EDITORS: L. HOTTINGER, K. DROBNE

PALEOGENE SHALLOW BENTHOS OF THE TETHYS

IGCP 286

CERA - DE A SAZU, 34/2

The 20 million years after the events at the Cretaceous-Tertiary boundary, when the dinosaurs became extinct, is a very particular period of Earth History. During that time, the diversity of life on Earth recovered step by step. A detailed history of this recovery may give a clue as to how life diversifies and why.

The present volume is a collection of historical documents illustrating some of the many facets of this recovery, documents that may help to show a more accurate general picture, and to brighten with their emphasis on recovery, the gloomy view of the Cretaceous-Tertiary catastrophes, as it is conceived by the genius of our time. This is the second of three volumes, presented under the common title ***Paleogene Shallow Benthos of the Tethys***. The present volume is focused on groups of conservative organisms such as dasyclad algae or ostracods, whereas the next will be dedicated to organisms evolving more rapidly.

The first volume presents an extensive updated bibliography on the subject. Together all three volumes, Dela-Opera SAZU 4 razr. 34/1-3, will show where and how to place the documents presented here in the general knowledge of our time.

The Editors: Lukas Hottinger, Katica Drobne

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PALEOGENE SHALLOW BENTHOS OF THE TETHYS, 2

Lukas HOTTINGER, Katica DROBNE
The Editors

Ljubljana
1998

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Hans Schaub

Dela – Opera SAZU 4. razr., 34/2, 6–10 Ljubljana 1998

In memoriam

HANS SCHAUB, 1913–1994

On 3rd of October, shortly after his 81st birthday, Professor Hans Schaub peacefully died in a Basle hospital, a finished manuscript for correction on his lap. A couple of days before, he actively had participated in the IGCP 286 final meeting in Aspet, southern France, and had introduced a student to field work in the Campo key-section in northern Spain.

Born in 1913 in Sissach, then a village in the countryside in the vicinity of Basel, he was educated to become a teacher for mathematics and geography at middle and high school. Beside his teaching activities at the Realgymnasium in Basel, he extended his studies at the Geological Institute of Basel University to Geology and Paleontology. His PhD thesis, delayed by long military service during World War II, focussed on the nummulites of the Schlierenflysch in order to interpret the controversial age of this long turbiditic sequence of prime importance for understanding alpine tectonics. Illustrated by numerous camera lucida drawings, his thesis — printed in 1951 — represents the first modern standard monograph on the genera Nummulites *and* Assilina *and their numerous species.*

The biostratigraphic distribution of the nummulites in the Schlierenflysch sedimentary sequence documents a succession of two main assemblages of species through time. Previously, similar assemblages and their species had been described in the Aquitaine basin (southern France) where they occur respectively in the eastern and western part of the basin. No stratigraphic relationship between the two assemblages had been observed in the Aquitaine. Their age relations, based on molluscs, had been misinterpreted in inverse order compared to the sequence of faunas in the Schlierenflysch. A lively discussion, mainly with French workers, arose about this discrepancy and resulted in the proposition of a new stage name, the Ilerdian, for the time period represented by the earlier Schlierenflysch and Eastern Aquitaine assemblage in contrast to the old Paris Basin stage name "Cuisian" to be apllied to the later Schlierenflysch assemblage and to the faunas of Gran near Paris and their Pyrenean and other north Italian equivalents in age. Hans Schaub's biostratigraphic conclusions derived from the Schlierenflysch succession were supported first by parallel investigations on alveolinid species and confirmed soon after by the rising nannoplankton (Discoaster) *stratigraphy.*

The biostratigraphic success in the Pyrenean realm confirmed the species concept conceived by Boussac for nummulites and carried through for biostratigraphic use by Hans Schaub: Multiple, parallel phylogenetic lineages evolving with different rates of progress through geological time. With the accurate registration of external and internal shell morphology of numerous specimens reproduced as drawings or photographs at standard enlargements for simultaneous comparison, the much

enhanced resolution power of the paleontological taxonomy permitted a regular biozonation subdividing the stages previously used as time units into 3–6 zonal sub-units each representing roughly one million years. Since the late fifties, Hans Schaub continued to elaborate the phylogenetic and biostratigraphic system of the nummulites by extending his area of research to all circum-mediterranean countries. A visit to the type sections on the Crimean peninsula, as well as material collected by oil companies from Libya contributed much to complete an overall picture of this exceptionally frequent and successful genus with its over 400 species evolving through 21 million years. The material collected during a life-time from all over the western Tethyan realm is stored in the Basle Museum as a carefully cured, huge collection of free shells of nummulites and assilinas documenting most known species not only with numerous prepared specimens from many localities but also by thousands of photographs. In the same time, washed but unsorted material of most localities studied by Hans Schaub will be available to the next generation of nummulite workers for further studies.

Hans Schaub published his life-time's work as a monumental, amply illustrated monograph in 1981. He has lived long enough to observe the international response to his book and to become assured of its standard value for many decades to come. His last manuscript on the nummulites of Israel will provide a valuable complement to his 1981 monograph where only a part of the faunas characterizing the North African faunal province are described. This paper will be published in Mémoires Suisses de Paléontologie (Basel).

In 1940, the large-sized monograph series of the Swiss Paleontological Society was separated from the latter and changed its name to "Mémoires Suisses de Paléontologie". The original numbering of the volumes was kept up nevertheless. Being the youngest member of the previous board, Hans Schaub took over the heavy task of an editor for all the volumes 63 to 107 published between 1942 and 1984, with the support of a new board elected directly by the Swiss Academy of Sciences. For more than four decades, Hans Schaub has managed to keep up the traditional, extraordinary quality of reproduction of the plates characterizing the "Mémoires Suisses" up to the present day, in spite of changing concepts of publication in the scientific community as well as of the dramatic change in printing technology and management. Thus, Hans Schaub provided a generation of Swiss paleontologists with exceptional means of publication for which we all are particularly grateful.

For many decades up to his last year, Hans Schaub has participated in mapping the alpine geology on sheet 379 Alpnach for the Geological Atlas of Switzerland on behalf of the Swiss Geological Commission. His last scientific grief was to have to leave his maps unfinished.

In 1958, Hans Schaub entered the staff of Basel University and received his professorial title one year later together with his directorial functions at the Natural History Museum of Basle, the largest of its kind in Switzerland. As director of the Museum he succeeded in transforming the somewhat sleepy curio cabinet into an institution promoting a scientific dialogue with the public and supporting modern research. Much of his time was devoted to realize the huge underground storage rooms built as air raid shelter under the still lively impression of what had happened to German museums during World War II. Ample, additional storage room was the prerequisite to disengage the show rooms of the museum from their vast and important scientific collections in order to gain space for modern exhibitions.

Hans Schaub was a passionate and gifted, occasionally even obsessed teacher with extensive professional experience aquired during his active years at high scool. At the university of Basel, his lectures covered general Earth History, methodology of litho-, bio- and chronostratigraphy, Paleogene alpine stratigraphy and nummulitic biostratigraphy and paleontology. For many years he lectured at the so-called Volkshochschule, a Laymans' high school organized by the University for a general public. He participated as well in the lecturing for the general public seniors, one of the most successful teaching endeavours of the university attracting for each lecture twice the capacity of the Universities' largest auditory.

Maybe, the intensity and occasional obsession in what he had to say about nummulites and their stratigraphy prevented him to have many disciples in nummulitic research. However, one thesis of very high quality was prepared under his impulsion and supervision by Ch. Kapellos providing an important and very welcome complement enriched by nannoplankton stratigraphy to Hans Schaub's work on the Schlierenflysch.

For many years, Hans Schaub represented Switzerland on the board of the so-called European Micropaleontological Colloquium organizing sam-

pling trips to European type or key localities in order to provide research laboratories of oil companies and universities with identical material, a kind of permanent paleontological intercalibration excercise. Nobody than a nummulite specialist would know better how important the availability of topotype material may be for identification or revision of ancient taxa on the species level. The 9th European colloquium was organized in Switzerland by Hans Schaub and Hanspeter Luterbacher in 1965. On this occasion, they edited an excursion guide providing an overview of the Swiss microfossil assemblages by a common effort of all Swiss micropaleontologists active at that time. These common trips were also a valuable means of mutual stimulation between academic and applied research involving also Hans Schaub as a specialist of shallow water Paleogene biostratigraphy in questions of applied geology. Hence, he supervised for instance Roger Lehmann in writing and illustrating an extensive report on nummulites for Exxon.

Hans Schaub, unconditionally opposed to nazism during World War II, committed himself to politics as a member of the socialist party and represented the latter in the Basle parliament from 1964–1976. He was a member of the Basle educational council from 1954 to 1984.

Country life was Hans Schaub's main recreational activity. His comfortable farm house far from town in Reigoldswil will be remembered by many colleagues visiting his hospitable permanent residence. In Dobrinj, a little village on the island of Krk in the Adriatic, he spent many summer holidays in the midst of olive trees, wine yards and nummulite bearing outcrops. The profession loses a colorful, good humored and equilibrated, very hard working colleague loyally supported in his multiple and often tiring tasks by competent professional assistance in the Natural History Museum in Basel and by a courageous and understanding wife.

Lukas Hottinger

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THREE LEVELS OF ABSTRACTION IN THE STUDY OF THE FOSSIL RECORD. AN INTRODUCTION TO ACTIVITIES WITHIN IGCP 286 EARLY PALEOGENE SHALLOW BENTHOS

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Key words: Shallow Benthic Zonation, (SBZ), Global Community Maturation (GCM), taxonomical hierarchy, mass-extinction, recovery events.

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The project 286 "Early Paleogene Shallow Benthos" in the frame of the International Geological Correlation Program was conceived as an 8 year study of the recovery of the shallow marine communities after the K-T boundary event including, as prerequisite, a revision of the biostratigraphic system and of the corresponding index taxa. The initial project was turned down but a second version, focussing on the time-correlations in the Early Paleogene and in particular of the Paleocene was finally accepted for 5 years in 1989. Although the main goal of this project was primarily a biostratigraphic one, the initial idea was kept up in the background. The results of the reinvestigation and updating of the biostratigraphic zonation of shallow benthic organisms and their direct correlation in particular with the magnetostratigraphy are given in Serra-Kiel *et al.* 1998 in the form of a revised zonation according to a system of numbered units (SBZ 1–20) for the Paleocene-Eocene as a whole. The traditional identification of the biozones by the names of index fossils, although preferable for mnemotechnical reasons, proved to be impractical because of the taxonomic revision of several index fossils enforcing changes of species names. The latter are, at present, not yet complete and risk to produce some instability in foraminiferan nomenclature for some time. The SBZ biozones were discussed at the final meeting of the project in Aspet 1994 and accepted by the participants in plenary session.

This zonation attempts to correlate the shallow water deposits of the low latitudes in the tethyan realm reaching from the Eastern shores of the Atlantic, as preserved in particular in Spain, to Eastern India and the Himalayans. The review in the field of Paleogene sections in the Salt Range and the Kohat Basin (Pakistan) represents a cornerstone for the establishment of transtethyan long-range biota-based correlations. The detailed meaning of the SBZ biozones based on these correlations is discussed by J. Pignatti in this volume.

The present and a subsequent, forthcoming volumes of Dela – Opera SAZU unite a number of contributions elaborated by participants of IGCP 286, papers which illustrate and support the SBZ zonation by reviewing the distribution of index fossils in particular sections of regions and/or describing or revising some key index

Fig. 1: Participants of the "IGCP 286" meeting in Postojna 1991.

fossils. Other contributions to IGCP 286 have been published elsewhere, as excursion guides for the IGCP meetings, or, for various reasons in other periodicals (Schaub *et al.*, 1995; Sirel 1996, 1997; Carbone *et al.*, 1993; Pugliese *et al.*, 1995 etc.). Aditional contributions are in preparation. In particular, the paleontological revisions or descriptions of new index taxa springing from the extensive study of the material collected during the numerous field trips will take time.

IGCP 286's view of shallow benthic faunal recovery after the K-T boundary events have been presented as contribution to IGCP 335 (Hottinger, 1997b) at its final meeting in Prague 1997, where in particular Kauffman's recovery model (1994) was exposed to discussion. In 1996, a new IGCP project, headed by E. Caus (Barcelona) was accepted for another 5 years under the number 393. This successor project to 286 shifts the focus to the transition Middle-Upper Eocene and tries in the same time to illuminate the corresponding faunal turnover in shallow benthics which seems not to be enforced by major environmental change.

The review of numerous shallow water sedimentary sequences and of their fossil content throughout the Tethyan realm permits to draw a picture of the events following the so-called mass-extinction at the K-T boundary. The new zonation permits to subdivide the time frame of this process of recovery in successive steps, four in the Paleocene and several more in the earliest Eocene, if the Paleocene-Eocene boundary is placed at the base of SBZ 5 as advocated for practical reasons by the participants of IGCP 286. The activities under this project have taught us to operate not only with diversity, i.e. the change of taxa richness with time, but to recognize the biological significance and ecological meaning of those taxa that are generated during this time interval as part of a process of ecological recovery in contrast to the survivors from Late Cretaceous.

Accordingly, the foraminiferal recovery from mass extinction means a reconstruction of K-strategy in foraminifera which is reflected by the reappearance of large-sized shells with gradually increasing dimorphism of the adult and/or the embryo, by a long ontogeny and by structures related to symbiosis. If there is a parallel phenomenon at the opportunistic end in the K-r gradient, in particular in the infaunal shallow benthics (buliminids, bolivinids), remains to be cleared by carefully comparing the corresponding faunas of the Late Cretaceous with the ones of Early Paleogene.

By trespassing the purely quantitative aspect of faunal turnover we step into the realm of qualitative change of the biota and of their environment during and after the so-called mass-extinction event, a step into the current debates about neocatastrophism (Glen, 1994). This is not the place to enter this discussion but, by introducing the contributions of this book susceptible to provide data and arguments for the debate, a general *caveat* seems appropriate if not necessary.

Mass-extinction and recovery means loss of the genetic information specific to the taxon considered on a world-wide scale. True biozonations operate with the

assumption that, from one time slice to the next, the genetic information of the index taxa is effectively lost and/or substituted by new genomes world-wide. This assumption is derived from empirical biostratigraphic knowledge based on the prediction that assemblage b will always be following assemblage a in the stratigraphic record. Hay (1972), Hay and Southam (1978) and Guex (1991) have elaborated the mathematical methods to verify or falsify biostratigraphic predictions.

The index taxa of the zonation, as defined by their phenotypes, are delimited (within a phylum) by testing their intraspecific morphological variability in the time gradient of the zonation. The resolution power of the method gets to its limits where the statistically least significant difference of the relevant morphological characters is reached when comparing the populations in two consecutive stratigraphic levels. Thus, the concepts of biozones and species are linked and depend on phenotypic change in geologic time within a phylum. The smallest correlatable time unit, a biozone, represents a time laps of the order of magnitude of 1 mio years. The moment of generation or extinction involving genetic change or destruction can not be indicated with more accuracy by definition of the taxon since the latter's range must be correlatable within the zonal scheme, if we want to be certain to recognize significant change in the genome or its substitution instead of local or regional presence or absence of a population depending on suitable or insuitable environments.

Consequently, time correlations between generation or extinction of taxa and abiotic events in Earth History produce a causal link only if the processes involved are slow enough to support the fuzziness of the one-million-year steps in the timescale. Processes such as the impact scenario with its consequences of "nuclear winter" etc. are too short lived to be causally linked to extinction patterns by biostratigraphic time correlations. This does not mean, that causal links between impact and mass-extinctions could not exist, but biostratigraphic time correlations are, however, not the appropriate instrument to prove it.

On the other hand, the local or regional sedimentary sequence may be subdivided into much smaller time units by high-resolution lithostratigraphy based on any kind of the sedimentary layers and stable isotopic signals to their magnetic susceptibility. Such time scales may be used to locally or regionally measure the rates of change in environmental conditions and of their effects on the presence, absence or frequency of taxa in ecological gradients. On this (lower) level of abstraction, the significance of generation and extinction of taxa can not be studied since we do not know, if the absence of a particular taxon from an assemblage is due to true extinction or to a lazarus phenomenon (Kauffman and Erwin, 1994), where the taxon will reappear where and when even appropriate environmental conditions are restored.

A third level of abstraction is produced when arguing on ranges of genera (or taxa of even higher rank) which is often the case in the mass-extinction debate. In contrast to the situation in so many other groups of organisms, the current concept of genus and species in Mesozoic to recent larger foraminifera (not fusulinids) is clear: genera are distinguished by qualitative characters of their phenotypic morphology, species by quantitative ones. In recent shallow faunas, the diversity in the depth gradient of species relative to the diversity of genera is not proportional in respect to total specific and generic diversity in the area (Hottinger, 1990): with rising specific diversity towards depth, the number of congeneric species rises out of proportion. This means that the quantitative differences in shell shape and size between foraminiferal populations have another, depth-dependant, and therefore ecological significance than the quality differences of the shell architecture separating different genera. The latter, if differing by patterns of arrangement in equivalent elements (stolons, pillars, septula etc.), reveal a different genetic history rather than different functionality. Nevertheless, the genus is not simply a category of classification on a higher level of the hierarchy in systematics but has a particular ecological meaning which is not expressed in the functional morphology of the shell but may be inferred from its comparatively large genetic distance from its neighbour in the community. Apparently, the rising stress in successivelly shallower water diminishes the overall diversity but favours the degree of disparity between the reduced number of participant populations in the community. This might be a device to reduce competition between the foraminiferal populations.

The results of IGCP 286 have clearly shown, that the significance of a taxon at genus level depends also on the historical situation in which the genus occurs: in early phases of a global community maturation cycle (GCM, Hottinger, 1997a) most genera are monotypic and "behave" therefore like species, while in later GCM stages a low number of genera with successful shell architecture are split into several or numerous parallel phyla (as in *Orbitolina, Alveolina, Nummulites* etc.) differing by quantitative characters of species rank only. Ecologically, the coexisting phyla play as diversified participants in the community a role similar to the one of the monotypic (or monophyletic) genera in earlier GCM cycle stages. Thus, when operating with generic ranges, we move on a third level of abstraction which integrates the additional concepts of community maturation and taxonomical hierarchy ranking phenotypic characters according to their qualitative or quantitative nature.

Table 1 may help to use the data in this book for further analysis by classifying the appropriate terms according to the three levels of abstraction discussed above, separately in respect to operations with a single taxon (or phylum) or with biotic assemblages of numerous taxa.

Table 1. Levels of abstraction in the study of the fossil record

Levels of abstraction	biological units	extensions in space	extension in geologic time (time size-class per unit, in years)	processes admitting time correlations as valid argument for causal relationships
Single taxa: A	deme population	habitat	one or several bed(s) (<1–10^5)	population dynamics seres
B	species	area	one or several biozone(s) (10^6)	"micro"-evolution extinction
C	genus	biogeographic range of all species involved	biostratigraphic range of all species involved (10^6–10^8)	"makro"-evolution
Multiple taxa: A	biotic association	biotop	in single outcrops or beds	successions
	guild	biotop or habitat	in single outcrops or beds	strategies for common exploitation of ressources
B–C	biocoenosis community	biotop; faunal province	one or several assemblage zone(s)	coevolution; global community maturation (GCM)

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THE PHILOSOPHY OF LARGER FORAMINIFERAL BIOZONATION — A DISCUSSION.

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Note

The present article was written in December 1991, shortly after the second IGCP 286 meeting, held in Postojna (Slovenia). With minor changes, it was sent as an internal circular to all participants of the third IGCP 286 meeting (Ankara, October 1992). In the latter meeting, as well as in the final one of Aspet/Toulouse in 1994, the decision was taken to adopt a new biozonation (the Paleogene "Shallow Benthics" zonation, SBZ). This new, continuous zonation, directly correlated to an integrated magnetostratigraphic framework, differs in principle from the Oppelian approach and postulates biochronozones. Nevertheless, a slightly modified form of the original paper is presented here, as it may help in understanding the internal debate which preceded the final IGCP 286 decisions.

Key words: Chronostratigraphy, biostratigraphy, larger forminiferal (LF) biozones, Oppelzones, traditional stages, stratotypes, sequence stratigraphy.

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INTRODUCTION

Recent developments in physical stratigraphy address the question whether the time for biostratigraphy's swan song is getting close. The gap between how biostratigraphers collectively view themselves and how they are viewed by others is distinctly widening. After the lively debate which preceded the birth of the International Stratigraphic Guide, some sort of acquiescence to its formal aspects has prevailed. Despite this consensus, splits occurred within the biostratigraphers' front, leaving the rationale underlying biozonation an almost neglected issue. Notable exceptions are to be found in the field of computer-based, quantitative and probabilistic treatments. Little is made of the fact that, although various parallel zonations based on microfossils exist, these scales are built using fundamentally different methods and founded on a very different interpretation of the fossil record. A stimulating forum on the rationale of biozonation and stratigraphic correlation as the one provided by the October 19–25, 1991 Meeting of the IGCP 286 working-group, held at Postojna (Slovenia), represented thus — *vox clamans in deserto* — a welcome exception. Notwithstanding the limited number of participants and their mainly larger foraminiferal background, the discussion went beyond the biostratigraphic units based on these organisms, addressing the stratigraphic meaning of the fossil record and casting some light on the "philosophy of biozonation". Consensus on some principles in biozonation based on larger foraminifera (LF) was achieved among the participants, although starting from different approaches to classification and phylogeny.

