<0.1	<0.1	31.5	22.8	23.8	<0.1	4.1	4.0	<0.1	<0.1	--
Number of planktonics per counted number of benthic forams	32	27	21	6	11	18	24	19	24	6	--	6	--	--	36	3	89	188	12	51	--	--	--

Table VI Distribution chart of benthic species at Lala, exp. 2.

Species	Samples 2	A	B	C	D	E	F	G	H	I	K	L	M	N
<i>Ammonia beccarii</i> var. <i>beccarii</i>		125	140	59	22	31	74	31	27	57	55	191	157	170
<i>A. beccarii</i> var. <i>tepida</i>		21	49	5	1	14	9	3	2	—	5	—	—	—
<i>Ammonia perlucida</i>		—	3	11	23	26	13	5	3	—	16	1	4	4
<i>Elphidium advenum</i>		7	1	8	—	1	2	—	—	—	3	4	2	6
<i>E. articulatum</i>		—	1	—	3	—	—	—	—	—	1	—	—	—
<i>E. crispum</i>		1	4	6	—	2	7	1	1	—	2	1	4	2
<i>E. excavatum</i>		—	—	—	1	1	2	1	1	—	1	—	—	—
<i>E. fichtelianum</i>		5	2	1	—	3	6	18	20	9	—	11	33	1
<i>E. granosum</i>		3	6	52	27	27	21	6	9	6	4	6	6	24
<i>E. incertum</i>		9	2	4	9	8	10	5	20	4	29	28	1	5
<i>E. minutum</i>		—	—	—	10	5	9	1	3	—	1	1	—	—
<i>E. pulvereum</i>		—	—	1	1	4	10	6	15	—	6	1	—	—
<i>E. semistriatum</i>		1	2	14	8	48	3	1	2	—	1	2	1	13
<i>E. semistriatum</i> var. <i>minimum</i>		2	7	5	28	9	18	3	3	—	1	—	2	1
<i>Nonion boueanum</i>		6	13	18	24	55	22	20	19	12	8	8	22	14
<i>Cancris auricula</i>		8	7	17	1	11	10	12	12	1	27	—	6	4
<i>Reussella spinulosa</i>		4	2	—	4	14	4	7	10	—	9	1	—	1
<i>Fursenkoina schreibersiana</i>		3	5	42	36	12	18	1	2	1	—	—	1	1
<i>Asterigerinata mamilla</i>		1	—	—	—	1	—	—	1	—	—	—	—	—
<i>Cibicides lobatulus</i> var. 1		—	—	—	2	8	21	60	60	13	46	1	—	—
<i>C. lobatulus</i> var. 2		71	50	42	3	—	3	—	—	2	55	37	50	14
<i>Planorbulina mediterraneensis</i>		—	—	—	1	1	—	1	—	—	—	—	—	—
<i>Rosalina globularis</i>		—	—	—	—	—	2	2	3	—	2	1	1	1
<i>Pyrgo oblonga</i>		—	—	—	—	—	—	2	1	—	—	—	—	—
<i>Quinqueloculina aspera</i>		—	—	—	—	—	1	5	5	12	—	—	—	—
<i>Q. elegans</i>		—	—	—	—	—	—	37	—	—	—	—	—	—
<i>Q. elegans</i> var. <i>A</i>		—	—	—	—	—	—	2	8	—	—	—	—	—
<i>Q. excavata</i>		—	—	—	5	—	—	3	3	6	—	—	—	—
<i>Q. jugosa</i>		—	—	—	—	—	—	9	13	74	—	—	1	—
<i>Q. longirostra</i>		—	—	—	1	2	—	16	18	39	—	—	—	—
<i>Q. longirostra</i> var. <i>striata</i>		—	—	—	—	—	—	4	2	—	—	—	—	—
<i>Q. seminula</i>		—	—	—	—	1	—	3	—	1	—	—	—	—
<i>Q. vulgaris</i>		—	—	—	10	1	1	2	12	14	—	—	—	—
<i>Q. spp. indet.</i>		—	—	—	2	2	7	1	—	—	1	—	—	—
<i>Triloculina oblonga</i>		—	—	—	—	3	2	7	6	3	—	—	—	—
<i>T. trigonula</i>		—	—	—	4	—	1	17	10	17	—	1	—	—
<i>T. trigonula</i> var. <i>adriatica</i>		—	—	—	—	—	—	—	1	19	—	—	—	—
<i>Textularia agglutinans</i>		4	—	3	60	3	14	1	1	1	3	—	—	7
<i>T. deperdita</i>		2	—	—	—	—	—	1	2	6	—	—	2	6
<i>Valvulinera complanata</i>		3	—	1	—	—	—	—	—	—	—	—	—	—
<i>Cibicides dutemplei</i>		1	1	4	—	1	2	4	1	—	—	1	1	3
<i>Bulimina elongata</i> subsp. <i>subulata</i>		2	—	—	6	1	2	—	—	—	—	—	—	5
<i>B. marginata</i>		1	—	1	—	—	—	—	—	—	—	—	—	—
<i>Trifarina angulosa</i>		1	—	—	—	—	—	—	—	—	—	—	—	1
<i>Uvigerina peregrina</i>		—	—	—	—	—	—	—	—	—	—	—	—	4
<i>Bolivina pseudoplicata</i>		—	—	—	2	—	2	—	—	—	—	—	—	—
<i>Coryphostoma silvestrina</i>		—	—	—	—	—	—	1	1	—	—	—	—	—
<i>C. sp.</i>		—	—	—	—	—	—	—	—	—	—	—	—	1
<i>Cassidulina carinata</i>		1	—	—	—	1	—	—	1	—	1	—	—	—
<i>Globocassidulina oblonga</i>		1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Fissurina sp.</i>		—	—	—	—	1	—	—	—	—	1	1	—	1
<i>Guttulina austriaca</i>		—	—	1	1	—	1	—	—	—	—	—	—	2

continued table VI.