Biostratigraphy is a classical and controversial field in Geology. A modern reclothing of it is actually unnecessary, also because there are several comprehensive albeit sometimes formal treatments. For those who like "geologese", glossaries by Schindewolf (1970), Hedberg (1976) and Sigal (1984) among others provide adequate references. This allows to comment here upon few selected topics only. The main thesis which shall be discussed herein is that the theoretical backbone of the classical Paleogene LF biozonation is essentially the same as that which marked the birth of biostratigraphy as a separate discipline, i.e. that the classical, discrete LF zones are Oppelzones. In contrast, continuous (Guex, 1987) biostratigraphic scales (interval, peak and acme zones), widely used in plankton and nannoplankton zonations, differ both in theory and in practice from those based on discrete units, and they moreover rely on a different rock record.

THE PLANKTONIC MICROFOSSIL DATUM PLANE APPROACH: ECHO OF THE DEEP OCEANS

Since the 1960's, also because of deep-sea drilling research, the development of planktonic-microfossil zonations has marked a tremendous progress in global age-determination and correlation. In planktonic microfossil biostratigraphy wide use is made of interval zones, based on FO/FAD's and LO/LAD's (First — respectively Last — Occurrence/Appearance Datum), of peak and acme zones, based on MO/LO's (Maximum resp. Lowest Occurrence), and, more recently, of quantitative or probabilistic treatments. These zonations are continuous and the limit between two biozones is an ideal surface (the datum plane). Guex (1987) discussed in detail the differences between discrete and continuous biozonations, elucidating some pitfalls of these treatments, which does not imply in the present author's opinion that they should be rejected, but signify their discrepancy with other methods. However, microfossil zones are not always continuous in the meaning of the term in Guex (1987), and may in some instances (e.g. in the case of the unitary associations of Baumgartner, 1984) be in fact analogous to the discrete, concurrent-range zones used in LF biozonation. The synthetic effort of Bolli *et al.* (1985) provides an-up-to date review in microfossil biozonation and correlation. At present it seems that a much deeper insight in the phylogeny of the various microfossil groups exists than previously, thus precluding some potential errors linked with the problem of species or subspecies recognition along evolutionary lineages. However, the dominance of these datum planes and markers in biostratigraphy appears sometimes to be accompanied by the assumption that these get closer to some sort of stratigraphic ultimate truth, probably because of their practical use. Their limits become evident when the different proposed biozonal schemes are compared: uncertainties in correlation remain still considerable. There being continuous biozonations does not imply that these continuously record geological time: although the pelagic record is much more complete than the continental-margin record, it is equally affected by limitations. The concept of a "continuous" record conflicts with the sedimentation rates in the deep-ocean domain (<1 cm/1,000 years), which allow them to be considered as condensed sections (Loutit *et al.*, 1988); mention is made that the occurrence of hiatuses in deep-water successions is so widespread that use of the latter as correlation planes has been proposed (Keller *et al.*, 1987). Moreover it must be underlined that the degree of stratigraphic resolution of most planktonic zonations does not differ significantly from the one provided by LF-biozonations, at least for the Upper Paleocene-Eocene timespan, in which LF assemblages reach a high temporal acuity. Moreover, although to lesser degree, microfossil zonations reflect different approaches similarly to the ones existing in LF zonations (see discussion below).

The thought that FO/LO should be dismissed in LF biostratigraphy is clearly unwarranted, but it has to be stressed that the value of FO's and LO's is not uniform. As far as LO data are concerned, the bias or overprint arising from taphonomic (mainly, reworking), ecological (environmental controls on the distribution of age-diagnostic organisms) or biogeographical factors (migrations) are the most obvious limiting factors and make their use often difficult. Besides, in many instances the very meaning of FO's is unclear, time and different shallow-water depositional environments being discontinuously represented in the rock record, and especially in the continental margin domain, as reflected in depositional cycles. As to FO's, an important point at issue is the taxonomical rank of the concerned forms (genera, lineages, species). While biostratigraphic constraints based on FO's of LF genera and lineages are easily recognizable and commonly used, defining biozones with FO's, especially those of single species within lineages, may be often a matter of interpretation and a source of error. Due also to intrinsic limitations of LF study, only in very few cases there exist high-resolution range charts or range-through charts (the latter are discussed in Boltovskoy, 1988). This seems at present one of the most urgent needs in Paleogene LF studies.

CONFLICTING CONCEPTS IN LF CLASSIFICATION AND THEIR BEARING ON BIOSTRATIGRAPHY

A basic principle on which biostratigraphers are agreed is that "true" biozones should be founded on taxa whose position within an evolutionary lineage is known (Schaub, 1981). A corollary of this is that the limits of the biozones depend directly on (and are as artificial as) the

definition of the taxa they are based upon within a given morphological group (Hottinger *et al.*, 1964; Maples & West, 1991). As in other taxonomical groups, evolution in LF has been explained advocating various models, ranging from gradualism to punctuated evolution (Eldredge & Gould, 1977; Drooger & De Klerk, 1985). It is however difficult to prove or refute alleged punctuating (Martín-Closas & Serra-Kiel, 1986) or gradualistic patterns in the evolution of LF, in particular when biometry is involved. Since the methods employed in morphometrics are often biased by reductionism, their meaning in the complex scenario of changing environmental conditions and evolutionary modes and patterns in time is uncertain. Any interpretation to support these theories depends on the criteria used to define morphology and its change in time. The irreversibility of time and evolution vindicates biostratigraphy's aim to measure time through the assessment of morphological change in organisms. The study of morphological change in LF and their classification basically follows two different approaches (typological vs. biometrical), which advocate also different types of biozones.

THE BIOMETRICAL APPROACH TO LF CLASSIFICATION AND BIOSTRATIGRAPHY

The biometrical or morphometrical investigation of LF, in particular of the embryonal features, is the main taxonomical approach of most specialists in orbitoidal or radial (Drooger, 1993) foraminifera (in particular the "Utrecht school"), at least at the lineage or species level. Species rank taxa, generally treated as formed of semi-statistical populations, are defined as morphometrical units. Accordingly, most orbitoidal LF biozones, based on the formal recognition of taxa by subdividing lineages representing a morphometrical *continuum* are phylozones, assertedly artificial except for a few cases of documented punctuations (Drooger & De Klerk, 1985). Although it is always possible to detect differences among "populations" along a vertical sequence, the role of critical factors as the incompleteness of the stratigraphic record, the obliteration of the characters of biological populations in it, and the difficulty of distinguishing minor adaptive shifts related to environmental changes from evolutionary change (Eldredge & Gould, 1977), remains often to be ascertained. Specialists in orbitoidal foraminifera advocate that biozonations should be either based on FO's or on conventional boundaries between species, drawn in order to subdivide lineages for fitting the biozones. An example of this mixed biostratigraphy (datum planes based on genus-level FO's plus conventional morphometric boundaries between species of the same lineage) is the Chattian LF biozonation by Drooger & Laagland (1986) and Laagland (1990), which is the most detailed LF biozonation for this timespan in the Mediterranean Neotethys. Biometry alone seems so far to suffice for biostratigraphic purposes only in comparatively simple, one-lineage cases, e.g. in the European lepidocyclinid or miogypsinid phylozonal biostratigraphy, although also in this instance there is conflicting evidence on the number of lineages. It might be rewarding to test whether for the same timespan a biozonation of analogous temporal acuity can be obtained *via* the typological approach or not.

THE TYPOLOGICAL APPROACH TO LF CLASSIFICATION AND BIOSTRATIGRAPHY

The typological approach to LF taxonomy has been widely used by Hottinger (1960) and by the members of the "Basel school" in general. In analogy with the typological classification, "typological" LF biostratigraphic correlation is done by comparison of the association in study with (ideally two) other ones (types) at a time. "In the comparison of single forms, the type is firstly the *tertium comparationis* and allows the correlation of a multitude of the former to an ideal centre. In the course of its utilization, the type appears more and more as the expression of objective necessity; the singular forms are related to it in a similar way as singular cases to a law." (A. Naef, *Idealistische Morphologie und Phylogenetik*, 1919, p. 11; my translation from the German).

Typologically defined LF biozones are composite (or concurrent-range) zones, based on faunal assemblages of both concurring and mutually exclusive species from key-localities (the "types"), each of which occupies a definite position within the LF biozonation scale (Hottinger *et al.*, 1964; Schaub, 1981). Key-localities or levels and their LF faunal content are those which allow to tie or characterize the LF zonations within a given paleobiogeographic domain, allowing also for the recognition of vicariant taxa in other areas. Formal establishment of "stratotypes" for LF biozones is deemed unnecessary, as in the case of Oppelzones, and may even become misleading (Hottinger *et al.*, 1964). The faunal succession and the association of its elements allows long-distance parallel correlation of LF biozones based on ecologically different groups (e.g. alveolinids, nummulites and assilinas).

The key-locality faunal assemblage represents the *central point* of a LF biozone; these zones are non-contiguous, separated by intervals and not by boundaries. Elements (not boundaries!) identifying biozones are not arbitrarily chosen, but reflect objective, repeatedly observable breaks in faunal assemblages. The relative stratigraphical position of each LF key-fauna may be determined through a variety of methods besides the paleontologic one (e.g. the superpositional criterion, radiometrical dating, etc.). An important consequence is that, except for a wrong positioning in time of one of them, it provides a very stable scale, verifiable in parallel wherever LF deposits occur. Due to their integrated nature and

their ties with the stratotypes of Paleogene stages, typological LF biozones are relatively stable in comparison to FO/LO-based biozones. Thus, except for minor new subdivisions, no substantial change has affected the biostratigraphic zonation proposed by Hottinger (1960) and Schaub (1981), although some amendments seem likely, especially for the Late Paleocene and Late Eocene biozones.

Because most fossil-rich LF deposits are formed in a transgressive context (Hottinger & Schaub, 1960), usually the base of each major transgressive sequence (and the FO's of taxa) roughly corresponds to the onset of the biozone in a given area. For example, the Lutetian neostratotype in the Paris Basin has been recently restudied in terms of sequence stratigraphy by Haq *et al.* (1988), in whose interpretation their third order cycle TA3, 3.1 transgressive deposits coincide biostratigraphically with the base of the *Nummulites laevigatus* zone (Hottinger *et al.*, 1964). Bearing in mind that the key-faunas are the ideal center of each biozone and the former are often deposited within a transgressive context, this begs the question whether the typologically defined LF biozones can be percieved as pear-shaped, bottom-heavy time-slices. This is probably not the case, because of the usually relative short duration of the marine LF-rich deposits within each depositional cycle, their relatively central position within each cycle, their being separated by relatively long sedimentary hiatuses, and because of the stratigraphic resolution limits in studying morphological change in time.

ARE LARGER FORAMINIFERAL BIOZONES OPPELZONES?

Oppel conceived stratigraphic divisions based on the general association and succession of fossils, independently of the actual succession at any one place. The resulting ideal profile has been often misinterpreted (and thus sometimes summarily dismissed) as "a concept sufficiently charismatic to attract, and sufficiently vague to allow us each to construct our own zonal succession" (Hancock, 1977). Truly, no simple definition of the Oppelzone as used by him is possible, although he implicitly introduced zones such as assemblage and concurrent-range zones. The index species provides a formal name for the zone (which could as well be named after localities) and is but one of the species of the assemblage which characterize the zone; these zones are non-contiguous, separated by intervals. "(...) *Each horizon, identifiable in any place by a number of peculiar and constant species*, is to be recognized with the same degree of certainty in distant regions. (...)" It necessarily involves exploring the vertical range of each separate species in the most diverse localities, while ignoring the lithological development of the beds; by this means will be brought into prominence those *zones which, through the constant and exclusive occurrence of certain species, mark themselves off from neighbours as distinct horizons*. In this way is obtained an *ideal profile*, of which the component parts of the same age in the various districts are characterized always by the same species. (A. Oppel, 1856 — *Die Juraformation Englands, Frankreichs und des südwestlichen Deutschlands, nach ihren einzelnen Gliedern eingetheilt und verglichen*; p. 3; translation by Arkell, 1933; italics by me).

As pointed out by Sigal (1984), Oppelzones are not simple biostratigraphic zones, but possess chronostratigraphic value; Oppel himself however distinguished between chrono- and biostratigraphy, building up each stage from zones, not taking each stage and subdividing it into zones.

In conclusion, a comparison of the principles above and the way LF zonation was achieved starting from the classical regions of the European Paleogene stages (Hottinger & Schaub, 1960) reveals that the heuristically powerful rationale of LF biozonation is the same one as Oppel's. A further point in common of LF and Oppelzones resides in the testability of their mutual superpositional control (Guex, 1987). In this context it may be useful to recall that the present IGCP meetings have proven the importance for LF workers of sharing well-preserved, topotypical material from key-sections, the latter providing the best term for taxonomical comparison and biostratigraphic correlation.

The Oppelian key-assemblage concept, widely employed in several fields of biostratigraphy, from radiolarians (Baumgartner, 1984) to continental vertebrate to ammonite biozonations, besides providing the most obvious means for the correlation of zonations based on different groups, points out both the incompleteness of the rock record and the latter's cyclic character, as postulated by sequence stratigraphy (which is also a chronobiostratigraphy).

THE CONTINENTAL-MARGIN ROCK RECORD, DOMAIN OF LF: "EVENT-DOMINATED" VS. "BACKGROUND-DOMINATED" STRATIGRAPHY

What, if anything, may emerge in conclusion from the discussion above, besides the emphasis — which seems quite necessary — upon the basic differences existing among biozonations? In my opinion, among various possibilities it might prove rewarding both to evidence the contradictions of correlations based on different groups and to investigate the controls on the distribution of age-diagnostic taxa within the rock record. A hypothetical case is outlined below, with reference to sequence stratigraphy and different biozonations.

The discontinuous record of continental-margin sedimentation provided the means for establishing a chronostratigraphy already in Geology's earlier history: traditional stages and their stratotypes reflect both sedimentary and faunal breaks. Sequence stratigraphy recognizes

three critical depositional surfaces (i.e. discontinuities): transgressive surfaces, maximum flooding surfaces and sequence boundaries (Haq *et al.*, 1988). A sequence, is interpreted to have been deposited during a cycle of eustatic sea level change and is composed of a relatively conformable succession of genetically related strata bounded by unconformities and their correlative conformities. The boundaries of each cycle (sequence) may be interpreted as coincident with maximum flooding surfaces (Galloway, 1989), or with truncation, erosional and subaerial exposure surfaces, corresponding to eustatic-fall inflection points (Haq *et al.*, 1988).

A preliminary hypothesis suggested is that if evolution in LF takes place *via* peripheral isolates (Eldredge & Gould, 1977), the chance that speciation may occur is highest in either maximum flooding situations or in maximum sea-level lowstand situations. In correspondence with the latter the LF as K-strategists (Hottinger, 1983) are challenged among other disfavourable factors by higher trophic levels and possibly by stronger competition (being the shallow-water areas reduced). Because the corresponding shallow-water sediments are usually lacking, the already remote probability of finding records from the area in which speciation occurred is practically nil (i.e. it is impossible to put a "golden spike" or a limit between two biozones, thus justifying the Oppelian character of LF biozonations) and in general therefore the new taxa first occur, to all appearances suddenly and with a wide geographical distribution given their fast dispersal rates, only within the next following transgressive sequence. This further rises the question why, in comparing and correlating the Haq *et al.*'s (1988) Paleogene chart of coastal onlap and the Paleogene LF biozonation (Schaub, 1981), practically no new taxa in LF seem to appear in correspondence to maximum sea-level highstand levels; the new zone-characteristic assemblages seem generally to be already fully developed well before the sea-level highstand progradation takes place, i.e. in (or "immediately before") the transgressive systems tracts. Analogous hypotheses might be formulated for planktonic organisms: whether sea-level highstands or lowstands correspond to timespans in which evolution is more likely to occur is unproved until now, but seems analogously to deserve further investigation. Similarly, it is still debated whether "global" hiatuses on platforms and in basins are coincident (Aubry, 1991) or not (Winterer, 1991). Finally, an answer to the previous questions may help in understanding whether we are dealing with basically "event-dominated" or "background-dominated" biostratigraphies.

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THE ZONATION OF THE MEDITERRANEAN UPPER PALEOCENE AND EOCENE BY ORTHOPHRAGMINAE

György Less

Abstract

Upper Paleocene and Eocene Orthophragminae (orbitoidal larger foraminfera) consist of several evolutionary lineages in the Tethys that makes them suitable for stratigraphical purposes. These lineages are subdivided mainly by artificial limits into taxa. The key-localities for Orthophragminae contain their characteristic assemblages. Based on them, 18 Oppel-zones can be defined for the Mediterranean that can be correlated with the shallow benthic (Alveolinidae, Nummulitidae) subdivisions.

Key words: Paleogene, Foraminifera, Discocyclinidae, Asterocyclinidae, zonation.

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INTRODUCTION

"Orthophragminae" is an informal collective name for Late Paleocene and Eocene orbitoidal larger foraminifera with almost rectangular equatorial chamberlets. These are grouped into two systematically independent families as follows:

Familia Discocyclinidae Vaughan and Cole, 1940

Genera *Discocyclina* Gümbel, 1868
Pseudophragmina Douvillé, 1923
Athecocyclina Vaughan and Cole, 1940
Asterophragmina Rao, 1942
Nemkovella Less, 1987

Familia Asterocyclinidae Brönnimann, 1951

Genera *Asterocyclina* Gümbel, 1868
Orbitoclypeus Silvestri, 1907
Neodiscocyclina Caudri, 1972

Further systematical details can be found in Brönnimann (1945, 1951), Caudri (1972), Less (1987, 1993), Ferrández-Cañadell and Serra-Kiel (1992) and Ferrández-Cañadell (1995). Both families are widespread in the Mediterranean. However, on the generic level only *Discocyclina, Nemkovella, Asterocyclina* and *Orbitoclypeus* can be found.

The stratigraphic value of Orthophragminae was obscure for long. Taxa were diagnosed mainly by their exterior aspect because internal features were accessible only by time-consuming thin-sectioning. The evolution of the interior was not so self-evident, either, as observed in the Upper Cretaceous (Van Gorsel, 1975, 1978; Drooger and De Klerk, 1985) or Oligo-Miocene (Drooger, 1952, 1963, 1993; Raju, 1974) larger foraminifera represented by only one or two evolutionary lineages per genus (or subgenus). Essentially this was the reason why the Utrecht School (Brolsma, 1973; Fermont, 1982; Setiawan, 1983) gave up studying Orthophragminae (see also Drooger, 1993).

Our studies went a somewhat different way. First, we managed to split the equatorial section by pliers (Less, 1981, see also Čosović, 1990) which gave a comparatively easy access to the internal morphology relevant for the taxonomical identification, i.e. the equatorial section. The emphasis of the investigations could be removed from the exterior — not having brought stratigraphic results — to the internal features. These studies covered a relatively large area and time-span (from SW France to the Crimean Peninsula and the whole Eocene, respectively). Based on this material we have discovered more than 20 parallel evolutionary lineages. Each lineage evolved internally making them suitable for stratigraphic purposes (Less, 1983, 1987, 1989, 1993).

THE ZONATION AND ITS PRINCIPLES

In the paleontological sense an evolutionary lineage is a continuous chain of successive and spatially co-productive populations. However, it is reconstructed by the human mind from the necessarily discontinuous geological record. Within evolutionary lineages no quantitative sharp discontinuities can be observed, although the first and last members of the chain may be rather dissimilar.

Orthophragminae differ very much from the Upper Cretaceous and Oligo-Miocene orbitoidal larger foraminifera by the multitude of their evolutionary lineages. However, the same phenomenon can be found in Nummulitidae (Hottinger, 1977; Schaub, 1981) and Alveolinidae (Hottinger, 1960; Drobne, 1977). Both families lived contemporarily with Orthophragminae. Thus, probably we are facing with an age-specific phenomenon.

In our monograph (Less, 1987) particular evolutionary lineages have been separated from each other on a typological basis. Later (Less, 1992, 1993) we have elaborated a biometrical system consisting of nine measurements, from which eleven morphometric parameters can be calculated. With their aid and using also four qualitative features, the populations within particular communities as represented by the collected samples can fairly well be separated on a population-statistical basis.

The details of this procedure will be discussed in an other paper (Less and Ó. Kovács, in prep.). The main conclusion is that the correctness of separating evolutionary lineages on a typological basis can also be proved biometrically. Both methods give essentially the same result. Therefore, after this verification, we may prefer the much quicker typological identification of the evolutionary lineages based upon the synthetic skill of the human mind, rather than on the biometrical determination.

In the case of many parallel evolutionary lineages the biometrical identification has an other danger, too. As Hottinger (1960, p. 13–14, fig. 1) has shown, it cannot filter out the phenomenon of heterochronic homeomorphy. This is discussed in detail for Orthophragminae in Less (1993, p. 209). Because of these dubious cases the ages of our samples can be detected most successfully by using as wide fossil material as it is possible, considering them as an assemblage. Following this way, we get Oppel-zones almost self-evidently. It is worth mentioning that there exists an other way, too, i.e. the numerical evolutionary correlation, introduced in a separate paper (Less and Ó. Kovács, 1996).

In establishing the Oppel-zonation it is necessary to dissect the development inside particular evolutionary lineages. In the practice used for larger foraminifera this is solved in two different ways. The Basel School (Hottinger, 1960, 1977; Drobne, 1977; Schaub, 1981) picks out particular moments of the evolution as types and groups the paleontological populations around them. Meanwhile the Utrecht School (as summarized in Drooger, 1993) subdivides the evolution by artificial boundaries using a well measurable, quickly evolving parameter of the lineage.

There leads a much easier way to Oppel-zones by the first method, since it uses essentially particular key-localities and their key-faunas as types for them. However, here the typological separation of successive taxa within the evolutionary lineages, being very close to each other, allows to make slight misdeterminations. In turn, the flexibility of the original definitions may appear immediately in the age-determination and the zonation system itself becomes unstable.

Therefore, we have chosen the second possibility to save the objectivity in determining taxa (Less, 1987, 1993). This does not contradict the idea written above about heterochronic homeomorphy, since two different evolutionary lineages may become similar at different time levels. In these cases the mutual control of parallel lineages solves the problem. So, the doubtfulness in the taxon-determination shall not appear in the age-determination.

This train of thought has the following nomenclatural consequence: In contrast to the procedures developed in alveolinids and nummulitids, particular orthophragminid lineages are disignated mostly by one single species name, each artificial member of a phylum by subspecies names, i.e. so-called chronosubspecies. This also reflects that in fact the species is the smallest entity recognizable for the human mind (at least for ours) at first sight being the successive subspecies already artificial units determinable by statistical methods.

Each evolutionary lineage of Orthophragminae shows the following evolutionary trends: 1. The increasing dimensions of both embryonic chambers of the A-forms; 2. the increasing height of equatorial annuli. In addition, the number of adauxiliary chamberlets also grows with only a few exceptions (*Asterocyclina alticostata, A. stellata, A. schweighauseri*).

Since these trends are parallel, they are in close correlation with each other, too. Therefore, any of them can characterize alone the evolution inside the given evolu-

tionary lineage. For this purpose the size-increase of the deuteroconch, the second chamber of the embryon of the A-forms, may be the most expedient character for each evolutionary lineage. This is the most easily and objectively measurable parameter, also it produces the fastest and least variable evolutionary progress.

Previously (Less, 1987, 1993) we used the "medium" diameter (D) of the deuteroconch for characterizing the successive chronosubspecies. It was measured in equatorial section and calculated by the geometrical mean of the diameters parallel and perpendicular to the axis of the embryon. We measured both diameters including the thickness of the wall of the deuteroconch. To spare time, it appears sufficient to measure only the cross-diameter of the deuteroconch (d), also including the whole thickness of the wall, for characterizing its size. At the centridiscodine embryon having more axes of symmetry, the largest diameter of the deuteroconch has to be measured (fig. 1). Deuteroconch-diameters have to be summarized per population by giving the number of specimens, the arithmetical mean of the diameters (marked by d) in μm, and its standard error (s.e.).

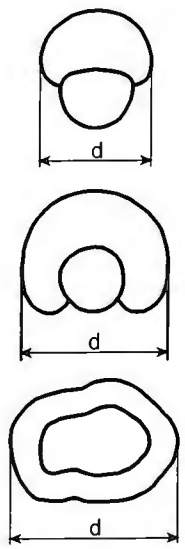

Figure 1: Measuring method of the cross-diameter (d) of the deuteroconch of Orthophragminae in different embryon types.

In turning from D to d, we have to redefine the values separating successive chronosubspecies, too. This is done in Appendix A where Mediterranean Orthophragminae are grouped by evolutionary lineages. Population-statistical data concerning d are summarized in Table 1 at the end of appendix B. New taxa will be described in the very near future. The list is based on data measured in material coming from the Northern and Southern slope of the Pyrenees, from SW Aquitaine, Northern Italy, Austria, Bavaria, Hungary, Bulgaria, the Crimean Peninsula and Israel. Fig. 2. displays their geographical distribution, while in Table 2 their Orthophragmina-content is tabulated.

The major part of the material from the localities (listed in Appendix B) was prepared and studied by myself. I have restudied and remeasured an other smaller quantity in the Basel Natural History Museum (the Schweighauser- and Brönnimann-collections) and in the Geological Institute of the Utrecht State University (the Fermont- and Setiawan-collections).

Based on the taxa summarized in Appendix A the time-span of about 24 million years — from the beginning of the Thanetian to the end of the Priabonian — can be subdivided into 18 zones. To avoid circular reasoning, the succession of these zones has been established simultaneously on the relatively rare direct superposition of our samples and mainly on the evolution of Orthophragminae. The zonation is controlled by the accompanying larger and planktonic foraminifera and the nannoplankton, too. Occasionally, there are smaller controversies with the accompanying fossil material but their degree is never more than one zone. However, these errors do not exceed those errors that are unavoidable in correlating any kind of zonations.

The zonal distribution of particular taxa is summarized in the range-chart of figs 3, 4, 5 and in textual form in Appendix C. Zones are numbered from 1 to 16 by our earlier nomenclature (Less, 1987, 1993). The 18 zones mentioned above are originated from these 16 zones by subdividing the former 1st and 8th zones into 1a and 1b, and 8a and 8b, respectively. These 18 zones have been

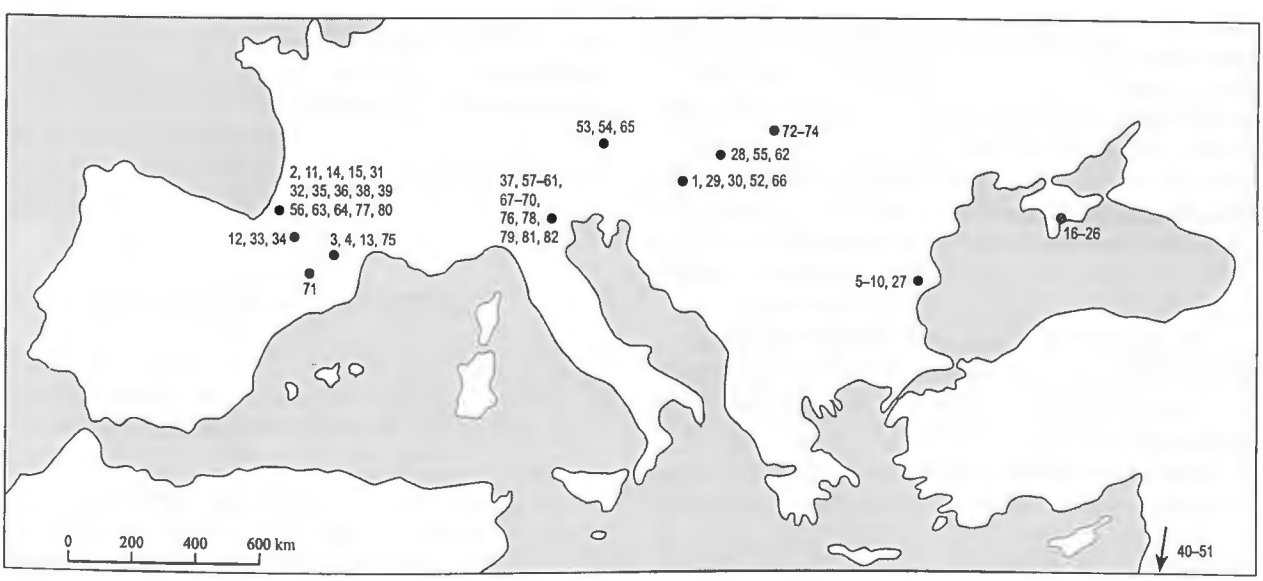

Figure 2: Geographical distribution of the samples studied. The meaning of numbers in the map can be found in Appendix B.

integrated into the shallow benthic (SBZ) zonation by the accompanying fossil content of particular samples. This zonation prepared by the I.G.C.P. project No. 286 ("Early Paleogene Benthos") is mainly based upon the zonations by Nummulitidae and Alveolinidae elaborated by Hottinger *et al.* (1964). However, in establishing it, Orthophragminae were also considered.

J. Serra-Kiel and L. Hottinger (pers. comm.) have coordinated the adjustment of the SBZ zonation to the planktonic foraminiferal, nannoplankton and magnetostratigraphic subdivisions. Its correctness is mostly supported by both the nannoplankton and planktonic foraminifera of our Orthophragmina-bearing samples, too. This correlation will be published in Bull. Soc. Geol. France.

FURTHER POSSIBILITIES TO EXTEND AND IMPROVE THE ZONATION

The Orthophragmina-zonation fixes the state-of-art of our studies in 1996. It can be developed both in time and space.

In time, the zonation probably cannot be extended but its precision can be increased. In the region studied there is no indication of the occurrence of the Orthophragminae either older than the SBZ 3 zone (i.e. Danian and Seelandian) or younger than the SBZ 20 zone (i.e. Rupelian and Chattian). The only reference against this can be found in Van Heck and Drooger (1984, p. 302). They suggest that in San Vicente de la Barquera (Spain) "in situ" Discocyclinae are cooccurring with primitive Oligocene Lepidocyclinae. Later this was corrected by C.W. Drooger in a letter written March 15, 1988: "Since Shirley van Heck studied sample SP 756, I revisited the section again and I found some other turbiditic levels with larger foraminifera. These samples solved the question of *Discocyclina*. I am convinced now that they must be reworked. In sample 756 they were rare, of similar small size and no other signs of reworking were found. I think this was due to sorting. In a sample lower down from a much coarser conglomerate, they are common and there are also frequent large *Nummulites* and *Assilina*. Moreover, the *Discocyclina* are especially found in lumps of sediment. So I think now that only the Lepidocyclinids are contemporaneous with the sediment, the rest being reworked. I think that it makes not much sense anymore to restudy the really poor, recrystallized material."

The spreading of the zonation towards the older parts of the Paleocene is theoretically possible. In contrast to the Upper Cretaceous and Oligo-Miocene orbitoidal larger foraminifera, we can only try to guess the roots of Orthophragminae (see Drooger, 1993). Their sudden appearance in the Tethys with relatively highly developed forms suggests rather their migration (from the Caribbean?) and gives not too much practical chance to find them here in pre-Thanetian beds.

Within the Thanetian-Priabonian time-span the relationship between the O.1a to O.4 Orthophragmina-zones and the 3rd to 9th SBZ-zones has to be precised. We have not studied so far Orthophragminae from SBZ-zones No. 4, 6 and 9. Meanwhile the Gamarde Orthophragminae coming from the 5th SBZ-zone proved to be of the same development as those of the 7th and 8th SBZ-zone (= 3rd and 4th Orthophragmina-zone, respectively). The temporal distribution of particular taxa has to be precised by increasing the number of the samples studied.

In space, the zonation may be expanded towards the Western and Eastern coasts of Africa and also towards Central and SE Asia and Australia. Both the depictions (Morocco: Brönnimann, 1940; Somalia: Silvestri, 1948; Azzaroli, 1950; Cutch (India): Samanta and Lahiri, 1985; Assam: Samanta, 1965; Australia: Cockbain, 1977) and our studies (Somalia: Eil) of the Orthophragminae from these regions suggest a link with the Mediterranean. However, the scarcity of data does not allow to spread our zonation into these territories. Already the Israeli (Fermont, 1982, and the personal study of his material) and Cutch (Samanta and Lahiri, 1985) localities differ significantly from the European ones in their generic dominance of the respective populations. However, no trend can be concluded so far: In the Israeli samples of Upper Cuisian to Middle Lutetian age the Discocyclinae (the dominant genus in Europe) are almost entirely lacking. Meanwhile, in the Bartonian/Biarritzian Cutch localities this genus is even more dominant than in Europe (simultaneously Orbitoclypei and Asterocyclinae are subordinate while Nemkovellae are missing). In the Upper Eocene Assam samples similar proportions can be observed.

The zonation is certainly not valid for America and the Pacific islands. The specific composition of these regions and that of the Tethys is entirely different. And even on the generic level *Asterocyclina* is the only common member.

The range-chart shown in fig. 3, 4 and 5 has significantly expanded the temporal distribution of particular evolutionary lineages and simultaneously the possibility to dissect them, as compared to our earlier versions (Less 1987, 1993). Further progress can be expected first of all around the Paleocene/Eocene boundary.

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APPENDIX A

Alphabetic list of the Orthophragmina-lineages and single species

For each lineage we list their taxa in the order of the increasing mean deuteroconch cross-diameter (d). There are also some single species not yet assigned to any lineage. The limit-value of possible further subdivision is given in brackets. In the brackets before successive subspecies the capital letters show their symbol in Table 2. The statistical data of the "d" values per populations can be found in Table 1. The five-letter abbreviations after species-names serve for identification with this table. In this list we repeat all the species names that can be found in Less (1987). However, some of them proved to be invalid, another part is ranked here as subspecies, while a very few ones do not occur in the Mediterranean. All these names are given in cornered brackets. New taxa will be described in the very near future.

***Asterocyclina alticostata*-lineage**

A. alticostata (ASALT)

(A) *A. alticostata gallica* d<275 µm
(B) *A. alticostata cuvillieri* d=275–350 µm
(C) *A. alticostata alticostata* d=350–450 µm
(D) *A. alticostata danubica* d>450 µm

Asterocyclina kecskemetii (ASKEC)

So far no further subdivision.

Asterocyclina priabonensis (ASPRI)

So far no further subdivision.

***Asterocyclina schweighauseri*-lineage**

A. schweighauseri (ASSCH)

(A, B) *A. schweighauseri* n. ssp. Bos d'Arros d<(320)–400 µm
(C) *A. schweighauseri schweighauseri* d>400 µm

Note: In Less (1987) *A. schweighauseri* is unsubdivided. For *A. schweighauseri* n. ssp. Bos d'Arros see Less (1987), pl. 43, figs 3–4.

***Asterocyclina stella*-lineage**

A. stella (ASSTL)

(A) *A. stella* n. ssp. Horsarrieu d<150 µm
(B) *A. stella stella* d=150–205 µm
(C, D) *A. stella praestellaris* d>205–(260) µm

Note: In Less (1987) *A. stella taramellii* was marked out as the most primitive chronosubspecies of the lineage. Here it is subdivided into the less developed *A. taramellii* (with no sharp rays in equatorial section) and the more developed *A. stella* n. ssp. Horsarrieu (with sharp rays in equatorial section). For the latter see Brolsma (1973), pl. 2, figs 1–2 and Less (1987), pl. 36, figs 8–13.

***Asterocyclina stellata*-lineage**

A. stellata (ASSTT)

(A) *A. stellata adourensis* d<150 µm
(B) *A. stellata stellata* d=150–190 µm
(C) *A. stellata stellaris* d=190–240 µm
(D) *A. stellata* n. ssp. Kisgyõr d>240 µm

Note: For *A. stellata* n. ssp. Kisgyõr there are no figures available at present in the literature.

Asterocyclina taramellii (ASTAR)

So far no further subdivision.

See also the note at the *A. stella*-lineage.

Discocyclina aaroni (DIAAR)

So far no further subdivision.

Note: In Less (1987) it is subdivided into two chronosubspecies. Here the former *D. aaroni chalossensis* is put in synonymy with *D. dispansa taurica* while *D. aaroni aaroni* is identified with *D. aaroni*.

Discocyclina aquitanica (DIAQU)

So far no further subdivision.

Note: In Less (1987) it is described as *D. pratti aquitanica*. Also *D. pratti montfortensis*, from the top of the *Nummulites distans* zone of the Crimea, is included here.

Discocyclina archiaci (DIARC) see the D. discus-lineage

***Discocyclina augustae*-lineage**

D. augustae (DIAUG)

(A, B) *D. augustae sourbetensis* d<(105)–145 µm
(C) *D. augustae atlantica* d=145–180 µm
(D) *D. augustae olianae* d=180–225 µm
(E) *D. augustae augustae* d>225 µm

Notes: 1. *D. dispansa ganensis* in Less (1987) is put in synonymy here with *D. augustae sourbetensis*.

2. The Ajka forms described in Less (1987) as *D. augustae augustae* are put in synonymy here with *D. dispansa hungarica*.

[*Discocyclina broennimanni*] — see *D. dispansa broennimanni*

***Discocyclina discus*-lineage**

D. archiaci (DIARC)

(A) *D. archiaci bakhchisaraiensis* d<305 μm
(B) *D. archiaci staroseliensis* d=305–390 μm
(C) *D. archiaci archiaci* d=390–600 μm
(D) *D. archiaci bartholomei* d>600 μm

D. discus (DIDSC)

(A) *D. discus discus* d<1350 μm
(B) *D. discus adamsi* d>1350 μm

Notes: 1. *D. furoni* from the *Nummulites crimensis* zone of the Crimea in Less (1987) is put in synonymy here with *D. archiaci bakhchisaraiensis*.

2. *D. weijdeni* and the Gan specimens of *D. furoni* in Less (1987) are put in synonymy here with *D. archiaci archiaci*.

3. *D. senegalensis* in Less (1987) is put in synonymy here with *D. archiaci bartholomei*.

4. *D. discus dudarensis* in Less (1987) is considered here as a junior synonym of *D. discus adamsi* Samanta and Lahiri, 1985. See also Samanta and Lahiri (1985), pl. 1, figs 6–7.

***Discocyclina dispansa*-lineage**

D. dispansa (DIDSP)

(A) *D. dispansa broennimanni* d<160 μm
(B) *D. dispansa taurica* d=160–230 μm
(C) *D. dispansa hungarica* d=230–290 μm
(D) *D. dispansa sella* d=290–400 μm
(E) *D. dispansa dispansa* d=400–520 μm
(F) *D. dispansa umbilicata* d=520–675 μm
(G) *D. dispansa* n. ssp. Kisgyõr d>675 μm

Notes: 1. *D. dispansa broennimanni* is described in Less (1987) as *D. broennimanni*.

2. *D. aaroni chalossensis* in Less (1987) is put in synonymy here with *D. dispansa tasurica*.

3. *D. dispansa nussdorfensis* and also *D. augustae augustae* from Ajka in Less (1987) are put in synonymy herewith *D. dispansa hungarica*. The Angoumé and Dudar populations, described in Less (1987) under this latter name, are ranked with *D. dispansa sella*.

4. For *D. dispansa* n. ssp. Kisgyõr there are no figures available at present in the literature.

5. *Discocyclina dispansa ganensis* in Less (1987) is put in synonymy here with *D. augustae sourbetensis*.

Discocyclina euaensis (DIEUA)

So far no further subdivision.

***Discocyclina fortisi*-lineage**

D. seunesi (DISEU)

(A) *D. seunesi seunesi* d<260 μm
(B) *D. seunesi* n. ssp. Beloslav d>260 μm

D. tenuis (DITEN)

(A) *D. tenuis* n. ssp. Ruisseau de Bec d<360 μm
(B) *D. tenuis tenuis* d>360 μm

D. pseudoaugustae (DIPSA)

So far no further subdivision.

D. fortisi (DIFOR)

(A) *D. fortisi fortisi* d<850 μm
(B) *D. fortisi simferopolensis* d>850 μm

D. stratiemanuelis (DISTR)

So far no further subdivision.

Notes: 1. *D. seunesi seunesi* is described in Less (1987) as *Orbitoclypeus seunesi*. B-forms from Beloslav (Bulgaria) proved their belonging to *Discocyclina*.

2. *D. tenuis tenuis* was ranked with *D. archiaci* in Less (1987). For figures see Samuel *et al.* (1972), pl. 97, fig. 2, 3; Massieux (1973), pl. 18, figs 1–2, 7.

3. The Angoumé forms, described as *D. stratiemanuelis* in Less (1987), are put in synonymy here with *D. pulcra* n. ssp. Angoumé.

4. For *D. seunesi* n. ssp. Beloslav and *D. tenuis* n. ssp. Ruisseau de Bec there are no figures available at present in the literature.

Discocyclina furoni (DIFUR)

With possible further subdivision (A, B d=250 μm).

Note: The Gan specimens, described in Less (1987) under this name, are put in synonymy here with *D. archiaci archiaci*, while those from the *Nummulites crimensis* zone of the Crimea with *D. archiaci bakhchisaraiensis*.

[*Discocyclina javana*] — see *D.* n. sp. Siest

Discocyclina kingae (DIKIN)

So far no further subdivision.

Discocyclina knessae (DIKNE)

So far no further subdivision.

***Discocyclina* n. sp. Siest** (DINSP)

So far no further subdivision.

Note: The Siest forms, described in Less (1987) as *D. javana*, cannot be identified with those from Indonesia and Assam, therefore, a new name is to be given for them. See Less (1987), pl. 6, figs 7, 9.

Discocyclina nandori (DINAN)

So far no further subdivision.

***Discocyclina pratti*-lineage**

D. pratti (DIPRT)

(A) *D. pratti montfortensis* d<440 μm
(B) *D. pratti pratti* d=440–700 μm
(C) *D. pratti minor* d>700 μm

Note: The specimens from the top of the *Nummulites distans* zone of the Crimea, described in Less (1987) as *D. pratti montfortensis*, and also *D. pratti aquitanica* there, are put in synonymy here with *D. aquitanica*.

Discocyclina pseudoaugustae (DIPSA) see at the *D. fortisi*-lineage

***Discocyclina pulcra*-lineage**

D. pulcra (DIPUL)

(A) *D. pulcra landesica* d<800 µm
(B) *D. pulcra pulcra* d=800–1000 µm
(C) *D. pulcra* n. ssp. Angoumé d=1000–1250 µm
(D) *D. pulcra balatonica* d=1250–1600µm
(E) *D. pulcra baconica* d>1600 µm

Note: *D. pulcra pulcra* is unsubdivided in Less (1987). Here its more developed part is separated as *D. pulcra* n. ssp. Angoumé (Less, 1987, pl. 8, fig. 9; pl. 21, figs 8–9). *D. stratiemanuelis* from this locality in Less (1987) is also included here. See also Less (1989).