Species	Samples 2	A	B	C	D	E	F	G	H	I	K	L	M	N
<i>Lagena</i> sp.		—	—	—	—	—	—	—	—	—	4	—	—	—
<i>Melonis barleeanus</i>		1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Nodosaria</i> sp.		—	—	—	—	—	—	—	—	—	—	—	—	9
<i>Nonionella</i> sp.		—	—	2	2	—	—	—	—	—	—	—	—	—
<i>Pseudopolymorphina incerta</i>		16	2	—	—	—	—	1	2	2	16	2	6	—
<i>Pullenia bulloides</i>		—	2	3	3	3	3	—	—	1	2	1	—	—
<i>Rotalia granulata</i>		—	1	—	—	—	—	—	—	—	—	—	—	—
Total number of counted specimens		300	300	300	300	300	300	300	300	300	300	300	300	300
Total number of counted species		26	20	22	29	31	31	37	36	22	26	20	18	25
Fisher $\alpha$ -index		7	5	5	8	$8\frac{1}{2}$	$8\frac{1}{2}$	10	10	5	7	5	4	$6\frac{1}{2}$
Number of specimens per cc sediment		4.3	6.8	17.8	19.2	24.6	32.8	22.2	26.1	12.5	16.0	10.9	9.3	2.1
Number of planktonics per counted number of benthic forams		85	9	9	14	6	8	3	6	—	38	5	1	24

Table III Distribution chart of benthic species at Grecka, exp. 305.

Species	Samples 305	A	B	C	D	E	F
<i>Ammonia beccarii</i> var. <i>tepida</i>		1	—	—	—	4	1
<i>Elphidium granosum</i>		—	—	—	—	1	—
<i>Nonion boueanum</i>		1	1	—	1	—	—
<i>Reussella spinulosa</i>		1	—	—	—	—	—
<i>Fursenkoina schreibersiana</i>		—	—	—	—	—	4
<i>Cibicides lobatulus</i> var. 1		3	—	1	—	—	—
<i>C. lobatulus</i> var. 2		3	1	1	2	—	1
<i>Gavelinopsis praegeri</i>		—	4	—	—	—	4
<i>Hanzawaia rhodiensis</i>		3	4	1	2	9	12
<i>Planorbulina mediterraneensis</i>		3	—	2	1	—	1
<i>Rosalina globularis</i>		2	1	1	2	1	—
Miliolidae indet.		—	—	3	4	4	7
<i>Quinqueloculina duthiersi</i>		3	—	—	—	—	—
<i>Q. longirostra</i>		2	2	1	—	—	—
<i>Q. seminula</i>		7	1	1	2	1	8
<i>Sigmoilina tenuis</i>		—	1	—	—	—	1
<i>Sigmoilopsis celata</i>		7	1	2	1	2	1
<i>Spiroloculina canaliculata</i>		1	—	—	1	—	1
<i>Triloculina oblonga</i>		—	—	—	—	—	1
<i>Bigenerina nodosaria</i>		—	—	—	—	—	3
<i>Dorothia gibbosa</i>		3	3	—	—	—	—
<i>Textularia agglutinans</i>		4	3	3	4	8	11
<i>T. pseudotrochus</i>		—	—	—	—	—	3
<i>T. sp.</i>		2	3	2	1	—	1
<i>Valvulineria complanata</i>		5	8	3	18	9	9
<i>Cibicides dutemplei</i>		6	4	—	3	—	2
<i>C. ungerianus</i>		6	—	—	4	10	6
<i>Oridorsalis stellatus</i>		—	35	—	—	1	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>		80	48	52	54	40	33
<i>B. marginata</i>		—	1	—	—	—	—
<i>Globobulimina ovata</i>		4	—	—	—	—	1
<i>Brizalina aenariensis</i>		86	49	58	1	—	13
<i>B. dilatata</i>		—	7	—	1	1	—
<i>B. spathulata</i>		48	40	21	11	27	30
<i>Coryphostoma silvestrina</i>		1	—	—	—	—	1
<i>C. sp.</i>		2	—	—	—	—	—
<i>Cassidulina carinata</i>		1	76	139	176	163	125
<i>Globocassidulina oblonga</i>		—	—	—	—	—	2
<i>Guttulina austriaca</i>		1	—	1	—	—	—
<i>Lagena</i> spp.		2	—	—	—	—	1
<i>Lenticulina</i> sp.		3	—	—	—	—	—
		7	2	3	3	11	11
<i>M. pompilioides</i>		2	5	4	6	6	4
<i>Nonionella opima</i>		—	—	—	1	—	—
<i>N. sp.</i>		—	—	—	1	—	—
<i>Sphaeroidina bulloides</i>		—	—	1	—	2	2
Total number of counted specimens		300	300	300	300	300	300
Total number of counted species		31	23	20	23	18	30
Fisher $\alpha$ -index		8	6	5	6	4	8
Number of specimens per cc sediment		32.2	24.4	28.6	30.6	21.2	23.3
Number of planktonics per counted number of benthic forams		34	6	8	16	18	51

Table VII Distribution chart of benthic species at Paleovarvaisena, exp. 109.