***Discocyclina radians*-lineage**

D. radians (DIRAD)

(A) *D. radians* n. ssp. Caupenne d>240 µm
(B) *D. radians noussensis* d=240–300 µm
(C) *D. radians radians* d=300–375 µm
(D) *D. radians labatlanensis* d>375 µm

Notes: 1. For *D. radians* n. ssp. Caupenne see Less (1987), pl. 15, fig. 1.

2. The Siest population, described in Less (1987) as *D. radians radians*, is put in synonymy here with *D. radians labatlanensis*.

Discocyclina samantai (DISAM)

So far no further subdivision.

[*Discocyclina senegalensis*] — put in synonymy here with *D. archiaci bartholomei*

Discocyclina seunesi (DISEU) see the *D. fortisi*-lineage

***Discocyclina spliti*-lineage**

D. spliti (DISPL)

(A) *D. spliti spliti* d<1300 µm
(B) *D. spliti ajkaensis* d>1300 µm

Discocyclina stratiemanuelis (DISTR) see the *D. fortisi*-lineage

Discocyclina tenuis (DITEN) see the *D. fortisi*-lineage

***Discocyclina trabayensis*-lineage**

D. trabayensis (DITRB)

(A) *D. trabayensis trabayensis* d<125 µm
(B) *D. trabayensis* n. ssp. Mossano d=125–170 µm
(C) *D. trabayensis vicenzensis* d>170 µm

Notes: 1. *D. trabayensis concentrica* in Less (1987) is put in synonymy here with *D. trabayensis trabayensis*.

2. *D. trabayensis vicenzensis* is unsubdivided in Less (1987). Here its less developed part is separated as *D. trabayensis* n. ssp. Mossano. It is figured in Less (1987), pl. 18, figs 3–4.

[*Discocyclina weijdeni*] — put in synonymy here with *D. archiaci archiaci*

Nemkovella bodrakensis (NMBOD)

So far no further subdivision.

Note: In Less (1987) it is described as *N. strophiolata bodrakensis*.

Nemkovella evae (NMEVA)

With possible further subdivision (A, B d=250 µm).

[*Nemkovella fermonti*] — see *N. strophiolata fermonti*

Nemkovella katoae (NMKAT)

So far no further subdivision.

Note: It is described in Less (1987) as *Orbitoclypeus katoae*.

Nemkovella rota (NMROT)

So far no further subdivision.

Note: See Ferrández-Cañadell (1995), pl. 9, figs 1–2, under the name of *N. rotae*. Ferrández-Cañadell (in litt., November 27, 1995): "The new taxon *Nemkovella rota* (note the change of name, from *rotae* to *rota*, a latin correction ...), will be published in the *Revue de Micropaleontologie*. The types will be deposited in the Museum of Natural History in Basel."

***Nemkovella strophiolata*-lineage**

N. strophiolata (NMSTR)

(A) *N. strophiolata fermonti* d<150 µm
(B) *N. strophiolata strophiolata* d=150–185 µm
(C) *N. strophiolata* n. ssp. Padragkút d=185–230 µm
(D) *N. strophiolata tenella* d>230 µm

Notes: 1. *N. strophiolata fermonti* is described in Less (1987) as *N. fermonti*.

2. *N. strophiolata tenella* is unsubdivided in Less (1987). Here its less developed part is separated as *N. strophiolata* n. ssp. Padragkút. Figures: Less (1987), pl. 25, fig. 11; Less (1993), pl. 2, fig. 4.

3. *N. strophiolata bodrakensis* in Less (1987) is separated here as *N. bodrakensis*.

Orbitoclypeus bayani (ORBAY)

So far no further subdivision.

Note: The Horsarrieu forms, described in Less (1987) under this name, are put in synonymy here with *O. munieri munieri*.

[*Orbitoclypeus chudeaui chudeaui* and *O. chudeaui pannonicus*] — included into the *O. douvillei*-lineage

Orbitoclypeus* (?) *daguini (ORDAG)

So far no further subdivision.

***Orbitoclypeus douvillei*-lineage**

O. douvillei (ORDOU)

(A, B) *O. douvillei douvillei* d<(200)–260 µm
(C) *O. douvillei* n. ssp. Gibret d=260–340 µm

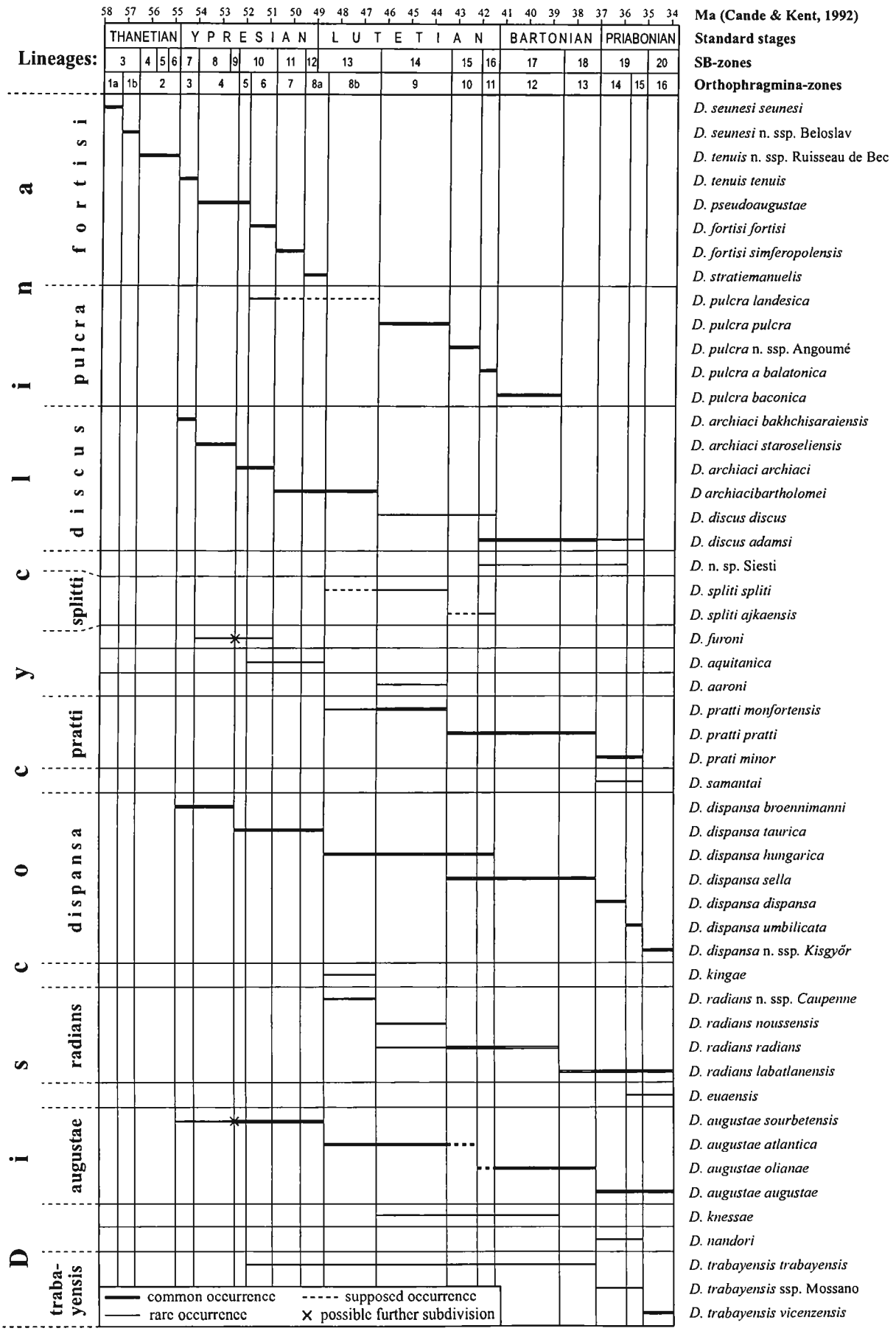


Figure 3: Range-chart for Mediterranean Discocyclinae.

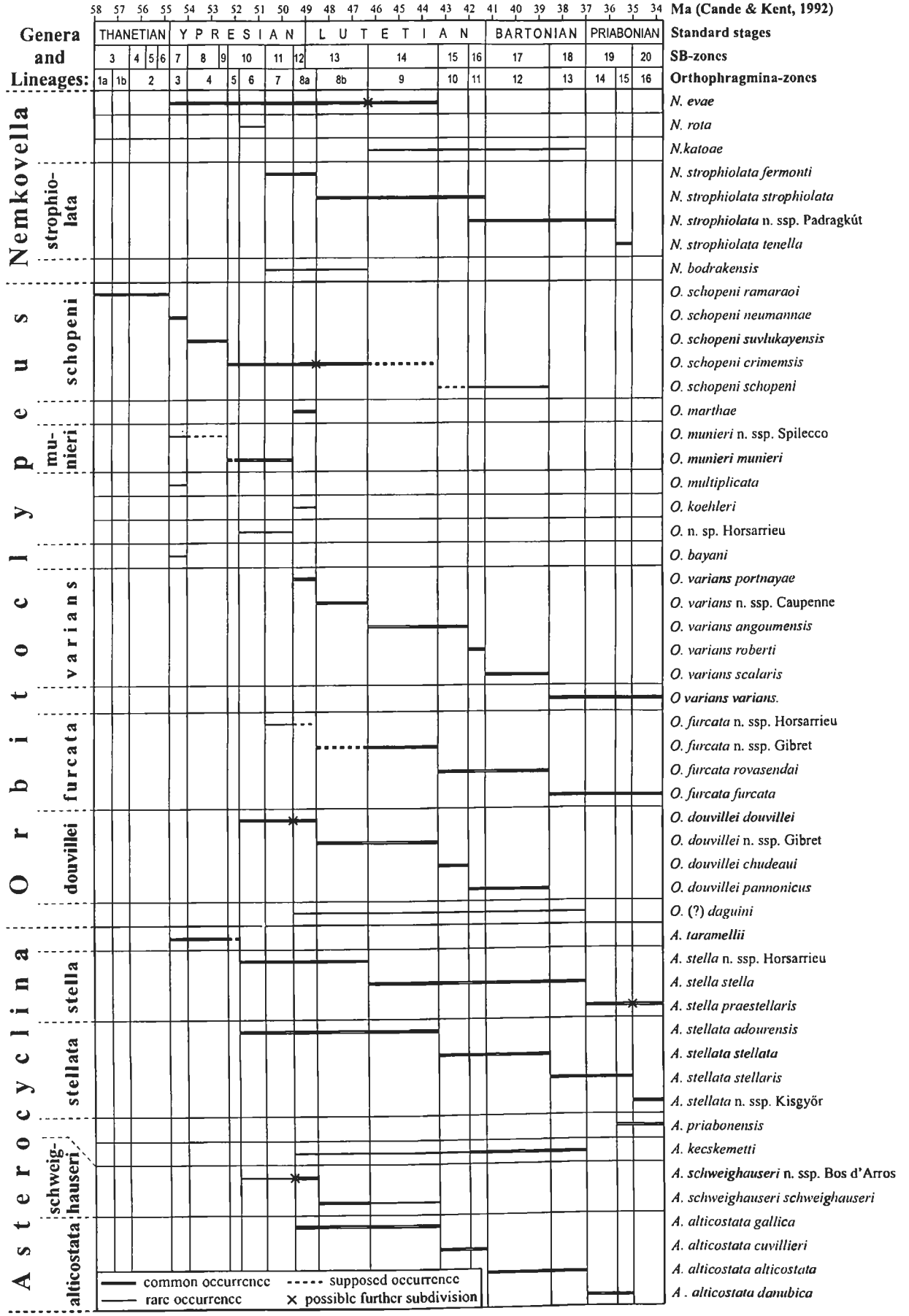
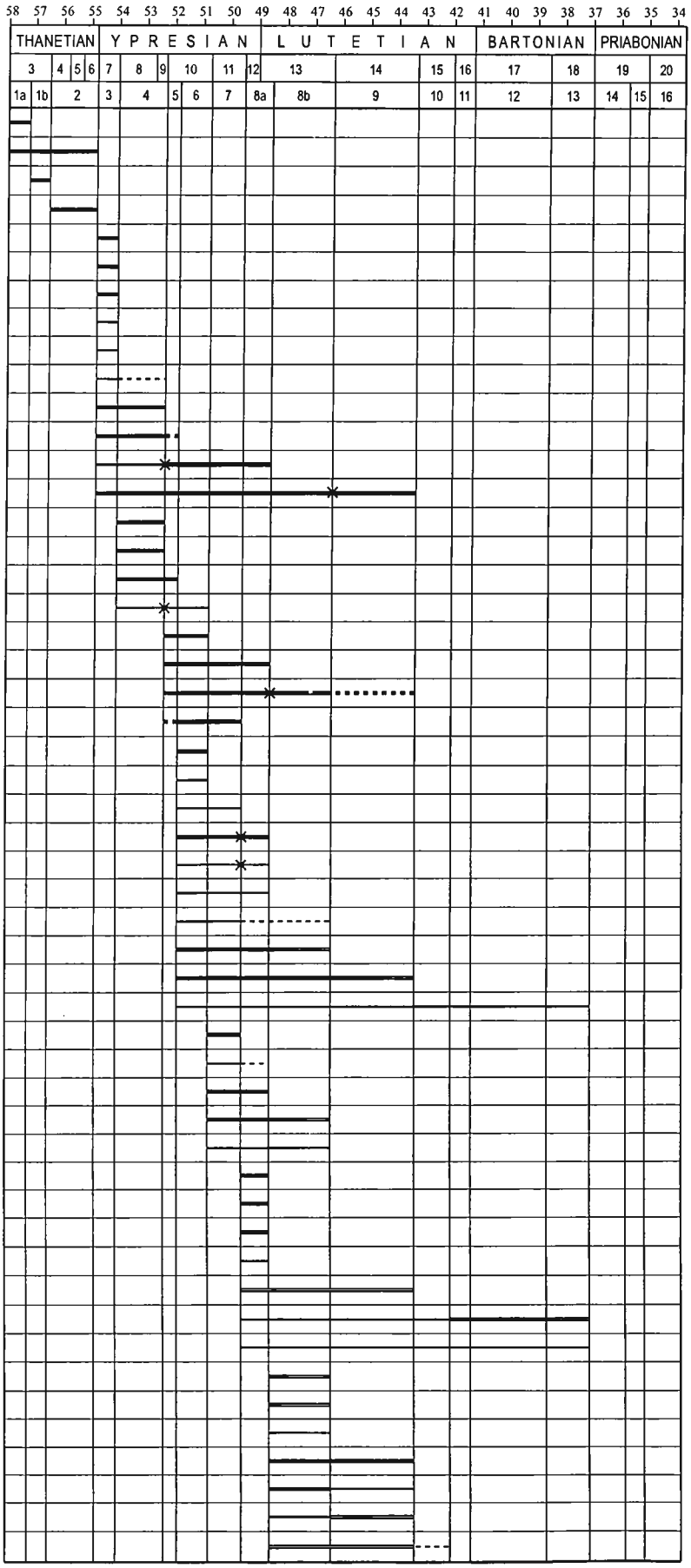


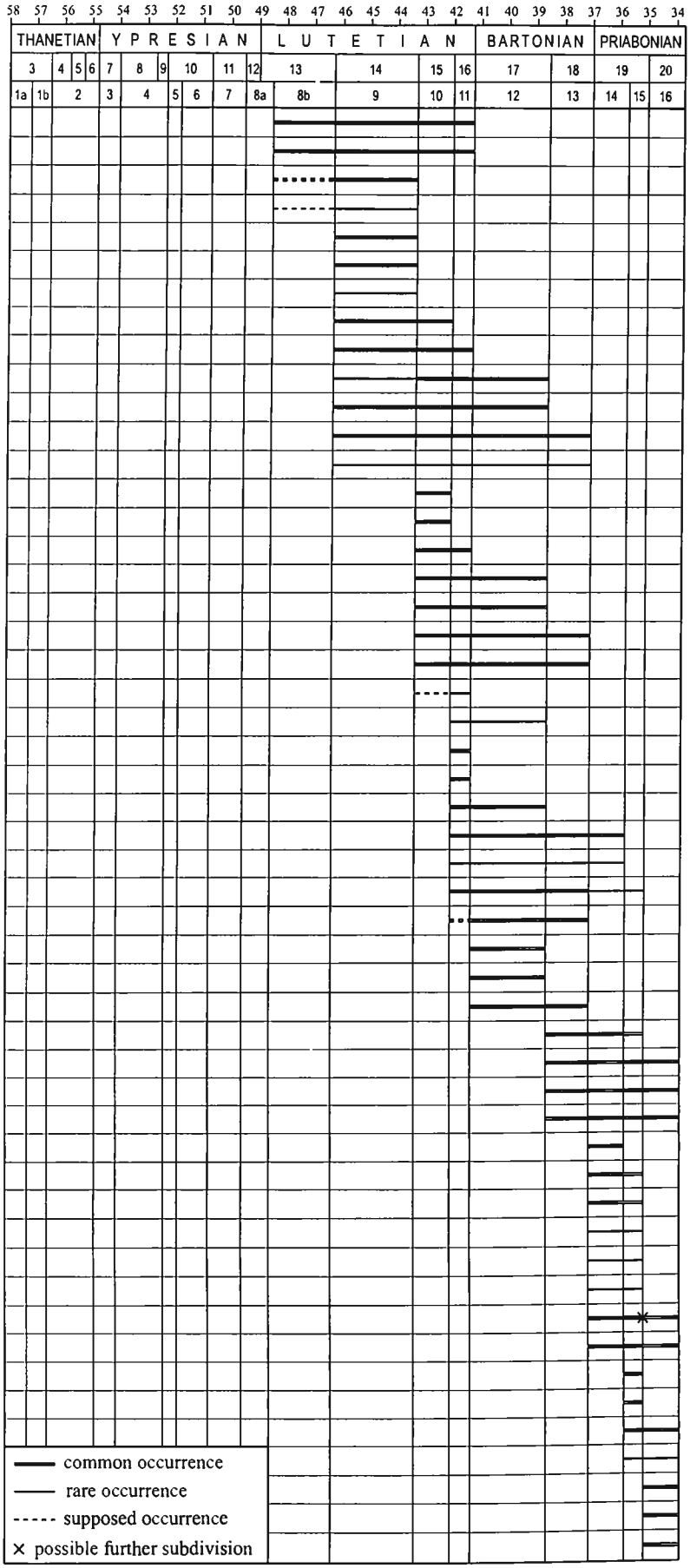
Figure 4: Range-chart for Mediterranean Nemkovellae, Orbitoclypei and Asterocyclinae.



Ma (Cande & Kent, 1992)
Standard stages
SB-zones
Orthophragmina-zones

D. seunesi seunesi
O. schopeni ramaraoi
D. seunesi n. ssp. Beloslav
D. tenuis n. ssp. Ruisseau de Bec
D. archiaci bakhchisaraiensis
D. tenuis tenuis
O. schopeni neumannae
O. bayani
O. multiplicata
O. munieri n. ssp. Spilecco
D. dispansa broennimani
A. taramellii
D. augustae sourbetensis
N. evae
D. archiaci staroseliensis
O. schopeni suvlukayensis
D. pseudoaugustae
D. furoni
D. archiaci archiaci
D. disponsa taurica
O. schopeni crimensis
O. munieri munieri
D. fortisi fortisi
N. rota
O. n. sp. Horsarrieu
O. douvillei douvillei
A. schweighauseri n. ssp. Bos d'Arros
D. aquitanica
D. pulcra landesica
A. stella n. ssp. Horsarrieu
A. stellata adourensis
D. trabayensis trabayensis
D. fortisi simferopolensis
O. furcata n. ssp. Horsarrieu
N. strophiolata fermonti
D. archiaci bartholemei
N. bodrakensis
D. stratiemanuelis
O. marthae
O. varians portnayae
O. koehleri
A. alticostata gallica
A. kecskemetii
O. (?) *daguini*
D. radians n. ssp. Caupenne
O. varians n. ssp. Caupenne
D. kingae
O. douvillei n. ssp. Gibret
A. schweighauseri schweighauseri
D. pratti montfortensis
D. augustae atlantica

Figure 5: Range-chart for Mediterranean Orthophragminae by the order of first appearences. ⟶



Ma (Cande & Kent, 1992)
Standard stages
SB-zones
Orthophragmina-zones

D. dispansa hungarica
N. strophiolata strophiolata
O. furcata n. ssp. Gibret
D. spliti spliti
D. pulcra pulcra
D. radians noussensis
D. aaroni
O. varians angoumensis
D. discus discus
D. radians radians
D. knessae
A. stella stella
N. katoae
D. pulcra n. ssp. Angoumé
O. douvillei chudeaui
A. alticostata cuvillieri
A. stellata stellata
O. fucata rovasendai
D. dispansa sella
D. pratti pratti
D. spliti ajkaensis
O. schopeni schopeni
D. pulcra balatonica
O. varians roberti
O. douvillei pannonicus
N. strophiolata n. ssp. Padragkút
D. n. sp. Siest
D. discus adamsi
D. augustae olianae
D. pulcra baconica
O. varians scalaris
A. alticostata alticostata
A. stellata stellaris
D. radians labatlanensis
O. furcata furcata
O. variansa varians
D. dispansa dispansa
A. alicostata danubica
D. pratti minor
D. nandori
D. samantai
A. trabayensis n. ssp. Mossano
A. stella praestellaris
D. augustae augustae
D. dispansa umbilicata
N. strophiolata tenella
A. priabonensis
D. euaensis
A. stellata n. ssp. Kisgyör
D. dispansa n. ssp.Kisgyör
D. trabayensis vicenzensis

A=Asterocyclina, D.=Discocyclina, N.= Nemkovella, O.=Orbitoclypeus

(D) *O. douvillei chudeaui* d=340–425 μm
(E) *O. douvillei pannonicus* d>425 μm

Notes: 1. *O. douvillei douvillei* is described in Less (1987) as *O. douvillei*. Also *O. varians horsarrieuensis* in Less (1987) is included here.

2. *O. douvillei* n. ssp. Gibret and *O. douvillei chudeaui* are unsubdivided in Less (1987) and described there as *O. chudeaui chudeaui*. Figures for the first, less developed chronosubspecies: Fermont (1982), pl. 9, figs 3–4; Less (1987), pl. 43, fig. 2.

3. *O. douvillei pannonicus* is described in Less (1987) as *O. chudeaui pannonicus*.

***Orbitoclypeus furcata*-lineage**

O. furcata (ORFUR)

(A) *O. furcata* n. ssp. Horsarrieu d<200 μm
(B) *O. furcata* n. ssp. Gibret d=200–270 μm
(C) *O. furcata rovasendai* d=270–340 μm
(D) *O. furcata furcata* d>340 μm

Note: For *O. furcata* n. ssp. Horsarrieu and *O. furcata* n. ssp. Gibret there are no figures available at present in the literature.

[*Orbitoclypeus katoae*] — see *Nemkovella katoae*

Orbitoclypeus koehleri (ORKOH)

So far no further subdivision.

Orbitoclypeus marthae (ORMAR)

So far no further subdivision.

Orbitoclypeus multiplicata (ORMUL)

So far no further subdivision.

***Orbitoclypeus munieri*-lineage**

O. munieri (ORMUN)

(A) *O. munieri* n. ssp. Spilecco d<280 μm
(B) *O. munieri munieri* d>280 μm

Notes: 1. The Horsarrieu forms, described in Less (1987) as *O. bayani* are put in synonymy here with *O. munieri munieri*.

2. For *O. munieri* n. ssp. Spilecco there are no figures available at present in the literature.

***Orbitoclypeus* n. sp. Horsarrieu** (ORNSP)

So far no further subdivision.

Note: No figures available at present in the literature.

[*Orbitoclypeus portnayae*] — see *O. varians portnayae*

[*Orbitoclypeus pygmaea*] — so far unknown from the Central and Western Tethys, probably belongs to *Nemkovella*, maybe the ancestor of *N. bodrakensis*

[*Orbitoclypeus ramaraoi crimensis*, *O. ramaraoi neumannae*, *O. ramaraoi ramaraoi* and *O. ramaraoi suvlukayensis*] — included into the *O. schopeni*-lineage

***Orbitoclypeus schopeni*-lineage**

O. schopeni (ORSCH)

(A) *O. schopeni ramaraoi* d<195 μm
(B) *O. schopeni neumannae* d=195–240 μm
(C) *O. schopeni suvlukayensis* d=240–300 μm
(D, E) *O. schopeni crimensis* d=300–(390)–500 μm
(F) *O. schopeni schopeni* d>500 μm

Notes: 1. *O. schopeni ramaraoi* is described in Less (1987) as *O. ramaraoi ramaraoi* and partly as *O. seunesi*.

2. *O. schopeni neumannae*, *O. schopeni suvlukayensis*, *O. schopeni crimensis* and *O. schopeni schopeni* are described in Less (1987) as *O. ramaraoi neumannae*, *O. ramaraoi suvlukayensis*, *O. ramaraoi crimensis* and *O. schopeni*, respectively.

[*Orbitoclypeus seunesi*] — see *Discocyclina seunesi* and *O. schopeni ramaraoi*

***Orbitoclypeus varians*-lineage**

O. varians (ORVAR)

(A) *O. varians portnayae* d<165 μm
(B) *O. varians* n. ssp. Caupenne d=165–205 μm
(C) *O. varians angoumensis* d=205–255 μm
(D) *O. varians roberti* d=255–320 μm
(E) *O. varians scalaris* d=320–400 μm
(F) *O. varians varians* d>400 μm

Notes: 1. *O. varians portnayae* is described in Less (1987) as *O. portnayae*.

2. For *O. varians* n. ssp. Caupenne there are no figures available at present in the literature.

3. *O. varians horsarrieuensis* in Less (1987) is put in synonymy here with *O. douvillei douvillei*.

APPENDIX B

List and characterization of the samples cited

Samples are characterized in alphabetic order. The code number in front of the 5-digit sample-abbreviation serves for the geographical identification in fig. 2. In brackets the number of the actual Orthophragmina-zone, described in Appendix C can be found. The "/" mark between the numbers means the intermediate position of the given sample between two zones.

Paragraphs marked by letters contain information as it follows:

a) Bibliographic and other data about the locality with previous and parallel data concerning its age. Zones marked by P are planktonic foraminiferal as given by Blow (1969), by NP are of the calcareous nannoplankton by Martini (1971), by A. are alveolinid by Hottinger (1960), by N. are nummulitid by Schaub (1981) and by O. are orthophragminid by Less (1987).

b) Origin of the sample and the method of exami-

nation of Orthophragminae in the sample (method of receiving data). Our own preparations were examined in split equatorial sections (Less, 1981, Čosović, 1990). NHMB = Naturhistorisches Museum (Basel), SCH = the Schaub-collection, TTMB = Természettudományi Múzeum (Budapest).

Where the paragraphs a and b are missing, the corresponding information can be found under the same sample-abbreviation in Less and Ó. Kovács (1996). The list of the Orthophragmina-fauna is displayed in Table 2. The statistical data of the populations can be found in Table 1.

1. AJKA1 (11) — Ajka, "*Discocyclina*" beds (Hungary)

2. ANGOU (10) — Angoumé, Marnière de Miretraine (France)

3–4. AURI9 (?3) and AUR12 (4) — Aurignac 9. and 12. (France, Petites Pyrenées)
   a) Tambareau and Villatte (1977): 107–110 and fig. 62: AURI9 corresponds to the passage between bed j (Marbres de Mancioux à Mélobésiées) and k (Marnes à Asterodiscus et Xanthopsis): P6; AUR12 represents the lower part of bed l (Marnes claires): P6, *N. exilis* zone, *A. corbarica* zone, NP11 (Tambareau, 1995).
   b) Sent by Y. Tambareau (Toulouse), own preparations.

5–10. BELO0 (1a), BELO1 (1a), BELO2 (1b), BELO3 (1b), BELO4 (1b) and BELO5 (1b) — Beloslav 0–5, in the vicinity of Varna (Bulgaria)
   a) Aladzhova-Khrischeva (1984): 36, 40–41, fig. 1. bed No. 1. ("varikova zadruga"); Muzilev in Aladzhova-Khrischeva *et al.* (1983): 938, NP6; Dzhuranov in Aladzhova-Khrischeva *et al.* (1983): 938, P4 (from the lithostratigraphic horizon of the locality). Six samples were collected from the altogether 6 m thick Thanetian series. From the bottom to the top: BELO0 is from 0, BELO1 from 0.75, BELO2 from 1.5, BELO3 from 2.5, BELO4 from 4 and BELO5 from 6 m.
   b) Collected by R. Nakov (Sofia), own preparations.

11. BIPEB (13) — Biarritz, Rocher de Peyreblanque (France)

12. BOSDA (6) — Bos d'Arros (France), SCH 54313 in NHMB

13. BOUSM (1a) — Boussan Mare (France, Petites Pyrenées)

14. CAUNE (13) — Cauneille (France)

15. CAUPE (8b) — Caupenne, Fontaine ou N de ferme Jean Gazé (France), SCH 55217 in NHMB

16–26. Crimean Peninsula, Bakhchisaraï: CRIBO (8b) — "Bodrakian stage"; CRICP (4) — *Nummulites crimensis-Assilina placentula* zone-limit; CRICR (3) — *N. crimensis* zone (Crimea); CRIDL (7) — *N. distans* zone, lower part; CRIDU (8a) — *N. distans* zone, upper part; CRINU (7) — *N. nemkovi* zone, upper part; CRIOS (3) — *Operculina semiinvoluta* zone; CRIPA (5) — *A. placentula* zone, lower part CRIPN (6) — *A. placentula-N. nemkovi* zone-limit CRIPO (8a) — *N. polygyratus* zone; CRIPU (5) — *A. placentula* zone, upper part
   a) Nemkov and Barkhatova (1961): 7–13, Nemkov (1967): 64–69, 75–76, 86 and Portnaya (1974): 40–56: CRIOS, CRICR, CRICP, CRIPA and CRIPU: Lower Eocene, CRIPN, CRINU, CRIDL, CRIDU and CRIPO: Middle Eocene, CRIBO: lower part of the Upper Eocene. Kapellos (1973): 33–41, CRIOS: NP11, CRICR, CRICP, CRIPA and CRIPU: NP12, CRIPN, CRINU, CRIDL and CRIDU: NP13, CRIPO and CRIBO: NP14. Schaub (1981): 67–68: CRIOS: *N. exilis* zone, CRICR and CRICP: *N. involutus* zone, CRIPA, CRIPU, CRIPN and CRINU: *N. planulatus* zone, CRIDL and CRIDU: *N. praelaevigatus* zone, CRIPO: *N. manfredi* zone, CRIBO: *N. laevigatus* zone Less (1987): 86–91: CRIOS and CRICR: O.3, CRICP: O.4, CRIPA and CRIPU: O.5, CRIPN: O.6, CRINU and CRIDL: O.7, CRIDU, CRIPO and CRIBO: O.8.
   b) Collected by us, own preparations.

27. DIKIL (5) — Dikilitash, in the vicinity of Varna (Bulgaria)
   a) Aladzhova-Khrischeva (1984): 37–39, 42–43, fig. 1. bed No. 9. ("dikilitashka svita"), *N. planulatus* zone; Less (1987): 91 (DK population), O.5.
   b) Collected by J. Oravecz, TTMB, own preparations.

28. DSZTM (9) — Dunaszentmiklós (Hungary)
   a) Less (1987): 91–92 (DM population), O.9. From the lithostratigraphic horizon of the locality: BÁLDI-BEKE (1984): NP16; Jámbor-Kness (1988): *Nummulites anomalus-N. subramondi* zone in the local subdivision (Upper Cuisian by her).
   b) Collected by us, own preparations.

29–30. DUDAR (12) and DUORD (12) — Dudar, Sûrûhegy and Ördögárok (Hungary)

31–32. GAMA2 (4) and GAMA7 (3) — Gamarde, Pont de Louer, Marnes à Discocyclines (France, Chalosse de Montfort), SCH 54027 and SCH 54022 in NHMB

33–34. GANBD (5) and GANTU (6) — Gan: Berdoulou and Tuilerie (France), GANBD is SCH 50031 in NHMB

35–36. GIBR1 (9) and GIBRE (9)— Gibret, église, Couches de Nousse (France). GIBR1 is SCH 60014 in NHMB

37. GRANE (15) — (Valle) Granella (Italy)

38–39. HORSA (6) and HORSX (6/7) — Horsarrieu, Marnière Sourbet, Marne à Xanthopsis (France)

40–51. IS187 (8a), IS199 (8a), IS221 (8a), IS273 (8a/b), IS276 (8a/b), IS278 (8a/b), IS335 (8b), IS336 (8b), IS366 (8b), IS382 (8b), IS399 (9) and IS407 (9) — Ein Avedat (Israel)
   a) BENJAMINI (1980): 325–330, IS187–221: P9, IS273–407: "*Sphaeroidinellopsis senni*" zone, introduced by him in between zones P9 and P10; Romein (1979): 28–35, IS187: NP12, IS199–278: NP13, IS335–407: NP14; Fermont (1982): 8–50; Benjamini (1990, in litt.): "I have found most of this section, including the top, to belong to planktic foraminiferal zone P10".
   b) Collected and sectioned by W.J.J. Fermont, Department of Micropaleontology, State University of Utrecht. In this paper we use Fermont's numbers of samples. Only those samples are mentioned that contain more than one Orthophragmina-population. Our studies and our measurements except *Asterocyclina stella* (see later). Comparing our measurements (including the whole wall's thickness) on all *A. alticostata* with those of Fermont's (1982, table 3, including only the half of the wall's thickness), we got about 15 μm surplus. This surplus was added to the means given by Fermont for the *A. stella*-populations not measured by us. However, Fermont's coefficients of variation were saved, and the standard errors were increased accordingly.

52. JOKAI (?9) — Ajka, Jókai-akna "*perforatus*" beds (Hungary)
   a) The locality is about 4 km to the SE from Ajka, a small road-cut on the SW side of the road from Ajka to Öcs, inside the territory of the coal-mine named Jókai-akna. It can be located in Less (1987, p. 94, textfig. 20), between Jókai-akna and site No. 4. (Csékúti-árok). It corresponds to the X. (*Nummulites perforatus*) level of the Bakony Mts. by Kopek *et al.* (1971) (= Upper Lutetian by them). Nummulitidae: *Nummulites* ex. gr. *perforatus*, *N.* ex. gr. *millecaput*, *Assilina spira* and other smaller forms (our tentative determinations).
   b) Collected by us, own preparations.

53. KBNBI (13) — Kirchberg bei Neubeuern am Inn (Bavaria)

54. KRESS (8a) — Kressenberg, Emanuel-Flöz, Schwarzerz (Bavaria)

55. LABAT (15) — Lábatlan, József-puszta (Hungary)

56. MONTF (9) — Montfort, Fontaine de la Médaille (France)

57–59. MOS31 (14), MOS44 (14/15) and MOS50 (15) — Mossano 31, 44 and 50 in Schweighauser (1953) (Italy)

60. MOS69 (16) — Mossano 69. (Italy)
   a) Schweighauser (1953): 13–15: upper part of the Priabonian.
   b) Collected (its number is the same as in fig. 3 and Table I of Schweighauser, 1953 concerning the Mossano profile) and thin-sectioned by J. Schweighauser, NHMB, our study and measurements.

61. MOSSA (14) — Mossano, base of Priabonian (Italy)

62. NESZM (9) — Neszmély (Hungary)

63. NOUCR (9) — Nousse-Crouts, Couches de Nousse (France)

64. NTSOR (1a) — Nouts-Oraas (France, Atlantic Pyrenees)
   a) Tambareau (1995): 294; Tambareau (in litt.): *A. (Glomalveolina) primaeva* zone.
   b) Sent by Y. Tambareau (Toulouse), own preparations.

65. NUSSD (?9) — Nussdorf (Austria)
   a) Less (1987): 100 (ND population), O.9.
   b) Collected by A. von Hillebrandt, TTMB, own preparations.

66. PADR3 (11) — Padragkút (Hungary)

67–70. PR049 (14), PR055 (14), PR126 (16) and PR135 (16) — Priabona 49, 55, 126 and 135 in SETIAWAN (1983) (Italy)

71. PYCM1 (4) — Campo, Pobla member (Spain, Southern Pyrenees)

72–74. REME2 (16), REME3 (16) and REME4 (16) — Remetekút 2, 3 and 4 (Kisgyõr, Bükk Mts., Hungary)
   a) Less (in prep.): Four isolated localities (REME1-4 but REME1 does not contain Orthophragminae) that are situated 20 km to the S of Miskolc (NE Hungary) and representing approximately the same stratigraphic horizon. In Less and Ó. Kovács (1996) they are united under the name of REMET. In the whole Bükk Mts. the transgression of the Eocene upon the Mesozoic basement started at the end of Priabonian. Well-preserved, rich fauna. Nummulitidae: *Nummulites fabianii retiatus* (REME1-3), *N. incrassatus* (REME1-4), *N. chavannesi* (REME1-4), *N. pulchellus* (REME1), *N. bouillei* (REME1), *N. budensis* (REME1), *N. stellatus* (REME2-4), *Operculina alpina* (REME2-4), *Spiroclypeus granulosus* (REME3), Upper Priabonian. Nannoplankton (det. M. Báldi-Beke): NP21, without discoasters. Stratigraphically 15 m above the localities Lower Oligocene sandy marls lacking larger Foraminifera and belonging to NP22 zone were found (A. Nagymarosy, pers. comm.).
   b) Collected by us, own preparations.

75. RUBEC (2) — Ruisseau de Bec (France, Petites Pyrenées)
76. SANPA (12) — San Pancrazio (Italy)
77. SIEST (14) — Siest (France)
78. SORGE (15) — Sorgente di Monte Baldo (Italy)
79. SPILE (3) — Spilecco (Italy)
80. STBAR (8a) — Saint-Barthélémy, Maisonnave (France)
81. VALDE (?5) — Valdeforte (Italy)
82. VANZI (8a) — Vanzi, "Valle Grande bei Malo" (Italy)

Table 1: Statistical data of the deuteroconch cross-diameter (d) values of the studied Orthophragminae.

Populations are grouped by lineages or single species and listed in the same order as in Appendix A. The meaning of the five-digit species-abbreviations can be found in Appendix A while those of the samples in Appendix B. Within each species populations are listed in the increasing order of the mean values. Nr. = number of specimens, Mean = the mean value (d), s.e. = its standard error, Min. = the minimal, Max. = the maximal value. These values are in µm. CV = the coefficient of variation (= standard deviation/mean) in %, zone = the number of the actual Orthophragmina-zone described in Appendix D. When e.g. 14/15 is written, it means intermediate between zones O.14 and O.15.

Lineage	Sample	Nr.	Mean	s.e.	Min.	Max.	CV	Zone
ASALT	IS276	1	204,0					8a/b
ASALT	IS221	12	226,8	9,8	170	277	14,9	8a
ASALT	GIBR1	17	230,3	5,2	190	265	9,3	9
ASALT	IS273	7	241,9	13,0	187	289	14,2	8a/b
ASALT	NOUCR	2	255,0		250	260		9
ASALT	IS278	5	258,4	12,2	218	298	10,5	8a/b
ASALT	GIBRE	5	270,0	7,9	255	300	6,5	9
ASALT	IS199	1	275,0					8a
ASALT	ANGOU	7	281,4	12,7	205	320	11,9	10
ASALT	PADR3	30	307,7	6,6	250	395	11,7	11
ASALT	AJKA1	10	308,0	11,4	245	360	11,7	11
ASALT	DUORD	38	370,4	7,1	295	465	11,8	12
ASALT	SANPA	5	379,0	10,4	340	405	6,2	12
ASALT	DUDAR	17	400,0	11,3	320	485	11,6	12
ASALT	CAUNE	2	432,5		360	505		13
ASALT	LABAT	12	507,0	21,8	400	715	14,9	15
ASKEC	STBAR	1	165,0					8a
ASKEC	IS276	1	184,0					8a/b
ASKEC	ANGOU	1	205,0					10
ASKEC	PADR3	4	240,0	6,4	225	255	5,3	11
ASKEC	AJKA1	4	250,0	16,0	205	265	12,8	11
ASKEC	KBNBI	1	250,0					13
ASKEC	BIPEB	14	263,2	4,8	240	310	6,8	13
ASKEC	SANPA	7	265,7	8,0	250	315	8,0	12
ASKEC	DUDAR	3	268,3	26,8	205	315	17,3	12
ASKEC	CAUNE	1	355,0					13
ASPRI	MOS69	2	205,0		165	245		16
ASPRI	PR126	22	209,6	3,2	173	241	7,2	16
ASPRI	MOS44	1	210,0					14/15
ASPRI	PR135	21	218,6	3,3	187	255	6,9	16
ASPRI	LABAT	3	245,0	8,2	225	255	5,8	15
ASSCH	BOSDA	4	273,8	13,6	250	320	10,0	6
ASSCH	STBAR	2	342,5		320	365		8a
ASSCH	IS273	1	348,0					8a/b
ASSCH	IS336	1	374,0					8b
ASSCH	IS366	1	442,0					8b
ASSCH	CAUPE	13	469,6	12,7	380	560	9,8	8b
ASSCH	MONTF	1	540,0					9
ASSTL	HORSX	15	124,7	2,4	105	139	7,6	6/7
ASSTL	IS278	15	125,6	2,3			7,0	8a/b
ASSTL	STBAR	6	125,8	6,3	100	140	12,2	8a
ASSTL	IS273	27	133,1	1,9			7,5	8a/b
ASSTL	IS276	41	133,6	1,9			9,2	8a/b
ASSTL	IS221	41	135,1	2,3			11,0	8a
ASSTL	HORSA	6	138,3	6,0	110	155	10,6	6
ASSTL	IS335	25	141,2	2,5			8,7	8b
ASSTL	CRIDU	3	143,3	3,6	135	150	4,4	8a
ASSTL	IS199	18	144,7	5,3			15,5	8a
ASSTL	IS336	25	146,2	3,7			12,5	8b
ASSTL	IS366	22	147,7	2,9			9,1	8b
ASSTL	ANGOU	1	150,0					10
ASSTL	PADR3	5	154,0	4,3	140	170	6,3	11
ASSTL	IS399	29	165,9	3,1			10,0	9
ASSTL	IS407	23	173,9	3,8			10,6	9
ASSTL	SANPA	7	178,6	8,6	135	210	12,7	12
ASSTL	CAUNE	1	195,0					13
ASSTL	BIPEB	5	196,0	4,6	180	210	5,2	13
ASSTL	PR055	4	218,0	6,8	201	238	13,6	14
ASSTL	PR049	5	218,3	7,3	190	241	7,5	14
ASSTL	LABAT	1	235,0					15
ASSTL	MOS44	2	247,5		245	250		14/15
ASSTL	MOSSA	1	275,0					14
ASSTL	MOS69	3	276,7	17,0	235	300	10,7	16
ASSTL	PR135	23	289,7	7,0	230	348	11,6	16
ASSTL	PR126	20	290,7	6,6	235	340	10,2	16
ASSTT	GIBR1	7	130,0	4,6	110	145	9,4	9
ASSTT	GANTU	4	130,3	8,7	113	155	13,3	6
ASSTT	STBAR	3	135,0	13,1	105	160	16,8	8a
ASSTT	NOUCR	14	137,1	3,4	115	150	9,2	9
ASSTT	GIBRE	4	142,5	8,2	115	155	11,5	9
ASSTT	CAUPE	5	146,0	10,4	115	185	16,0	8b
ASSTT	ANGOU	9	152,8	3,7	140	175	7,3	10
ASSTT	MONTF	1	155,0					9
ASSTT	NUSSD	1	160,0					?9
ASSTT	DUORD	13	160,0	4,3	140	195	9,6	12
ASSTT	AJKA1	17	161,8	3,9	130	195	10,0	11
ASSTT	PADR3	21	168,6	4,1	150	210	11,1	11
ASSTT	SANPA	12	181,3	4,8	150	200	9,1	12
ASSTT	DUDAR	3	185,0	6,2	175	200	5,8	12
ASSTT	GRANE	1	185,0					15
ASSTT	CAUNE	4	190,0	10,1	155	205	10,7	13
ASSTT	BIPEB	17	191,8	3,4	155	205	7,4	13
ASSTT	KBNBI	6	195,8	4,9	180	210	6,2	13
ASSTT	PR049	13	198,2	5,1	167	224	9,2	14
ASSTT	MOSSA	8	204,4	4,2	185	225	5,8	14
ASSTT	PR055	12	206,1	5,4	180	246	9,0	14