Species	Samples 109	A	B	C	D	E	F	G	H	I	K	L	M	N
<i>Ammonia beccarii</i> var. <i>beccarii</i>	—	15	—	—	—	—	18	1	2	5	4	25	30	1
<i>A. beccarii</i> var. <i>inflata</i>	—	—	—	—	—	—	10	—	—	—	—	—	1	—
<i>A. beccarii</i> var. <i>tepida</i>	5	82	9	3	—	—	33	71	38	24	80	24	46	4
<i>Ammonia perlucida</i>	—	—	—	—	—	—	—	38	16	82	3	3	5	—
<i>Elphidium advenum</i>	—	1	—	—	—	—	—	1	1	—	—	6	4	—
<i>E. crispum</i>	—	1	—	—	—	—	7	6	1	10	3	57	5	—
<i>E. granosum</i>	—	1	—	—	—	—	18	41	18	14	19	19	26	—
<i>E. incertum</i>	—	—	—	—	—	—	—	2	1	—	—	—	9	—
<i>E. minutum</i>	—	—	—	—	—	—	—	—	27	2	—	—	8	—
<i>E. pulvereum</i>	—	—	—	—	—	—	—	—	—	—	—	—	2	—
<i>E. semistriatum</i>	—	1	—	—	—	—	3	9	13	12	1	11	25	—
<i>E. semistriatum</i> var. <i>minimum</i>	—	—	—	—	—	—	63	15	3	3	8	13	12	—
<i>Nonion boueanum</i>	—	1	—	—	—	—	35	17	97	99	161	100	59	—
<i>Cancris auricula</i>	—	—	—	—	—	—	12	3	1	—	10	8	22	—
<i>Reussella spinulosa</i>	—	—	—	—	—	—	2	1	—	—	—	1	1	—
<i>Fursenkoina schreibersiana</i>	—	—	—	—	—	—	3	57	37	33	3	14	13	4
<i>Asterigerinata mamilla</i>	—	—	—	—	—	—	3	—	—	—	—	—	7	—
<i>Cibicides lobatulus</i> var. 1	—	—	—	—	—	—	5	2	—	—	1	1	9	—
<i>C. lobatulus</i> var. 2	—	—	—	—	—	—	6	—	1	—	—	—	4	—
<i>Gavelinopsis praegeri</i>	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Rosalina globularis</i>	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Miliolidae indet.	—	—	—	—	—	—	12	—	—	—	—	—	—	—
<i>Quinqueloculina excavata</i>	—	—	—	—	—	—	10	1	—	7	—	—	—	—
<i>Q. longirostra</i>	—	—	—	—	—	—	6	—	—	—	—	—	—	—
<i>Q. pygmaea</i>	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Q. seminula</i>	—	—	—	—	—	—	4	—	—	1	—	—	—	—
<i>Q. vulgaris</i>	—	—	—	—	—	—	—	—	—	1	—	—	—	—
<i>Triloculina trigonula</i>	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Dorothia gibbosa</i>	—	—	—	—	—	—	—	—	—	—	—	1	—	—
<i>Textularia agglutinans</i>	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Valvulineria complanata</i>	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Cibicides dutemplei</i>	—	—	—	—	—	—	32	—	—	—	—	12	6	—
<i>C. ungerianus</i>	—	—	—	—	—	—	5	—	—	—	—	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>	—	—	—	—	—	—	—	2	—	—	—	—	—	—
<i>B. marginata</i>	—	—	—	—	—	—	—	—	—	1	—	—	—	—
<i>Coryphostoma silvestrina</i>	—	—	—	—	—	—	—	—	—	—	4	—	—	—
<i>Cassidulina carinata</i>	—	—	—	—	—	—	3	12	7	—	2	—	—	—
<i>Guttulina austriaca</i>	—	—	—	—	—	—	2	—	—	—	—	—	—	—
<i>Nonion depressulum</i>	—	—	—	—	—	—	1	10	1	6	—	5	1	—
<i>N. paraliium</i>	—	—	—	—	—	—	—	—	—	—	1	—	4	—
<i>Nonionella opima</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1
<i>Nonionella</i> sp.	—	—	—	—	—	—	—	11	36	—	—	—	—	—
<i>Pseudopolymorphina incerta</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Total number of counted specimens		5	102	9	3	—	300	300	300	300	300	300	300	11
Total number of counted species		1	7	1	1	—	29	19	17	15	14	16	23	5
Fisher $\alpha$ -index		—	—	—	—	—	8	4 $\frac{1}{2}$	4	3	3	4	6	—
Number of specimens per cc sediment		<0.1	<0.1	<0.1	<0.1	—	32.1	26.5	22.7	23.0	18.2	27.2	12.4	<0.1
Number of planktonics per counted number of benthic forams		26	19	3	—	—	15	35	23	13	3	7	6	—

Table VIII Distribution chart of benthic species at Neraida, exp. 109.