Lineage	Sample	Nr.	Mean	s.e.	Min.	Max.	CV	Zone
ASSTT	SIEST	7	209,3	8,0	190	255	10,2	14
ASSTT	LABAT	13	211,9	7,1	165	250	12,1	15
ASSTT	SORGE	5	223,0	8,1	195	250	8,1	15
ASSTT	MOS44	20	228,0	4,2	190	250	8,2	14/15
ASSTT	REME3	9	248,9	3,0	235	260	3,6	16
ASSTT	REME4	23	254,6	4,3	210	300	8,1	16
ASSTT	REME2	1	260,0					16
ASTAR	PYCM1	1	116,0					4
ASTAR	AURI9	25	137,3	4,0	97	173	14,5	?3
ASTAR	SPILE	10	147,0	8,1	110	190	17,5	3
ASTAR	CRICP	1	150,0					4
DIAAR	NUSSD	1	285,0					?9
DIAAR	GIBR1	1	310,0					9
DIAAR	NESZM	6	340,8	30,0	255	470	21,6	9
DIAAR	DSZTM	3	378,3	15,7	350	415	7,2	9
DIAQU	CRINU	1	260,0					7
DIAQU	HORSA	2	327,5		305	350		6
DIAQU	CRIDU	2	415,0		400	430		8a
DIAUG	GAMA7	1	82,0					3
DIAUG	CRIDL	2	110,0		105	115		7
DIAUG	CRINU	3	115,0	10,3	100	140	15,5	7
DIAUG	GANBD	2	120,0		107	133		5
DIAUG	CRIDU	3	120,0	6,2	105	130	9,0	8a
DIAUG	HORSX	41	129,8	2,7	99	177	13,5	6/7
DIAUG	HORSA	8	130,0	6,1	105	160	13,3	6
DIAUG	STBAR	2	130,0		110	150		8a
DIAUG	IS199	9	132,4	5,3	109	162	12,0	8a
DIAUG	BOSDA	4	135,0	8,5	110	155	12,6	6
DIAUG	GANTU	6	140,8	6,3	115	155	10,9	6
DIAUG	CRIBO	2	152,5		140	165		8b
DIAUG	NESZM	5	155,0	2,0	150	160	2,9	9
DIAUG	NOUCR	17	155,0	3,9	125	190	10,4	9
DIAUG	GIBR1	5	178,0	8,8	150	200	11,0	9
DIAUG	DUORD	3	196,7	8,9	175	210	7,9	12
DIAUG	KBNBI	10	198,0	3,8	170	210	6,0	13
DIAUG	BIPEB	14	198,9	6,2	160	240	11,7	13
DIAUG	CAUNE	1	205,0					13
DIAUG	LABAT	4	237,5	15,6	185	265	13,1	15
DIAUG	SIEST	12	242,5	8,8	190	305	12,6	14
DIAUG	GRANE	3	245,0	10,3	220	260	7,3	15
DIAUG	MOS44	14	250,7	8,4	210	340	12,5	14/15
DIAUG	MOS50	4	256,3	21,3	200	320	16,6	15
DIAUG	MOSSA	2	270,0		245	295		14
DIAUG	MOS31	6	280,0	13,9	230	340	12,1	14
DIAUG	REME4	7	292,9	10,2	255	340	9,2	16
DIAUG	REME2	14	301,5	11,7	235	365	14,5	16
DIAUG	PR055	47	307,6	5,6	207	371	12,7	14
DIAUG	PR049	43	314,2	5,4	255	401	11,3	14
DIAUG	REME3	7	339,3	19,0	275	445	14,8	16
DIAUG	PR135	1	370,0					16
DIARC	CRIOS	3	275,0	13,1	250	305	8,3	3
DIARC	CRICR	14	282,9	17,4	200	440	23,0	3
DIARC	GAMA7	7	303,1	13,9	228	343	12,1	3
DIARC	PYCM1	9	309,0	11,9	260	381	11,6	4
DIARC	GAMA2	16	331,6	8,5	267	400	10,2	4
DIARC	CRICP	20	351,3	12,4	275	485	15,8	4
DIARC	AUR12	13	356,9	18,2	250	460	18,3	4
DIARC	CRIPU	1	360,0					5
DIARC	CRIPA	15	416,7	13,4	310	500	12,4	5
DIARC	GANBD	7	423,4	29,1	324	579	18,2	5
DIARC	GANTU	17	426,5	28,1	230	640	27,2	6
DIARC	HORSX	16	433,8	16,0	360	565	14,8	6/7
DIARC	BOSDA	22	436,4	20,5	260	655	22,0	6
DIARC	DIKIL	1	450,0					5
DIARC	HORSA	6	515,0	37,7	405	695	17,9	6
DIARC	CRIPN	1	600,0					6
DIARC	CRIDL	8	658,1	28,4	500	774	12,2	7
DIARC	CRINU	10	659,5	26,2	510	840	12,5	7
DIARC	STBAR	16	665,9	35,0	440	980	21,0	8a
DIARC	CRIDU	6	710,8	55,7	505	950	19,2	8a
DIARC	VANZI	5	714,0	37,4	600	850	11,7	8a
DIARC	CAUPE	8	722,5	28,7	620	885	11,2	8b
DIDSC	NOUCR	6	1202,5	57,6	985	1350	11,7	9
DIDSC	GIBRE	2	1255,0		1200	1310		9
DIDSC	GIBR1	4	1261,3	40,4	1200	1400	6,4	9
DIDSC	PADR3	6	1270,0	59,7	1100	1550	11,5	11
DIDSC	BIPEB	2	1475,0		1350	1600		13
DIDSC	AJKA1	14	1478,9	78,5	1025	2040	19,9	11
DIDSC	DUORD	4	1515,0	63,2	1385	1690	8,3	12
DIDSC	DUDAR	11	1555,0	97,6	1140	2410	20,8	12
DIDSC	LABAT	1	2020,0					15
DIDSP	CRICR	10	113,5	4,7	100	145	13,2	3
DIDSP	GAMA7	1	130,0					3
DIDSP	CRICP	2	142,5		140	145		4
DIDSP	GAMA2	4	151,9	6,4	137	171	8,4	4
DIDSP	GANBD	1	171,0					5
DIDSP	BOSDA	11	177,7	5,1	155	205	9,5	6
DIDSP	HORSA	2	187,5		165	210		6
DIDSP	CRIDU	23	192,0	3,7	155	235	9,2	8a
DIDSP	HORSX	10	215,0	4,4	190	235	6,4	6/7
DIDSP	STBAR	9	216,7	6,4	195	250	8,8	8a
DIDSP	CAUPE	14	241,4	11,6	160	310	18,0	8b
DIDSP	GIBR1	8	249,4	7,0	225	292	7,9	9
DIDSP	DSZTM	1	250,0					9
DIDSP	NOUCR	3	251,7	7,6	240	270	5,2	9
DIDSP	NUSSD	4	253,8	3,2	245	260	2,6	?9
DIDSP	AJKA1	17	254,1	14,9	165	405	24,1	11
DIDSP	MONTF	1	260,0					9
DIDSP	GIBRE	4	265,0	11,6	240	295	8,7	9
DIDSP	NESZM	2	280,0		255	305		9
DIDSP	DUDAR	12	305,0	8,6	245	350	9,8	12
DIDSP	BIPEB	4	316,2	8,7	300	345	5,5	13
DIDSP	ANGOU	5	320,0	32,6	230	450	22,8	10
DIDSP	PADR3	62	327,1	10,1	160	515	24,4	11
DIDSP	DUORD	7	328,6	20,6	280	450	16,6	12
DIDSP	KBNBI	5	374,0	13,1	350	410	7,9	13
DIDSP	SIEST	2	452,5		410	495		14
DIDSP	MOS31	5	454,0	21,1	380	520	10,4	14
DIDSP	PR049	10	465,3	20,7	391	575	14,0	14
DIDSP	PR055	12	492,4	29,3	374	714	20,6	14
DIDSP	MOSSA	4	500,0	0,0	500	500	0,0	14
DIDSP	MOS44	11	508,2	14,4	430	620	9,4	14/15
DIDSP	MOS50	2	555,0		550	560		15
DIDSP	SORGE	1	560,0					15
DIDSP	GRANE	14	641,8	32,3	500	960	18,8	15
DIDSP	LABAT	3	653,3	18,9	615	695	5,0	15
DIDSP	REME3	9	708,9	43,0	480	990	18,2	16
DIEUA	LABAT	8	438,1	18,9	360	535	12,2	15
DIEUA	PR126	3	566,7	53,4	493	697	16,3	16
DIEUA	SORGE	2	570,0		560	580		15
DISEU	NTSOR	14	229,6	7,4	190	285	12,1	1a
DISEU	BELO1	27	230,0	4,8	190	305	10,7	1a
DISEU	BOUSM	18	236,7	8,3	160	300	14,8	1a
DISEU	BELO0	10	246,5	8,7	205	305	11,1	1a
DISEU	BELO5	23	270,4	6,5	225	345	11,5	1b

Lineage	Sample	Nr.	Mean	s.e.	Min.	Max.	CV	Zone
DISEU	BELO2	27	273,3	5,3	225	350	10,0	1b
DISEU	BELO3	20	275,0	6,9	220	365	11,3	1b
DISEU	BELO4	4	283,8	10,1	255	305	7,1	1b
DITEN	RUBEC	29	336,9	7,9	260	400	12,7	2
DITEN	SPILE	2	385,0		355	415		3
DITEN	GAMA7	7	412,5	13,7	381	495	8,8	3
DIPSA	CRICP	10	546,0	25,7	445	700	14,9	4
DIPSA	PYCM1	6	632,0	25,0	560	712	9,7	4
DIPSA	DIKIL	5	637,0	48,2	505	800	16,9	5
DIPSA	GANBD	15	728,6	28,3	590	952	15,1	5
DIPSA	CRIPU	1	830,0					5
DIFOR	CRIPN	2	717,5		710	725		6
DIFOR	HORSA	3	745,0	49,0	625	805	11,4	6
DIFOR	HORSX	31	915,8	39,8	610	1440	24,2	6/7
DIFOR	CRINU	18	940,3	40,3	615	1255	18,2	7
DIFOR	CRIDL	20	980,6	28,9	830	1310	13,2	7
DISTR	CRIDU	12	1028,8	46,1	795	1470	15,5	8a
DISTR	CRIPO	4	1115,0	98,4	910	1440	17,6	8a
DISTR	KRESS	6	1263,3	79,1	1000	1600	15,3	8a
DIFUR	PYCM1	7	196,7	9,8	160	238	13,2	4
DIFUR	CRIPN	4	318,8	11,5	290	350	7,2	6
DIKIN	CRIBO	11	251,8	8,0	220	300	10,5	8b
DIKNE	DSZTM	7	146,4	8,6	100	180	15,5	9
DIKNE	DUDAR	1	200,0					12
DINSP	PADR3	2	980,0		960	1000		11
DINSP	SIEST	7	1130,0	62,0	860	1440	14,5	14
DINAN	GRANE	2	210,0		195	225		15
DINAN	MOSSA	2	212,5		210	215		14
DINAN	LABAT	5	320,0	9,3	300	350	6,5	15
DIPRT	CAUPE	1	305,0					8b
DIPRT	NOUCR	1	345,0					9
DIPRT	MONTF	5	426,0	10,8	400	455	5,7	9
DIPRT	ANGOU	15	485,7	23,8	350	685	19,0	10
DIPRT	AJKA1	3	486,7	26,8	440	550	9,5	11
DIPRT	KBNBI	1	500,0					13
DIPRT	PADR3	7	532,1	15,4	460	580	7,7	11
DIPRT	SANPA	3	550,0	34,0	490	630	10,7	12
DIPRT	DUDAR	37	551,6	22,2	385	1055	24,5	12
DIPRT	BIPEB	4	573,8	38,4	450	645	13,4	13
DIPRT	DUORD	51	630,0	18,9	405	1025	21,4	12
DIPRT	MOS31	1	700,0					14
DIPRT	LABAT	16	914,7	49,7	570	1385	21,7	15
DIPUL	HORSA	1	570,0					6
DIPUL	GIBR1	20	842,3	23,4	650	1075	12,4	9
DIPUL	GIBRE	1	905,0					9
DIPUL	ANGOU	8	1132,5	53,7	910	1470	13,4	10
DIPUL	AJKA1	30	1454,7	50,5	1050	2100	19,0	11
DIPUL	PADR3	8	1463,1	140,2	1080	2400	27,1	11
DIPUL	DUDAR	15	1833,0	74,5	1280	2600	15,7	12
DIRAD	CRIBO	1	200,0					8b
DIRAD	CAUPE	10	203,5	8,5	170	260	13,2	8b
DIRAD	MONTF	2	272,5		250	295		9
DIRAD	NOUCR	26	274,0	5,9	225	355	11,1	9
DIRAD	GIBRE	5	291,0	8,6	255	310	6,6	9
DIRAD	GIBR1	8	313,8	13,5	255	355	12,2	9
DIRAD	ANGOU	8	321,9	11,3	275	360	9,9	10
DIRAD	AJKA1	24	336,7	10,3	230	450	15,0	11
DIRAD	PADR3	23	367,2	17,6	260	530	22,9	11
DIRAD	SIEST	5	383,0	13,5	345	420	7,9	14
DIRAD	KBNBI	1	390,0					13
DIRAD	REME3	12	391,7	22,6	275	580	20,0	16
DIRAD	PR049	2	408,0		405	411		14
DIRAD	PR055	3	419,3	32,2	343	476	13,3	14
DIRAD	REME4	4	451,3	15,1	410	495	6,7	16
DIRAD	PR135	22	479,9	14,8	371	680	14,4	16
DIRAD	LABAT	9	565,0	28,5	455	715	15,1	15
DISAM	PR049	1	830,0					14
DISAM	LABAT	5	875,0	36,1	750	1000	9,2	15
DISPL	JOKAI	22	1027,9	27,5	835	1310	12,6	?9
DISPL	AJKA1	8	1446,9	89,3	1200	2000	17,5	11
DITRB	CRIBO	6	97,5	2,8	85	105	7,1	8b
DITRB	HORSA	3	100,0	2,3	95	105	4,1	6
DITRB	CRINU	2	100,0		95	105		7
DITRB	STBAR	2	105,0		105	105		8a
DITRB	GIBRE	2	107,5		105	110		9
DITRB	BIPEB	2	107,5		100	115		13
DITRB	HORSX	1	116,0					6/7
DITRB	AJKA1	4	118,8	2,7	110	125	4,6	11
DITRB	GIBR1	2	120,0		120	120		9
DITRB	PADR3	1	120,0					11
DITRB	PR049	2	136,0		121	151		14
DITRB	MOS50	1	145,0					15
DITRB	MOSSA	4	146,3	7,4	130	170	10,1	14
DITRB	MOS44	1	150,0					14/15
DITRB	PR055	1	167,0					14
DITRB	GRANE	2	170,0		165	175		15
DITRB	PR126	22	176,3	2,9	153	201	7,6	16
DITRB	PR135	9	179,3	3,1	167	190	5,2	16
DITRB	REME2	17	197,6	5,5	168	240	11,6	16
DITRB	REME3	16	210,6	6,0	155	250	11,4	16
DITRB	REME4	22	223,0	4,3	200	255	9,0	16
NMBOD	HORSX	2	80,0		72	88		6/7
NMBOD	STBAR	2	90,0		85	95		8a
NMBOD	CRIBO	3	95,0	8,2	75	105	14,9	8b
NMEVA	IS199	2	171,5		170	173		8a
NMEVA	GAMA2	1	175,0					4
NMEVA	GAMA7	6	177,4	7,3	152	198	10,0	3
NMEVA	IS276	1	178,0					8a/b
NMEVA	IS221	6	187,3	9,7	150	221	12,7	8a
NMEVA	IS187	1	189,0					8a
NMEVA	STBAR	2	200,0		195	205		8a
NMEVA	HORSA	6	205,0	23,2	145	305	27,7	6
NMEVA	CRIDL	1	210,0					7
NMEVA	IS366	17	215,4	9,1	170	289	17,5	8b
NMEVA	CRINU	11	216,4	11,2	165	300	17,2	7
NMEVA	IS273	5	220,7	8,7	204	255	8,8	8a/b
NMEVA	BOSDA	8	222,5	8,9	170	250	11,3	6
NMEVA	CRIPN	4	223,8	6,5	205	240	5,8	6
NMEVA	IS382	14	225,0	8,2	187	272	13,7	8b
NMEVA	IS336	9	227,0	8,3	173	264	10,9	8b
NMEVA	GANBD	1	228,0					5
NMEVA	HORSX	22	231,0	5,2	200	280	10,6	6/7
NMEVA	IS407	10	279,6	15,3	230	391	17,3	9
NMEVA	IS399	31	311,5	10,2	238	459	18,3	9
NMKAT	GIBR1	9	376,1	13,2	305	435	10,5	9
NMKAT	BIPEB	2	395,0		390	400		13
NMKAT	AJKA1	9	426,7	12,1	355	480	8,5	11
NMROT	BOSDA	3	195,0	0,0	195	195	0,0	6
NMSTR	HORSX	16	130,7	2,5	114	152	7,8	6/7
NMSTR	ANGOU	1	140,0					10