Species	Samples 310	A	B	C	D	E	F	G	H	I	K	L	M
<i>Ammonia beccarii</i> var. <i>beccarii</i>		27	16	4	3	15	14	50	15	25	60	76	3
<i>A. beccarii</i> var. <i>inflata</i>		—	—	—	—	—	—	1	1	—	4	—	—
<i>A. beccarii</i> var. <i>tepida</i>		150	29	26	23	48	31	27	30	29	15	21	2
<i>Ammonia perlucida</i>		3	—	5	3	7	12	3	16	24	1	—	—
<i>Elphidium aculeatum</i>		—	—	—	—	—	2	3	—	—	—	—	—
<i>E. advenum</i>		—	—	—	—	9	2	—	—	—	1	—	—
<i>E. articulatum</i>		—	—	—	—	—	—	—	—	—	—	—	—
<i>E. crispum</i>		1	7	3	—	8	3	5	6	3	11	6	—
<i>E. excavatum</i>		—	—	—	1	—	1	—	—	—	—	—	—
<i>E. granosum</i>		2	25	6	45	20	17	18	46	16	8	60	3
<i>E. incertum</i>		1	—	—	—	4	—	—	1	—	—	—	—
<i>E. minutum</i>		1	19	14	15	27	8	6	6	15	19	14	—
<i>E. pulvereum</i>		—	—	—	2	2	2	—	8	—	3	3	—
<i>E. semistriatum</i>		—	2	—	—	1	—	—	2	—	—	—	—
<i>E. semistriatum</i> var. <i>minimum</i>		2	18	23	—	20	11	—	36	12	9	—	1
<i>Nonion boueanum</i>		51	15	79	69	98	82	137	89	111	81	54	1
<i>Canceris auricula</i>		6	3	—	—	4	—	3	1	14	24	12	—
<i>Reussella spinulosa</i>		6	12	4	9	3	7	3	1	6	3	—	—
<i>Fursenkoia schreibersiana</i>		8	2	6	3	4	5	4	3	4	—	—	—
<i>Asterigerinata mamilla</i>		1	—	—	—	—	—	1	—	1	1	—	—
<i>Cibicides lobatulus</i> var. 1		8	4	3	—	10	9	16	—	12	12	4	—
<i>C. lobatulus</i> var. 2		—	20	5	5	2	—	9	1	5	38	17	1
<i>Discorbinella bertheloti</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Gavelinopsis praegeri</i>		—	1	—	—	—	1	—	1	1	—	—	—
<i>Hanzawaia rhodiensis</i>		—	13	2	—	—	—	—	—	—	—	—	—
<i>Rosalina globularis</i>		—	—	1	—	—	—	—	—	—	—	—	—
Miliolidae indet.		1	12	17	15	—	5	—	5	1	—	—	—
<i>Pyrgo elongata</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Quinqueloculina aspera</i>		—	—	4	3	—	—	—	—	—	—	—	—
<i>Q. excavata</i>		—	7	15	3	—	18	—	1	—	—	—	—
<i>Q. jugosa</i>		—	—	1	—	—	—	—	—	—	—	—	—
<i>Q. longirostra</i>		—	10	3	8	—	—	—	4	—	—	—	—
<i>Q. longirostra striata</i>		—	—	—	4	—	—	—	—	—	—	—	—
<i>Q. parvula</i>		—	—	—	—	—	6	—	—	—	—	—	—
<i>Q. pygmaea</i>		—	—	—	5	—	1	—	1	—	—	—	—
<i>Q. seminula</i>		—	1	5	9	—	13	—	—	—	—	—	—
<i>Q. ungeriana</i>		—	—	2	—	—	—	—	—	1	—	—	—
<i>Q. vulgaris</i>		—	9	1	—	—	3	—	1	—	—	—	—
<i>Triloculina trigonula</i>		—	4	—	3	—	3	—	3	—	—	—	—
<i>T. trigonula</i> var. <i>adriatica</i>		—	—	—	—	—	—	—	—	—	—	—	—
<i>Dorothia gibbosa</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Textularia agglutinans</i>		9	38	20	14	8	6	—	6	3	—	3	—
<i>T. deperdita</i>		—	3	—	—	—	—	—	—	—	—	—	—
<i>T. sp.</i>		—	2	8	8	—	7	—	1	1	—	—	—
<i>Valvulineria complanata</i>		—	2	12	15	5	15	—	8	13	—	—	2
<i>Cibicides burdigalensis</i>		—	—	2	—	—	—	—	1	—	—	—	—
<i>Cibicides dutemplei</i>		7	11	3	9	—	—	—	1	—	—	3	1
<i>Oridorsalis stellatus</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>		—	1	2	1	—	—	1	2	—	—	—	—
<i>Bolivina pseudoplicata</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Brizalina dilatata</i>		—	—	—	—	—	—	—	—	—	—	4	—
<i>Coryphostoma silvestrina</i>		—	—	—	1	—	—	—	—	—	1	—	—

continued table VIII.

Species	Samples 310	A	B	C	D	E	F	G	H	I	K	L	M
<i>C. sp.</i>		—	3	2	3	—	3	—	1	1	—	—	—
<i>Cassidulina carinata</i>		—	1	4	—	—	—	—	—	—	—	—	—
<i>Guttulina austriaca</i>		—	1	—	—	—	—	—	—	—	—	—	1
<i>Lagena sp.</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Melonis barleeanus</i>		—	—	—	—	—	—	1	—	—	—	—	—
<i>Nonion depressulum</i>		—	—	6	5	—	6	4	—	—	4	—	—
<i>Nonion/Elphidium spp. indet.</i>		4	1	5	5	—	4	6	—	—	—	3	—
<i>Pseudopolymorphina incerta</i>		9	—	2	—	—	—	—	—	—	—	14	9
<i>Rotalia granulata</i>		3	4	5	9	5	3	2	2	2	5	6	—
Total number of counted specimens		300	300	300	300	300	300	300	300	300	300	300	24
Total number of counted species		20	36	34	31	20	30	20	31	22	19	16	10
Fisher $\alpha$ -index		5	11	10	8 $\frac{1}{2}$	5	8	5	8 $\frac{1}{2}$	5	4 $\frac{1}{2}$	4	—
Number of specimens per cc sediment		16.2	28.8	28.1	20.7	12.3	19.0	14.5	16.2	10.1	19.3	12.4	<0.1
Number of planktonics per counted number of benthic forams		10	9	5	8	7	8	4	9	5	0	8	0

Table IX Distribution chart of benthic species at Grillos, exp. 723.

Species	Samples 723	A	B	C	D	E	F	G	H
<i>Ammonia beccarii</i> var. <i>beccarii</i>		—	—	—	—	—	—	—	8
<i>A. beccarii</i> var. <i>tepida</i>		99	163	189	6	—	—	283	270
<i>Elphidium granosum</i>		6	4	15	—	—	—	16	2
<i>E. granosum</i> var. <i>demens</i>		—	2	90	—	—	—	—	—
<i>E. semistriatum</i>		1	1	6	—	—	—	—	—
<i>Cancris auricula</i>		—	—	—	—	—	—	1	12
<i>Textularia agglutinans</i>		—	—	—	—	—	—	—	8
Total number of counted specimens		106	170	300	6	—	—	300	300
Total number of counted species		3	4	4	1	—	—	3	5
Fisher $\alpha$ -index		$\frac{1}{2}$	1	$\frac{1}{2}$	—	—	—	$\frac{1}{2}$	1
Number of specimens per cc sediment		<0.1	<0.1	0.5	—	—	—	2.8	19.9
Number of planktonics per counted number of benthic forams		6	2	—	—	—	—	—	3

Table X Distribution chart of benthic species at Kaiafas, exp. 313.