Lineage	Sample	Nr.	Mean	s.e.	Min.	Max.	CV	Zone
NMSTR	CRIDU	5	146,0	4,1	135	155	6,3	8a
NMSTR	STBAR	3	148,3	3,6	140	155	4,2	8a
NMSTR	IS273	2	150,5		139	162		8a/b
NMSTR	GIBRE	4	153,8	5,1	145	170	6,7	9
NMSTR	NOUCR	18	158,1	2,8	140	185	7,6	9
NMSTR	CAUPE	7	159,3	4,9	140	180	8,1	8b
NMSTR	DUDAR	1	160,0					12
NMSTR	GIBR1	6	160,8	3,6	150	175	5,5	9
NMSTR	AJKA1	10	172,5	6,3	145	210	11,6	11
NMSTR	PADR3	18	197,2	5,1	155	230	11,0	11
NMSTR	KBNB1	1	205,0					13
NMSTR	MOS31	1	205,0					14
NMSTR	MOSSA	2	210,0	7,1	200	220	4,8	14
NMSTR	BIPEB	6	210,8	4,6	195	230	5,4	13
NMSTR	DUORD	8	215,0	10,6	160	260	14,0	12
NMSTR	MOS44	9	241,1	9,1	195	290	11,4	14/15
NMSTR	LABAT	3	255,0	13,1	230	285	8,9	15
NMSTR	MOS50	2	265,0		260	270		15
ORBAY	SPILE	21	332,3	9,4	249	405	13,0	3
ORDAG	STBAR	1	55,0					8a
ORDAG	AJKA1	2	72,5		65	80		11
ORDAG	PADR3	1	80,0					11
ORDAG	CAUNE	1	100,0					13
ORDOU	BOSDA	6	160,8	5,4	150	190	8,3	6
ORDOU	GANTU	2	161,5		151	172		6
ORDOU	HORSA	4	176,3	13,4	150	210	15,2	6
ORDOU	HORSX	43	185,3	2,9	154	250	10,4	6/7
ORDOU	IS187	3	218,2	15,0	184	246	11,9	8a
ORDOU	IS221	1	238,0					8a
ORDOU	IS199	13	243,5	5,5	218	269	8,1	8a
ORDOU	STBAR	1	250,0					8a
ORDOU	IS336	1	272,0					8b
ORDOU	IS276	21	272,1	5,6	241	354	9,5	8a/b
ORDOU	IS273	39	280,7	5,1	221	360	11,3	8a/b
ORDOU	GIBR1	10	291,0	8,6	250	340	9,3	9
ORDOU	GIBRE	2	327,5		300	355		9
ORDOU	NOUCR	1	335,0					9
ORDOU	ANGOU	1	400,0				10	
ORDOU	AJKA1	10	443,5	20,7	350	570	14,7	11
ORDOU	DUDAR	25	499,8	12,7	355	630	12,7	12
ORDOU	PADR3	9	500,0	11,4	450	550	6,8	11
ORDOU	SANPA	6	519,2	18,8	460	600	8,9	12
ORDOU	DUORD	2	575,0		540	610		12
ORFUR	HORSX	16	185,2	5,0	158	230	10,9	6/7
ORFUR	GIBR1	10	217,0	5,8	195	240	8,4	9
ORFUR	PADR3	19	290,3	6,9	240	350	10,4	11
ORFUR	AJKA1	14	293,2	7,8	245	340	9,9	11
ORFUR	ANGOU	1	300,0				10	
ORFUR	DUDAR	2	330,0		300	360		12
ORFUR	BIPEB	1	370,0					13
ORFUR	LABAT	8	397,5	22,4	305	515	15,9	15
ORFUR	PR135	1	472,0					16
ORKOH	CRIDU	4	632,5	32,8	550	730	10,4	8a
ORMAR	STBAR	8	292,5	10,9	255	355	10,6	8a
ORMAR	VANZI	7	312,1	14,2	265	380	12,0	8a
ORMUL	SPILE	12	392,5	16,4	295	460	14,5	3
ORMUN	SPILE	7	210,0	4,2	195	230	5,2	3
ORMUN	HORSA	3	323,3	13,0	305	355	7,0	6
ORMUN	HORSX	39	385,2	10,2	270	525	16,8	6/7
ORNSP	HORSX	36	927,9	24,8	630	1260	16,0	6/7
ORSCH	BOUSM	1	170,0					1a
ORSCH	RUBEC	11	184,5	6,6	150	210	11,8	2
ORSCH	NTSOR	4	192,5	9,8	160	210	10,1	1a
ORSCH	SPILE	51	219,3	4,2	170	290	13,8	3
ORSCH	CRICP	7	248,6	9,1	205	290	9,6	4
ORSCH	PYCM1	14	256,4	8,3	202	312	12,1	4
ORSCH	CRIPN	1	310,0					6
ORSCH	VALDE	14	314,6	10,3	245	380	12,2	?5
ORSCH	CRIPA	6	320,0	7,1	300	345	5,4	5
ORSCH	GANBD	13	321,3	11,0	267	400	12,3	5
ORSCH	CRIDL	2	330,0		300	360		7
ORSCH	IS273	18	336,1	8,9	280	408	11,2	8a/b
ORSCH	IS199	10	345,6	12,2	292	394	11,2	8a
ORSCH	IS221	18	351,0	10,5	255	434	12,7	8a
ORSCH	STBAR	1	370,0					8a
ORSCH	IS276	5	381,8	15,6	337	439	9,1	8a/b
ORSCH	IS187	3	384,2	18,1	340	408	8,1	8a
ORSCH	IS335	5	395,1	20,2	314	442	11,4	8b
ORSCH	IS336	7	411,9	21,1	314	484	13,6	8b
ORSCH	IS366	6	417,9	18,6	348	468	10,9	8b
ORSCH	IS382	15	448,2	13,2	348	578	11,4	8b
ORSCH	SANPA	1	610,0					12
ORSCH	PADR3	1	700,0					11
ORVAR	CRIDU	4	145,0	4,0	135	155	5,4	
ORVAR	CAUPE	13	191,1	5,2	155	220	9,9	8b
ORVAR	ANGOU	29	246,4	7,0	185	345	15,2	10
ORVAR	GIBR1	5	247,0	14,5	200	290	13,2	9
ORVAR	PADR3	53	266,9	4,1	205	360	11,1	11
ORVAR	AJKA1	46	289,5	4,0	245	370	9,4	11
ORVAR	SANPA	50	330,4	7,2	240	480	15,4	12
ORVAR	DUDAR	20	345,8	8,9	270	420	11,5	12
ORVAR	DUORD	7	347,9	17,6	310	455	13,4	12
ORVAR	MOSSA	1	400,0					14
ORVAR	MOS50	8	429,4	28,1	320	550	18,5	15
ORVAR	MOS44	13	432,3	7,8	390	480	6,5	14/15
ORVAR	CAUNE	10	437,0	29,1	305	600	21,1	13
ORVAR	REME4	24	444,4	13,4	310	605	14,8	16
ORVAR	REME3	1	450,0					16
ORVAR	BIPEB	26	453,8	21,2	190	615	23,9	13
ORVAR	SIEST	2	455,0		400	510		14
ORVAR	MOS31	18	463,9	14,8	365	610	13,5	14
ORVAR	LABAT	12	468,8	19,4	375	625	14,3	15
ORVAR	SORGE	20	498,5	11,2	370	600	10,1	15

APPENDIX C

Short characterization of the Orthophragmina-zones

Our 18 Orthophragmina-zones are of the Oppelian-type. They are characterized by the assemblage that can be found in the key-localities. The boundaries of the zones are not clear-cut, there may be either overlaps (these are indicated in the notes between the actual zones) or gaps between them.

The taxa in the assemblages can be subdivided into 4 groups. Exclusive taxa can be found only in the given zone and they are always listed below. As first appearances we list taxa starting in the respective zone and continuing upwards. Last occurrences mean taxa with final appearence in the given zone but coming from deeper horizons. These two categories are listed below only if exclusive taxa are lacking. Finally, transitional forms can be found both in the deeper and higher zones but they are not listed below. Very rare taxa (e.g. *Nemkovella rota* or *Orbitoclypeus* n. sp. Horsarrieu) are not mentioned because at present their range is highly uncertain. "Small" or "large" in brackets mean the less or more developed part of a taxon possibly to be subdivided. The limit-value of this possible further subdivision can be found in Appendix A in brackets with the actual taxon.

The range-chart of each taxon can be read from figs 3 and 4 where the tentative correlation of the Orthophragmina- and shallow benthos- (SBZ) zones is displayed, too. The SBZ-zonation has been correlated with the planktonic and magnetostratigraphic subdivisions by Hottinger and Serra-Kiel (in Hardenbol *et al.*, 1996). More information about the fossil-content of the key-localities can be found in Table 2.

Zone O.1a

Key-localities: France: Boussan Mare (BOUSM) and Nouts-Oraas (NTSOR); Bulgaria: Beloslav, the lower about 1 m of the section (BELO0 and BELO1).

Exclusive taxon: *Discocyclina seunesi seunesi.*

Zone O.1b

Key-locality: Bulgaria: Beloslav, the upper about 5 m of the section (BELO2-BELO5).

Exclusive taxon: *Discocyclina seunesi* n. ssp. Beloslav.

Zone O.2

Key-locality: France: Ruisseau de Bec (RUBEC).

Exclusive taxon: *Discocyclina tenuis* n. ssp. Ruisseau de Bec.

Zone O.3

Key-localities: France: Gamarde, the lower part of the section (GAMA7); Italy: Spilecco (SPILE); Crimea: the *Operculina semiinvoluta* zone (CRIOS) and the lower 2/3 of the *Nummulites crimensis* zone (CRICR).

Exclusive taxa: *Discocyclina archiaci bakhchisaraiensis, D. tenuis tenuis, Orbitoclypeus schopeni neumannae.*

Zone O.4

Key-localities: Spain: Campo, Pobla member (PYCM1); France: Gamarde, the upper part of the section (GAMA2); Crimea: the boundary of the *Nummulites crimensis* and *Assilina placentula* zones (CRICP).

Exclusive taxa: *Discocyclina archiaci staroseliensis, Orbitoclypeus schopeni suvlukayensis.*

Zone O.5

Key-localities: France: Gan, Berdoulou (GANBD); Crimea: the *Assilina placentula* zone with the exception of its lowermost and topmost parts (CRIPA and CRIPU); Bulgaria: Dikilitash (DIKIL).

No exclusive taxa.

First appearances: *Discocyclina archiaci archiaci, D. augustae sourbetensis* ("large"), *D. dispansa taurica, Orbitoclypeus schopeni crimensis* ("small").

Last occurrence: *Discocyclina pseudoaugustae.*

Zone O.6

Key-localities: France: Gan, Tuilerie (GANTU), Bos d'Arros (BOSDA), Horsarrieu, Marnière Sourbet without its topmost part (HORSA); Crimea: the boundary of the *Assilina placentula* and *Nummulites nemkovi* zones (CRIPN).

Exclusive taxon: *Discocyclina fortisi fortisi.*

Note: The exceptionally rich Orthophragmina-fauna of the topmost part of the Sourbet marl-pit in Horsarrieu (HORSX) from France shows intermediate features between zones O.6 and O.7. It contains together *Discocyclina archiaci archiaci* (characteristic for zones O.5 and O.6) and *D. fortisi simferopolensis* (characteristic for zone O.7). The first appearances of the new lineages in this sample (*Nemkovella strophiolata, Orbitoclypeus furcata*) are included into the characteristics of zone O.7.

Zone O.7

Key-localities: Crimea: the upper part of the *Nummulites nemkovi* (CRINU) and the lower part of the *N. distans* zone (CRIDL).

Exclusive taxon: *Discocyclina fortisi simferopolensis.*

Zone O.8a

Key-localities: France: Saint-Barthèlèmy, Maisonnave (STBAR); Italy: Vanzi (VANZI); Crimea: the upper part of the Nummulites distans zone (CRIDU) and the N. polygyratus zone (CRIPO); Israel: Ein Avedat section, from about 13 to 22 m from its bottom (IS199 and IS221).

Exclusive taxa: *Discocyclina stratiemanuelis, Orbitoclypeus douvillei douvillei* ("large"), *O. marthae, O. varians portnayae.*

Note: The Orthophragmina-faunas from about 40 m from the bottom of the Ein Avedat (Israel) section (IS273

and IS276) shows intermediate features between zones O.8a and O.8b. They contain together "small" *Orbitoclypeus schopeni crimensis* (characteristic for zones O.5-8a) and *O. douvillei* n. ssp. Gibret (characteristic for zones O.8b and O.9).

Zone O.8b

Key-localities: France: Caupenne, Ferme Jean Gazé, upper part (CAUPE); Crimea: "Bodrakian stage", lower part (CRIBO); Israel: Ein Avedat section, from about 55 to 80 m from its bottom (IS336, IS366 and IS382).

Exclusive taxa: *Discocyclina radians* n. ssp. Caupenne, *Discocyclina kingae*, *Orbitoclypeus varians* n. ssp. Caupenne.

Zone O.9

Key-localities: France: "Couches de Nousse", Nousse and Gibret (NOUCR, GIBR1 and GIBRE); Israel: Ein Avedat section, from about 85 to 88 m from its bottom (IS399 and IS407).

Exclusive taxa: *Discocyclina pulcra pulcra*, *D. radians noussensis*, *D. aaroni*, *Nemkovella evae* ("large").

Zone O.10

Key-locality: France: Angoumé, Marnière de Miretraine (ANGOU).

Exclusive taxa: *Discocyclina pulcra* n. ssp. Angoumé, *Orbitoclypeus douvillei chudeaui*.

Zone O.11

Key-localities: Hungary: Ajka, "*Discocyclina*" beds (AJKA1) and Padragkút (PADR3).

Exclusive taxa: *Discocyclina pulcra balatonica*, *Orbitoclypeus varians roberti*.

Zone O.12

Key-localities: Italy: San Pancrazio (SANPA); Hungary: Dudar, Sûrûhegy (DUDAR) and Ördögárok (DUORD).

Exclusive taxa: *Discocyclina pulcra baconica*, *Orbitoclypeus varians scalaris*.

Zone O.13

Key-localities: France: Biarritz, Rocher de Peyreblanque (BIPEB), Cauneille (CAUNE).

No exclusive taxa.

First appearances: *Asterocyclina stellata stellaris*, *Discocyclina radians labatlanensis*, *Orbitoclypeus furcata furcata*, *O. varians varians*.

Last occurrences: *Asterocyclina alticostata alticostata*, *A. kecskemetii*, *A. stella stella*, *Discocyclina augustae olianae*, *D. discus adamsi* (acme), *D. dispansa sella*, *D. pratti pratti*, *D. trabayensis trabayensis*.

Zone O.14

Key-localities: France: Siest (SIEST); Italy: Mossano: the base of the Priabonian lower marls (MOSSA) and just under it (MOS31), Priabona: "*Discocyclina* beds" (PR049 and PR055).

Exclusive taxon: *Discocyclina dispansa dispansa*.

Note: The rich Orthophragmina-fauna of the middle part of the Priabonian lower marls of the Mossano section (MOS44) from Italy shows intermediate features between zones O.14 and O.15. It contains *Discocyclina dispansa dispansa* (characteristic for zone O.14) together with *Nemkovella strophiolata tenella* (marking zone O.15) and *Asterocyclina priabonensis* (ranging from zone O.15 to O.16).

Zone O.15

Key-localities: Italy: Granella (GRANE), Sorgente di Monte Baldo (SORGE), Mossano, the upper part of the Priabonian lower marls (MOS50); Hungary: Lábatlan, József-puszta (LABAT).

Exclusive taxa: *Discocyclina dispansa umbilicata*, *Nemkovella strophiolata tenella*.

Zone O.16

Key-localities: Italy: Priabona, "*Asterocyclina* beds" (PR126 and PR135), Mossano, the Priabonian upper marls (MOS69); Hungary: Kisgyõr, Remete-kút (REME2, REME3 and REME4).

Exclusive taxa: *Asterocyclina stella praestellaris* ("large"), *A. stellata* n. ssp. Kisgyõr, *Discocyclina dispansa* n. ssp. Kisgyõr, *D. trabayensis vicenzensis*.

Table 2: The Orthophragmina-content of the samples studied

The meaning of the letters A to G can be found in Appendix A at the actual species. X means the occurrence of a species without any (existing or possible further) subdivision. The typing of the letters marks tentatively the number of specimens in the actual population: A single specimen is marked by italics, 2–4 specimens by normal, while 5 and more specimens by bold characters.

	Samples	1a				1b				2	3					4				5					6				7			8a								8a / 8b			8b						9										10	11		12			13			14					15					16					
	Species	BOSUM	NTSOR	BELO 0	BELO 1	BELO 2	BELO 3	BELO 4	BELO 5	RUBEC	ARUI 9	SPILE	CRIOS	CRICR	GAMA 7	GAMA 2	PYCM 1	CRICP	AUR 12	CRIPA	DIKIL	CRIPU	VALDE	GANBD	GANTU	BOSDA	CRIPN	HORSA	HORSX	CRINU	CRIDL	CRIDU	CRIPO	KRESS	VANZI	SRBAR	IS 187	IS 199	IS 221	IS 273	IS 276	IS 278	IS 335	IS 336	IS 366	IS 382	CRIBO	CAUPE	IS 399	IS 407	DSZTM	NESZM	JOKAI	NUSSD	NOUCR	GIBRE	GIBRI	MONTF	ANGOU	AJKA 1	PADR 3	DUDAR	DOURD	SANPA	KBNBI	BIPEB	CAUNE	SIEST	PR 049	PR 055	MOS 31	MOSSA	MOS 44	MOS 50	SORGE	GRANE	LABAT	MOS 69	PR 126	PR 135	REME 2	REME 3	REME 4
Discocyclina	*D. seunesi*	**A**	**A**	**A**	**A**	**B**	**B**	B	**B**																																																																												
	D. tenuis									**A**		B			**B**																																																																				
	D. pseudoaugustae																**X**	**X**			**X**	*X*		**X**																																																												
	D. fortisi																										A	A	**B**	**B**	**B**																																																						
	D. stratiemanualis																															**X**	X	**X**																																																			
	D. pulcra																											*A*																												*B*	**B**		**C**	**D**	**D**	**E**																						
	D. archiaci												**A**	**A**	**A**	**B**	**B**	**B**	**B**	C	*C*	*B*		**C**	**C**	**C**	*C*	**C**	C	**D**	**D**	**D**			**D**	**D**												**D**																																			
	D. discus																																																						**A**	A	A			**B**	**A**	**B**	B			B											*B*						
	D. n. sp. Siest																																																												X							**X**															
	D. spliti																																																				**A**															**B**															
	D. furoni														**A**												B																																																									
	D. aquitanica																											X		*X*		X																																																			
	D. pratti																																															*A*							*A*			**A**	**B**	B	**B**	**B**	**B**	B	*B*	B					*C*						C						
	D. samantai																																																																				*X*								**X**						
	D. aaroni																																																		X	**X**		*X*			*X*																										
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Nemkovella	*N. evae*														**A**	*A*								*A*		**A**	A	**A**	**A**	**A**	*A*					A	*A*	A	A	A	*A*			A	A	A			**B**	**B**																																	
	N. rota																									X																																																										
	N. katoae																																																								**X**			**X**						X																	
	N. strophiolata																												**A**			**A**				A				B								**B**							**B**	B	**B**		*A*	**B**	C	*B*	C		*C*	C					*C*	C	**D**	D		D							
	N. bordrakensis																												X							X											X																																						
Orbitoclypeus	*O. schopeni*	*A*	A							**A**		**B**					C	C		**D**			D	**D**			*D*				D					*D*	D	**D**	**D**	**D**	**D**		**E**	**E**	**E**	**E**															*F*			*F*																			
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	O. (?) *daguini*																																			*X*																								X	*X*						*X*																
Asterocyclina	*A. taramellii*										**X**	**X**					*X*	*X*																																																																		
	A. stella																											**A**	**A**			A				**A**		**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**				**B**	**B**									*B*		**B**			**B**		**B**	*B*		C	C		*D*	C				*C*	D	**D**	**D**			
	A. stellata																								A											A												**A**						*B*	**A**	A	**A**	*B*	**B**	**B**	**B**	B	**B**	**B**	C	C	C	C	C	C		C	C		C	*B*	C				*D*	**D**	**D**
	A. priabonensis																																																																									*X*				X	X	**X**	**X**			
	A. kecskemetii																																			*X*					*X*																		*X*	X	X	X		**X**	*X*	**X**	*X*																
	A. schweighauseri																									A										B					*B*			*B*	*C*			**C**										*C*																									
	A. alticostata																																					*A*	**A**	A	*A*	A													A	A	A		**B**	**B**	**B**	C	C	C			**C**										**D**						

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Dela – Opera SAZU 4. razr.	34/2	45–57	1 Fig.	4 Plates		Ljubljana 1998

THE PALAEOCENE DASYCLADACEAN GENUS ZITTELINA FROM THE WESTERN CARPATHIANS (SLOVAKIA)

Stanislav Buček

Abstract

The species *Zittelina radoicicae* (Bystrický) and *Zittelina bystrickyi* (Dieni, Massari and Radoičić) from the pebbles and blocks of the Palaeocene reef limestones of the Western Carpathians are revised in this paper. A more detailed description of both species from new, better preserved material is given. Taking into consideration the associations with other organisms, the most probable age of the studied material is Danian-Thanetian.

Key words: Algae, Dasycladales, *Zittelina radoicicae*, *Z. bystrickyi*, re-determinations, Palaeocene, Western Carpathians, Slovakia.

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INTRODUCTION

The dasyclydacean algae of the reef limestones from the Western Carpathian Palaeocene are still insufficiently studied. Until recently they have been known only from the locality Hričovské Podhradie from where some of their fragments were described by Pia (1934). Later findings of dasycladaceans in the Myjavská pahorkatina Upland and in the pebbles of "exotic conglomerates" from the Chocholová beds in Orava region near the village Brezovica, some of them preliminarily determined or undetermined, were figured by Mišík, 1966; Mišík *et al.*, 1968 and Samuel *et al.*, 1972. Only J. Bystrický started to study the Palaeocene dasycladaceans from the above localities more systematically and his work (Bystrický, 1976) became the starting point of further research.

GEOLOGICAL AND STRATIGRAPHICAL REMARKS

All studied localities are situated on the internal side of the most complicated structural unit of the Western Carpathians — the Klippen Belt, being a part of the so-called Peri-Klippen Paleogene. The paleontological material collected for this study originates from the following localities:

a) Myjavská pahorkatina Upland: Kravárikovci-1 (Fig. 1a); Priepasné-2, 3, 4; Batíková-5 (Fig. 1b); Matejovec-6, 7, 8, 9, 10; Jeruzalem-11, 12, 13 (Fig. 1c); Juríkovci-14 (Fig. 1d);

b) Váh river Valley: Hričovské Podhradie, old quarry in the village -15 (Fig. 1e).