Species	Samples 313	A	B	C	D	E	F	G	H	I
<i>Ammonia beccarii</i> var. <i>beccarii</i>	70	35	12	1	2	5	20	20	7	
<i>A. beccarii</i> var. <i>inflata</i>	—	11	15	15	7	5	3	—	—	
<i>A. beccarii</i> var. <i>tepida</i>	46	27	19	8	15	15	24	—	—	
<i>Ammonia perlucida</i>	1	9	11	40	28	64	21	10	1	
<i>Elphidium advenum</i>	5	2	2	3	—	—	5	2	1	
<i>E. articulatum</i>	—	4	3	2	3	2	1	—	—	
<i>E. crispum</i>	7	9	9	5	5	4	4	—	2	
<i>E. excavatum</i>	—	—	—	—	1	—	—	—	—	
<i>E. granosum</i>	—	9	15	27	40	33	19	2	1	
<i>E. incertum</i>	—	—	1	3	1	3	2	—	—	
<i>E. minutum</i>	—	3	5	1	4	—	8	—	—	
<i>E. pulvereum</i>	2	—	—	—	1	—	1	—	—	
<i>E. semistriatum</i>	11	42	54	81	70	41	49	3	—	
<i>E. semistriatum</i> var. <i>minimum</i>	—	1	—	—	—	2	6	—	—	
<i>Nonion boueanum</i>	27	66	70	57	58	48	73	7	—	
<i>Cancris auricula</i>	10	4	12	1	18	18	26	—	—	
<i>Reussella spinulosa</i>	8	7	9	5	14	10	4	—	—	
<i>Fursenkoina schreibersiana</i>	2	3	3	7	5	14	10	—	1	
<i>Asterigerinata mamilla</i>	3	—	1	—	—	—	1	—	—	
<i>Cibicides lobatulus</i> var. 2	76	19	10	6	6	3	6	2	1	
<i>C. lobatulus</i> var. 1	1	7	10	—	—	—	—	—	—	
<i>Gavelinopsis praegeri</i>	—	—	—	—	—	1	—	—	1	
<i>Hanzawaia rhodiensis</i>	—	5	5	—	—	—	—	—	—	
<i>Planorbulina mediterraneensis</i>	—	—	1	—	—	—	—	—	—	
<i>Rosalina globularis</i>	1	2	—	1	—	—	—	—	1	
Miliolidae indet.	—	—	—	—	1	—	—	—	2	
<i>Sigmoilopsis celata</i>	—	—	—	2	—	—	—	—	—	
<i>Dorothia gibbosa</i>	—	—	—	5	—	—	—	—	—	
<i>Textularia agglutinans</i>	3	4	6	4	5	3	—	—	—	
<i>T. deperdita</i>	1	—	—	—	1	—	—	—	—	
<i>T. sp.</i>	—	—	—	2	—	—	—	—	—	
<i>Valvulineria complanata</i>	—	6	4	3	1	—	7	—	1	
<i>Cibicides dutemplei</i>	18	20	16	8	—	7	4	—	1	
<i>Bulimina elongata</i> subsp. <i>subulata</i>	1	—	—	—	—	—	—	—	—	
<i>Stainforthia complanata</i>	—	—	—	—	1	—	—	—	—	
<i>Bolivina pseudoplicata</i>	1	—	—	1	—	—	—	—	1	
<i>Coryphostoma</i> sp.	—	—	—	—	—	2	—	—	1	
<i>Cassidulina carinata</i>	2	3	1	—	—	1	2	1	—	
<i>Nonion depressulum</i>	—	—	—	3	9	6	—	—	—	
<i>N. paraliium</i>	—	—	—	—	—	—	1	—	—	
<i>Nonionella opima</i>	—	—	2	1	2	3	—	—	—	
<i>N. sp.</i>	4	1	3	7	1	9	2	—	—	
<i>Pseudopolymorphina incerta</i>	—	—	1	1	—	—	—	—	—	
<i>Rotalia granulata</i>	—	1	—	—	1	1	1	—	1	
Total number of counted specimens	300	300	300	300	300	300	300	300	47	23
Total number of counted species	22	25	27	28	26	24	25	8	15	
Fisher $\alpha$ -index	5	6 $\frac{1}{2}$	7	7 $\frac{1}{2}$	7	6	6 $\frac{1}{2}$	—	—	
Number of specimens per cc sediment	62.2	48.7	21.8	19.4	14.1	21.3	20.3	<0.1	<0.1	
Number of planktonics per counted number of benthic forams	15	25	20	15	20	4	6	1	—	

Table XI Distribution chart of benthic species at Agios Andreas, exp. 320.

Species	Samples 320	A	B	C	D	E	F	G
<i>Ammonia beccarii</i> var. <i>beccarii</i>		8	29	21	32	15	24	14
<i>A. beccarii</i> var. <i>inflata</i>		—	—	1	—	—	1	—
<i>A. beccarii</i> var. <i>tepida</i>		61	93	86	126	189	122	111
<i>Ammonia perlucida</i>		30	18	27	9	10	15	18
<i>Elphidium excavatum</i>		—	—	—	1	—	1	—
<i>E. granosum</i>		21	20	21	23	21	30	24
<i>E. incertum</i>		—	—	—	—	—	1	—
<i>E. minutum</i>		3	1	6	6	—	4	1
<i>E. semistriatum</i>		3	5	16	9	8	—	9
<i>E. semistriatum</i> var. <i>minimum</i>		68	52	26	34	36	28	69
<i>Nonion boueanum</i>		9	20	33	34	7	9	16
<i>Cancris auricula</i>		26	14	6	2	5	18	9
<i>Reussella spinulosa</i>		—	—	6	—	1	—	1
<i>Fursenkoina schreibersiana</i>		1	1	3	—	—	2	4
<i>Asterigerinata mamilla</i>		—	—	—	—	—	—	1
<i>Hanzawaia rhodiensis</i>		1	—	—	—	—	—	—
<i>Planorbulina mediterraneensis</i>		—	—	3	2	—	—	—
Miliolidae indet.		—	3	—	—	—	—	—
<i>Quinqueloculina longirostra</i>		1	—	—	—	—	—	—
<i>Quinqueloculina seminula</i>		3	—	13	—	—	—	—
<i>Q. vulgaris</i>		—	—	1	—	—	—	—
<i>Triloculina oblonga</i>		1	3	1	2	—	—	—
<i>T. trigonula</i>		1	—	—	—	—	—	—
<i>T. trigonula</i> var. <i>adriatica</i>		1	—	—	—	—	—	—
<i>Dorothia gibbosa</i>		4	—	12	—	—	—	—
<i>Textularia agglutinans</i>		47	39	12	15	7	30	16
<i>Cibicides ungerianus</i>		—	—	—	—	1	—	—
<i>Oridorsalis stellatus</i>		2	—	—	—	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>		—	1	—	—	—	—	—
<i>Bulimina marginata</i>		1	—	—	—	—	—	—
<i>Brizalina dilatata</i>		3	—	—	—	—	—	1
<i>B. spathulata</i>		1	—	—	—	—	—	—
<i>Coryphostoma</i> sp.		—	—	—	—	—	—	1
<i>Loxostomum alatum</i>		1	—	—	—	—	—	—
<i>Cassidulina carinata</i>		2	—	1	—	—	—	—
<i>Alabamina</i> sp.		1	—	—	—	—	—	—
<i>Nonionella</i> sp.		—	—	5	5	—	7	3
<i>Rotalia granulata</i>		—	1	—	—	—	8	2
Total number of counted specimens		300	300	300	300	300	300	300
Total number of counted species		25	15	20	14	11	15	17
Fisher $\alpha$ -index		6 $\frac{1}{2}$	3	5	3	2	3	4
Number of specimens per cc sediment		23.8	19.7	17.2	13.4	12.1	22.5	9.5
Number of planktonics per counted number of benthic forams		48	33	36	15	24	18	36

Table XII Distribution chart of benthic species at Pigadion I, exp. 703.

Species	Samples 703	A	B	C	D	E	F	G	H	I	K	L	M
<i>Ammonia beccarii</i> var. <i>beccarii</i>		68	76	3	107	58	132	163	217	145	84	112	—
<i>A. beccarii</i> var. <i>inflata</i>		—	—	—	—	1	—	—	—	—	—	—	—
<i>A. beccarii</i> var. <i>tepida</i>		208	164	21	126	85	73	47	19	95	6	89	274
<i>Ammonia perlucida</i>		—	12	—	11	10	28	8	14	5	5	73	7
<i>Elphidium advenum</i>		—	—	—	5	1	8	7	8	4	—	3	—
<i>E. crispum</i>		—	—	—	1	—	—	—	—	1	—	—	—
<i>E. excavatum</i>		—	—	—	3	3	—	—	—	4	—	—	—
<i>E. granosum</i>		—	1	—	9	2	5	6	6	10	2	—	5
<i>E. incertum</i>		—	3	—	4	1	12	12	1	1	2	—	—
<i>E. minutum</i>		1	9	—	4	11	—	—	—	1	—	—	—
<i>E. pulvereum</i>		—	—	—	—	1	1	—	1	—	—	3	—
<i>E. semistriatum</i>		2	—	1	—	—	5	24	4	—	—	6	—
<i>E. semistriatum</i> var. <i>minimum</i>		2	3	1	3	—	1	—	—	8	—	—	—
<i>Nonion boueanum</i>		—	—	—	1	—	3	4	2	2	3	—	—
<i>Cancris auricula</i>		—	—	—	5	—	4	3	4	2	—	—	—
<i>Reussella spinulosa</i>		1	3	—	1	1	1	3	5	—	—	—	1
<i>Fursenkoina schreibersiana</i>		—	3	—	—	2	4	4	1	—	—	—	—
<i>Asterigerinata mamilla</i>		—	—	—	1	—	1	—	—	—	—	—	—
<i>Gibicides lobatulus</i> var. 1		3	—	—	—	2	4	5	—	3	2	—	—
<i>C. lobatulus</i> var. 2		—	—	—	—	—	6	2	1	—	—	—	—
<i>Discorbinella theloti</i>		—	—	—	—	—	—	1	—	1	—	—	—
<i>Neoconorbina milletti</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Planorbulina mediterraneensis</i>		—	—	—	—	—	—	—	—	1	—	—	—
<i>Rosalina bradyi</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>R. globularis</i>		—	1	—	5	—	—	—	—	1	—	—	—
Miliolidae indet.		—	1	—	1	—	—	—	—	—	—	—	—
<i>Quinqueloculina duthiersi</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Sigmoilopsis celata</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Triloculina trigonula</i> var. <i>adriatica</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Textularia agglutinans</i>		—	3	—	—	1	—	—	—	5	—	—	—
<i>T. deperdita</i>		—	—	—	—	—	—	—	—	1	—	—	—
<i>Valvulineria complanata</i>		—	—	—	—	—	—	—	—	2	—	—	—
<i>Gibicides dutemplei</i>		—	—	—	—	—	—	—	—	1	—	—	—
<i>C. ungerianus</i>		—	—	—	—	—	2	—	—	1	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>		7	4	—	2	4	3	2	2	—	—	—	—
<i>B. marginata</i>		1	—	—	—	—	—	—	—	—	—	—	—
<i>Stainforthia complanata</i>		1	—	—	1	—	—	—	—	—	—	—	—
<i>Trifarina angulosa</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Bolivina pseudoplicata</i>		—	1	—	—	—	—	—	—	—	—	—	—
<i>Coryphostoma silvestrina</i>		—	1	—	—	1	—	—	—	2	3	—	—
<i>C. sp.</i>		—	1	—	—	—	—	—	6	—	3	—	—
<i>Cassidulina carinata</i>		—	—	—	—	—	1	2	2	—	—	—	—
<i>Ammonia bassleri</i>		—	—	—	1	—	—	—	—	—	—	—	—
<i>Nonion depressulum</i>		1	11	—	2	2	5	—	1	1	—	2	—
<i>N. paraliun</i>		—	—	—	3	—	2	8	5	—	—	12	13
<i>Nonionella opima</i>		5	—	—	—	1	—	—	—	—	—	—	—
<i>Pseudopolymorphina incerta</i>		—	—	—	—	—	—	—	—	1	—	—	—
<i>Rotalia granulata</i>		—	1	—	—	—	—	—	1	—	—	—	—
Total number of counted specimens		300	300	26	300	187	300	300	300	300	110	300	300
Total number of counted species		12	20	4	25	18	20	17	19	25	9	8	5
Fisher $\alpha$ -index		$2\frac{1}{2}$	5	—	$6\frac{1}{2}$	5	5	4	$4\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{1}{2}$	2	1
Number of specimens per cc sediment		3.2	11.5	<0.1	4.8	0.2	2.9	5.0	5.2	16.7	<0.1	3.5	2.3
Number of planktonics per counted number of benthic forams		6	5	2	4	6	6	4	0	2	0	0	0

Table XIV Distribution chart of benthic species at Pigadion III, exp. 703.

Species	Samples 703	GG	HH	II	KK	LL	MM	NN	OO
<i>Ammonia beccarii</i> var. <i>beccarii</i>	—	—	—	—	16	—	—	35	—
<i>A. beccarii</i> var. <i>tepida</i>	201	—	—	—	9	132	65	210	243
<i>Ammonia perlucida</i>	21	—	—	—	2	3	5	31	11
<i>Elphidium aculeatum</i>	—	—	—	—	2	5	—	—	—
<i>E. advenum</i>	4	—	—	—	19	5	2	—	5
<i>E. articulatum</i>	—	—	—	—	2	2	2	—	—
<i>E. complanatum</i> var. <i>tyrrhenianum</i>	—	—	—	—	—	—	1	—	—
<i>E. crispum</i>	1	—	—	—	6	7	—	—	1
<i>E. fichtelianum</i>	—	—	—	—	1	3	—	—	1
<i>E. granosum</i>	3	—	—	—	9	11	1	—	2
<i>E. incertum</i>	2	—	—	—	4	4	2	—	1
<i>E. minutum</i>	—	—	—	—	12	3	2	11	3
<i>E. pulvereum</i>	2	—	—	—	18	6	2	—	1
<i>E. semistriatum</i>	2	—	—	—	3	3	2	—	8
<i>E. semistriatum</i> var. <i>minimum</i>	—	—	—	—	4	—	—	—	4
<i>E. spp. indet.</i>	6	—	—	—	—	—	—	—	—
<i>Nonion boueanum</i>	2	—	—	—	—	1	—	—	7
<i>Cancris auricula</i>	—	—	—	—	—	1	2	—	—
<i>Reussella spinulosa</i>	1	—	—	—	1	2	—	—	1
<i>Fursenkoina schreibersiana</i>	1	—	—	—	4	—	—	—	1
<i>Cibicides lobatulus</i> var. 1	1	—	—	—	142	37	22	—	3
<i>C. lobatulus</i> var. 2	—	—	—	—	—	44	—	—	—
<i>Neoconorbina milletti</i>	—	—	—	—	6	9	—	—	—
<i>Rosalina bradyi</i>	—	—	—	—	—	2	—	—	—
<i>R. globularis</i>	1	—	—	—	10	12	4	—	1
<i>Quinqueloculina duthiersi</i>	—	—	—	—	1	—	—	—	—
<i>Textularia agglutinans</i>	26	—	—	—	2	1	—	—	—
<i>Cibicides ungerianus</i>	—	—	—	—	—	1	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>	1	—	—	—	8	1	—	—	—
<i>Trifarina angulosa</i>	—	—	—	—	3	—	—	—	—
<i>Bolivina pseudoplicata</i>	—	—	—	—	7	—	—	—	—
<i>Coryphostoma silvestrina</i>	—	—	—	—	—	1	1	—	—
<i>C. sp.</i>	2	—	—	—	—	—	—	—	—
<i>Cassidulina carinata</i>	1	—	—	—	—	—	—	—	—
<i>Fissurina sp.</i>	—	—	—	—	—	—	1	—	—
<i>Guttulina austriaca</i>	—	—	—	—	1	1	—	—	—
<i>Lagena sp.</i>	1	—	—	—	—	—	1	—	—
<i>Melonis barleeianum</i>	1	—	—	—	—	—	—	—	—
<i>Nodosaria sp.</i>	—	—	—	—	—	—	2	—	—
<i>Nonion depressulum</i>	18	—	—	—	8	1	—	3	—
<i>N. paraliium</i>	2	—	—	—	—	—	7	10	7
<i>Rotalia granulata</i>	—	—	—	—	—	2	—	—	—
Total number of counted specimens	300	—	—	—	300	300	124	300	300
Total number of counted species	22	—	—	—	26	27	18	6	17
Fisher $\alpha$ -index	5	—	—	—	7	7	6	1	4
Number of specimens per cc sediment	17.0	—	—	—	30.2	21.5	<0.1	?	3.3
Number of planktonics per counted number of benthic forams	6	—	—	—	12	5	2	0	1



continued table XIII.

Species	Samples 703	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF
<i>Q. seminula</i>		—	—	2	—	—	4	—	5	7	—	7	12	—	—	—	—	1	—	—
<i>Q. vulgaris</i>		—	—	—	—	—	13	—	5	4	—	8	4	—	—	—	—	—	—	—
<i>Q. spp. indet.</i>		—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Sigmoilina grata</i>		—	—	—	—	—	6	—	2	—	—	1	—	—	—	—	—	—	—	—
<i>S. tenuis</i>		—	—	—	—	—	—	—	1	5	—	—	—	—	—	—	—	—	—	—
<i>Sigmoilopsis celata</i>		—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Triloculina oblonga</i>		—	—	—	—	—	2	—	2	1	—	4	1	—	—	—	—	—	—	—
<i>T. trigonula</i>		—	—	1	—	—	15	—	2	6	—	—	5	—	—	—	—	—	—	—
<i>T. trigonula var. adriatica</i>		—	—	—	—	—	11	—	5	15	—	7	2	—	—	—	—	—	—	—
<i>Eggerella scabra</i>		—	—	—	—	—	4	—	—	2	—	4	—	—	—	—	—	—	—	—
<i>Textularia agglutinans</i>		—	—	—	—	—	6	—	5	—	—	4	—	—	—	—	—	—	—	—
<i>T. deperdita</i>		—	—	—	—	—	—	—	5	1	1	—	2	—	—	—	—	—	—	—
<i>Valvulineria complanata</i>		—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—
<i>Cibicides dutemplei</i>		—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—
<i>C. ungerianus</i>		—	—	—	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—
<i>Bulimina elongata</i> subsp. <i>subulata</i>		—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>Trifarina angulosa</i>		—	—	1	—	—	1	3	—	1	—	1	—	—	—	—	—	—	—	—
<i>Bolivina pseudoplicata</i>		—	—	1	1	—	1	9	5	2	1	4	4	—	—	—	—	—	—	—
<i>Coryphostoma silvestrina</i>		—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Globocassidulina oblonga</i>		—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Ammonia bassleri</i>		—	—	—	—	—	—	5	—	3	10	6	4	—	—	—	10	—	—	—
<i>Fissurina</i> spp.		—	—	—	—	—	—	8	—	—	2	—	2	—	—	—	—	—	—	—
<i>Guttulina austriaca</i>		—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Lagena</i> spp.		—	—	—	—	—	1	3	1	—	1	—	—	—	1	—	—	—	—	—
<i>Lenticulina</i> spp.		—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—
<i>Nonion depressulum</i>		—	—	—	2	5	—	—	2	3	1	—	2	14	2	7	—	—	4	6
<i>N. paraliium</i>		—	—	—	—	17	—	—	3	1	—	—	—	2	—	—	—	—	—	—
<i>Nonionella opima</i>		—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
<i>N. sp.</i>		—	—	2	2	9	—	—	—	1	—	—	—	—	—	—	—	—	—	—
<i>Pseudopolymorphina incerta</i>		—	—	2	—	—	2	—	—	—	—	—	1	—	1	—	—	—	—	—
<i>Rotalia granulata</i>		—	—	1	—	—	1	—	—	—	—	—	—	1	—	2	3	1	—	2
<i>Siphonina</i> sp.		—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Total number of counted specimens		—	—	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Total number of counted species		—	—	26	15	19	49	29	40	39	21	31	29	13	12	15	13	14	14	15
Fisher $\alpha$ -index		—	—	7	3	4 $\frac{1}{2}$	14	8	11	11	5	8 $\frac{1}{2}$	8	3	2 $\frac{1}{2}$	3	3	3	3	3
Number of specimens per cc sediment		0	0	?	3.4	30.0	279	29.5	90	154	72	24.8	32.3	22.8	6.4	15.9	20.1	4.3	7.0	4.7
Number of planktonics per counted number of benthic forams		—	—	—	1	—	6	—	5	6	1	2	0	0	31	0	6	0	2	1

STRATIGRAPHIC COLUMNS	FREQUENCY DIAGRAMS	SEDIMENTOLOGICAL SYMBOLS
 Fine Sand	 ( <i>Globo</i> ) <i>Cassidulina</i>	 Parallel lamination
 Coarse Sand	 " <i>Brizalina</i> "	 Small scale cross lamination
 Clay	 <i>Uvigerina</i> " <i>Bulimina</i> "	 Large scale low angle cross lamination
 Silty Clay	 Biconvex trachoid spp.	 Slumping
 Silt	 <i>Valvulineria complanata</i>	 Scour and fill structure
 Limestone	 Agglutinants	 Indurated level
 Gypsum	 Miliolids	 Bioturbation
 Lignite	 Plano-convex spp.	<b>PALEONTOLOGICAL ABBREVIATIONS</b>
 Conglomerate	 <i>Fursenkoina schreibersiana</i>	C <i>Cardium</i> single (C) scattered few double (CC) abundant
 Breccia	 <i>Reussella spinulosa</i>	G Gastropods
 Mollusc Shells	 <i>Cancris auricula</i>	M Molluscs
	 <i>Nonion boueanum</i>	O Oysters
	 <i>Elphidium</i>	P Pelecypods
	 <i>Ammonia pertucida</i>	PI Plant remains
	 <i>A. beccarii tepida</i> <i>A. beccarii beccarii</i> <i>A. beccarii inflata</i>	V Venus
		<b>LEGEND</b>

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