Kravárikovci locality: In the Lower Eocene Kravárikovci conglomerate sequence (Samuel *et al.*, 1980; Salaj

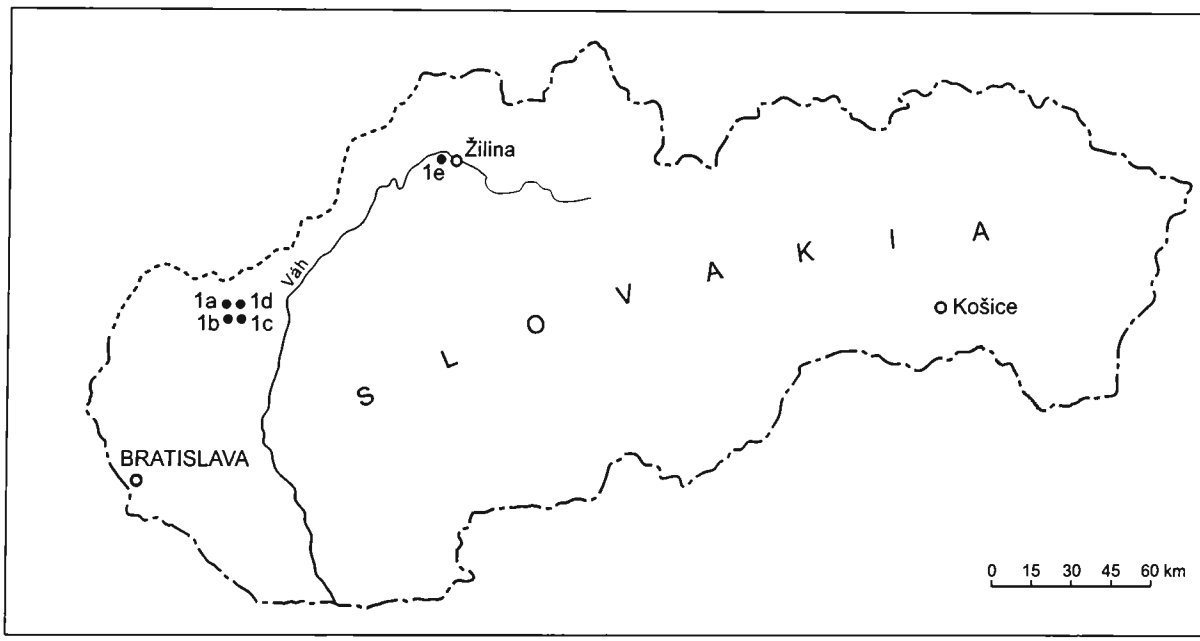

Fig. 1: Map of occurrences of Zittelina radoicicae and Zittelina bystrickyi in the West Carpathians. 1a – Kravárikovci, 1b – Priepasné and Batiková, 1c – Matejovec and Jeruzalem, 1d – Juríkovci, 1e – Hričovské Podhradie.

Fig. 1a

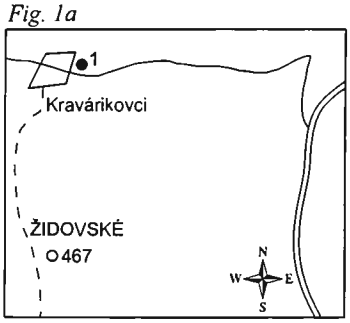

Fig. 1d

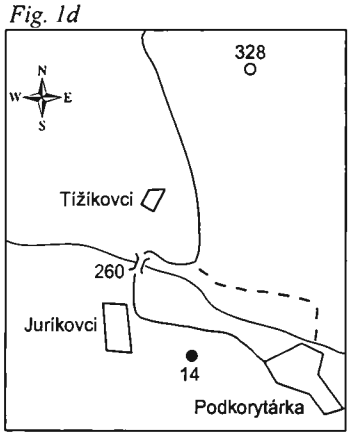

Fig. 1e

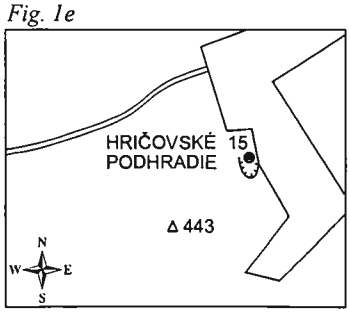

Fig. 1b

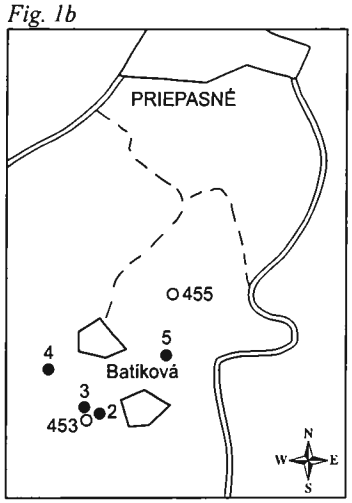

Fig. 1c

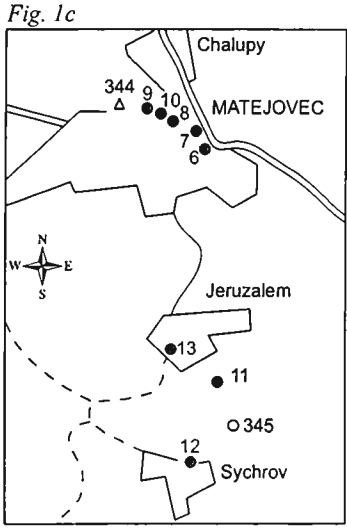

Fig. 1a: Situation map of locality Kravárikovci, N of Brezová pod Bradlom.

Fig. 1b: Situation map of locality Priepasné and Batiková, NE of Brezová pod Bradlom. Locality Batiková-2 corresponds to the locality Široké Bradlo, elev. point 453 in Bystrický, 1976, p. 248, Fig. 2.

Fig. 1c: Situation map of locality Matejovec and Jeruzalem, SE of Myjava. The locality Matejovec-6, 7 corresponds to the locality Matejovec in Bystrický, 1976, p. 248, Fig. 1.

Fig. 1d: Situation map of locality Juríkovci, ESE of Myjava.

Fig. 1e: Situation map of locality Hričovské Podhradie, W of Žilina.

et al., 1983) there are several large (up to 200 cm in diameter) but also smaller blocks (up to 20 cm) of red and yellow-grey limestones. Andrusov (1959) considered them of Upper Cretaceous age, but the presence of abundant *Broeckella belgica* Morellet et Morellet and of *Zittelina* cf. *bystrickyi* (Dieni, Massari and Radoičić) indicates their Palaeocene (probably Dano-Montian) age.

Priepasné and Batíková localities: The microfaunal association — *Discocyclina seunesi* Douvillé, *D. ramaraoi* Samanta, *Planorbulina cretae* (Marsson) (Köhler, 1961, 1988) indicates a Palaeocene age (Thanetian). The microfloral association comprises *Zittelina bystrickyi* (Dieni, Massari and Radoičić), *Broeckella belgica* Morellet et Morellet, *Neomeris* sp., *Uteria* sp., *Jodotella* sp., *Frederica coniconvexa* Dieni, Massari and Radoičić, *Sandalia multipora* Dieni, Massari and Radoičić and *Rusoella radoicicae* Barattolo.

Matejovec and Jeruzalem localities: In the Lubiná sequence (Samuel *et al.*, 1980; Salaj *et al.*, 1983) the microfaunal association — *Discocyclina ramaraoi* Samanta, *D. seunesi* Douvillé occuring in the blocks of reef limestones in Matejovec dates these limestones as Palaeocene (Thanetian), while the presence of the species *Glomalveolina primaeva* (Reichel) at the locality Jeruzalem indicates the same age.

Microfloral association:

Zittelina bystrickyi (Dieni, Massari and Radoičić)
Z. radoicicae (Bystrický)
Broeckella belgica Morellet et Morellet
Cymopolia elongata (Defrance) Munier-Chalmas
Neomeris (*N.*) *herouvalensis* Steinmann
N. (*L.*) *koradae* Dieni, Massari and Radoičić
N. (*L.*) *oroseiana* Dieni, Massari and Radoičić
N. (L.) *grandis* Dieni, Massari and Radoičić
Jodotella sloveniaensis Deloffre and Radoičić
Sarosiella feremolis Segonzac
Sandalia multipora Dieni, Massari and Radoičić
Frederica coniconvexa Dieni, Massari and Radoičić
F. arbuticormis Dieni, Massari and Radoičić
Terquemella macrocarpus Morellet et Morellet
Orioporella villatae Segonzac
Uteria sarda Dieni, Massari and Radoičić
U. cf. *brocchii* Morellet et Morellet
Acicularia sp.
Halimeda sp.

Juríkovci locality: Smaller blocks (20–40 cm in diameter) of light grey and yellowish-grey reef limestones occur in the Lower Eocene sequence. Microfauna association — *Discocyclina ramaraoi* Samanta, *D. seunesi* Douvillé and *Miscellanea juliettae* Leppig refers to Thanetian age.

Microfloral association:

Zittelina bystrickyi (Dieni, Massari and Radoičić)
Z. radoicicae (Bystrický)
Jodotella sloveniaensis Deloffre and Radoičić
Cymopolia elongata (Defrance) Munier-Chalmas
Neomeris (L.) oroseiana Dieni, Massari and Radoičić
Broeckella belgica Morellet et Morellet
Uteria sarda Dieni, Massari and Radoičić
Uteria sp.
Sarosiella sp.
Sandalia multipora Dieni, Massari and Radoičić
Halimeda sp.

Hričovské Podhradie locality: Old quarry in the village (loc. 53 sensu Samuel *et al.*, 1972). In the Lower Eocene flyschoid sequence belonging to the so-called Peri-Klippen Paleogene there are algal-foraminiferal limestone banks with abundant occurrence of the index Thanetian form — *Glomalveolina primaeva* (Reichel). The microfloral association consists of *Zittelina bystrickyi* (Dieni, Massari and Radoičić), *Orioporella villatae* Segonzac, *Neomeris* sp., *Cymopolia* sp. and *Acicularia* sp.

Microfaunal associations were identified by E. Köhler (Geological Institute of the Slovak Academy of Sciences, Bratislava) from his thin-section material.

PALEONTOLOGICAL PART

The calcareous algae which are the subject of this study were investigated in 152 thin sections. The slides containing figured specimens are housed at the Geological Institute of the Slovak Academy of Sciences, Bratislava.

A system of symbols designates various measurable parameters; for their significance I refer to Deloffre and Génot (1982) and Barattolo (1983, 1984).

SYSTEMATIC DESCRIPTIONS

Family Dasycladaceae Kutzing, 1843 orth. mut. Stizenberger, 1860

Tribe Bornetelleae Morellet et Morellet, 1913; emend. Bassoullet *et al.*, 1979

Genus *Zittelina* Munier-Chalmas, 1877 ex Morellet et Morellet, 1913; emend. Génot, 1987

Diagnosis (sensu Génot, 1987, p. 107): Claviform, cylindrical or ovoidal thallus. Distal ends of the branches formed cortex. Ampullae have variable shape: spherical, lenticular or ovoidal with calcareous envelopes whose surface is flat or littler gathered.

Zittelina radoicicae (Bystrický, 1976)
(Pl. 1, Figs 1–8; Pl. 2, Figs 1–10; Pl. 3, Figs 1–2; Pl. 4, Fig. 8)

1976 *Digitella radoicicae* — Bystrický, p. 258, 260–261; pl. 3, figs 1, 1a; pl. 4, figs 1, 1a–c.
NF 1980 *Digitella radoicicae* Bystrický; Deloffre, p. 615–616, tab. 1.

NF 1984 *Digitella radoicicae* Bystrický; Baratollo, p. 6 and 13.

NF 1987 *Zittelina radoicicae* (Bystrický, 1976); Génot, p. 107.

Diagnosis: Test in shape of small simple tube with thick walls. In a circular transverse section the thallus seems very close to the test wall. Branches, set in one-row whorls, are quite thick and often get narrower in their central part. Between the whorls are calcified oval-shaped sporangia (= ampullae) with small spherical cavities at their periphery. Such sporangia are only rarely found in swollen parts of branches.

Description: On the basis of axial and subaxial sections of the best preserved and figured specimens, cylindrical (Pl. 2, Fig. 3) and ovoidal to claviform (Pl. 1, Fig. 2; Pl. 2, Fig. 6) shapes of the thallus are assumed. Two of the latter sections show an opening in the lower portion of the thallus corresponding to the main axis and directly extending from the pedunculus. Characteristic feature of this species is a strong calcification manifested by thick walls of the calcareous envelope and its penetration even to the main axis.

The main axis with a thin calcified wall is often preserved (Pl. 1, Figs 4–6, 8). In the specimen of Pl. 2, Fig. 3a part of the main axis which was cylindical is preserved; in the transverse sections it appears as oval shaped element. The inner part of the calcified wall of the main axis is smooth without intusannulation. Sometimes (Pl. 1, Figs 1–3, 7) it is very slightly transversally undulated in the places where branches occur.

By the distribution of the reproductive organs (see below) and of the pores in the calcareous wall it can be argued that the primary branches are perpendicular to the thallus axis for most of its length. In the highest part of the thallus they bend progressively upwards and become vertical at the apex (Pl. 1, Fig. 2). On the contrary, moving towards the thallus base, the branches bend progressively downwards.

The primary branches are arranged in simple one-row whorls of euspondyl type. Along most of *Zittelina radoicicae* thalli, the primary branch is made up of probably rather short, thin, cylidrical akrophorous portions. In its continuation outwards, the primary branch is quickly swollen to the ampullaceous shape with almost parallel walls (Pl. 1, Figs 2, 3). Beyond the subterminal outward narrowing just at the calcareous wall, the primary branch shows a short portion, akrophorous again, a bit thicker than before. Afterwards, it flares outwards quickly (chloiophorous portion of the branch) giving rise to a cortex (Pl. 1, Fig. 1). The ampullaceous part of the branch is often narrowed for about a half of its length, so that it is getting a shape of two "spheres" connected with each other by a thin channel.

Reproducive organs consist of ovoidal ampullae which are regularly arranged along almost the total length of the primary branches, two to three in number, occuring between the branches of the neighbouring whorls in the calcareous envelope. Either there is a thin calcified part between two neighbouring fertile ampullae, so that they do not touch each other (Pl. 1, Figs 2, 3: Pl. 2, Fig. 4), or they more or less touch each other according to the degree of calcification (cf. Fig. 1 in Pl. 1). The diameter of fertile ampullae is a little larger than the space between branches of the neighbouring whorls, therefore ampullae are pressed into the branches deforming them from the outer side. Calcification in ampullae took place probably earlier than in the other algal parts (Pl. 1, Figs 4, 6).

Each ampulla contains 3–8, max. 10 spherical cysts placed tightly along their periphery (Pl. 1, Figs 1, 2).

Dimensions (in mm): D: 2.180–4.256; d: 1.228; st: 0.175–2.287; s/D %: 17.51–66.45; (D-s)/2: 0.675–1.327; w: 40 ?–60 ?; h: 0.290–0.375; pp: 0.025–0.076; ps: 0.079–0.282; pd: 0.045–0.118; pl: 0.121–0.206; psa: 0.022–0.099; lpp: 0.028–0.090; lps: 0.417–1.127; lpd: 0.045–0.169; lps: 0.194–0.324; dc: 0.031–0.076; de: 0.203–0.318; da: 0.062–0.197; nc: 3–8, max.10; L: 4.296–14.572.

Explanations of biometrical parameters which were not explained in Bystrický (1976, p. 260) and are used in this paper:

pp: proximal width of the primary branch
ps: central width of the primary branch
pd: distal width of the primary branch
pl: distal width of the primary branch on surface of the calcareous wall
psa: diameter of the connecting channel between sporangial parts of the branch (= width in this paper)
lpp: length of the thin, proximal part of the branch
lps: length of the branch part with ampullae
lpd: length of the thin, distal part of the branch
sp: diameter of the cysts (values of sp and spg are changed in tab. 2)
spg: diameter of the fertile ampullae
lsp: length of the connecting part between ampullae.

Remarks: Systematic position of Cenozoic genera and species of the tribe Bornetelleae (Chlorophyta, Dasycladales) is dealt with in detail in Barattolo (1984) and Génot (1987). In the present paper I referred to Génot's criteria of distinguishing the Dactylopora Lamarck and *Zittelina* Munier-Chalmas ex Morellet et Morellet.

Occurrence and stratigraphic position: Stratigraphical range of the above described species *Zittelina radoicicae* (Bystrický) was limited to Dano-Montian? by Bystrický (1976).

Newly described specimens of this species occur at the following localities: Myjavská pahorkatina Upland:

1. Matejovec-6, (= type locality of the holotype), 7, 9, 10 (Fig. 1c)

2. Jeruzalem-11, 12, 13 (Fig. 1c)
3. Juríkovci-14 (Fig. 1d)

The established microfaunal association at all three localities refers them to the Thanetian stage.

Zittelina bystrickyi (Dieni, Massari and Radoičić, 1983) (Pl. 3, Figs 3–9; Pl. 4, Figs 1–7)

1976 *Dactylopora* aff. *cylindracea* Lamarck; Bystrický, p. 252–254, pl. 1, figs 1–4; pl. 3, fig. 2.
+ 1983 *Dactylopora bystrickyi* — Dieni, Massari and Radoičić, p. 44–45, pl. 3, figs 1–2.
1985 *Dactylopora bystrickyi* Dieni, Massari and Radoičić; Dieni, Massari and Radoičić, p. 7, text-fig. 2, C; pl. 5, figs 1–9; pl. 6, figs 1–11.
NF 1984 *Zittelina bystrickyi* (Dieni, Massari and Radoičić); Barattolo, p. 13.
NF 1987 *Dactylopora bystrickyi* Dieni, Massari and Radoičić; Génot, p. 105.

Diagnosis: Ovoid thallus consising of a claviform main axis and densely set verticils of primary branches alternating in successive verticils. Primary branches irregularly tubular, distally widened, with very short narrow proximal part ("pedunculus"). Numerous cysts surrounding primary branches, except for the lowermost two or three verticils; the latter with branches shorter, thinner and, unlike the others, also calcified in the proximal part.

Description: Ovoidal (Pl. 4, Figs 1, 4), rarely also claviform (Pl. 3, Fig. 7) or spherical (Pl. 3, Fig. 9) thallus. Calcareous envelope around the large axial cavity. Only the distal half or somewhat more of the whorls is calcified. Axial or subaxial sections (Pl. 3, Figs 4, 8) show an opening in the lower portion of the thallus corresponding to the main axis and directly extending from the pedunculus (Pl. 3, Fig. 7). Only the lowermost whorls are completely calcified, as distinctly observed in some sections (Pl. 3, Figs 4, 6, 9; Pl. 4, Fig. 4). Whorls of the basal part of the thallus consist of somewhat thinner branches; these lowermost whorls do not show any ampullae.

The main axis with a thin calcified wall is rarely preserved (Pl. 3, Figs 3, 4, 6). In the specimen of Pl. 3, Fig. 4a part of the main axis which obviously was claviform, i.e. widening upwards is preserved. Sections of some perforated thin-walled calcareous tubules or their fragments can be observed (Pl. 4, Fig. 7).

The primary branches are densely set in simple one-row whorls. Branches are irregularly spindle-shaped. Their proximal portions are probably thin, outwardly getting thinner and tight. At the outer surface of the calcareous wall they again become thinner. Afterwards, they flare outwards (phloiophorous portion) giving rise to a cortex (see Dieni, Massari and Radoičić, 1985, Pl. 5, Fig. 9).

Reproductive organs consist of oval up to lenticullar ampullae which are more or less regularly (but often irregularly) arranged around the primary branches. They tightly touch each other. Each ampulla contains 2–4 spherical cysts.

Dimensions (in mm): D: 2.620–4.417; d: 1.237–2.389; st: 0.360–0.673; d/D %: 27.63–62.95; st/D %: 13.49–20.34; e: 0.598–1.139; pp. 0.028–0.079; ps: 0.093–0.220; pd: 0.039–0.084; h: 0.175–0.183; dc: 0.042–0.090; de: 0.170–0.191; da: 0.090–0.206; L: 3.220–8.090.

Remarks: Some specimens resemble *Zittelina praturloni* (Barattolo and De Castro). The values obtained for the vertical spacing of the whorls indicate denser setting in *Zittelina bystrickyi*; D is also smaller in this species. From the comparison of Sardinian (l. c) and Carpathian (Bystrický, 1976) specimens the conclusion can be drawn that they belong to the same species.

Occurrence and stratigraphic position: The age of the Sardinian specimens is supposed to be Dano-Montian, of Carpathian specimens also Dano-Montian at Matejovec and Thanetian at Hričovské Podhradie.

The newly described specimens of this species occur at the following localities: Myjavská pahorkatina Upland:

1. Kravárikovci-1 (Fig. 1a) — Dano-Montian
2. Priepasné-2, 3, 4 (Fig. 1b) — Thanetian
3. Batíková-5 (Fig. 1b) — Thanetian
4. Matejovec-6, 7, 8, 9, 10 (Fig. 1c) — Thanetian
5. Jeruzalem-11, 12 (Fig. 1c) — Thanetian
6. Juríkovci-14 (Fig. 1d) — Thanetian

Váh river Valley:

7. Hričovské Podhradie-15 (Fig. 1e) — Thanetian.

CONCLUSION

The described assemblage of dasycladacean algae from the Western Carpathians (Slovakia) corresponds to a great extent to the microflora described from Eastern Sardinia (Orosei, Italy). The stratigraphical range of both assemblages is the same: Dano-Montian? or Dano-Montian? up to Thanetian.

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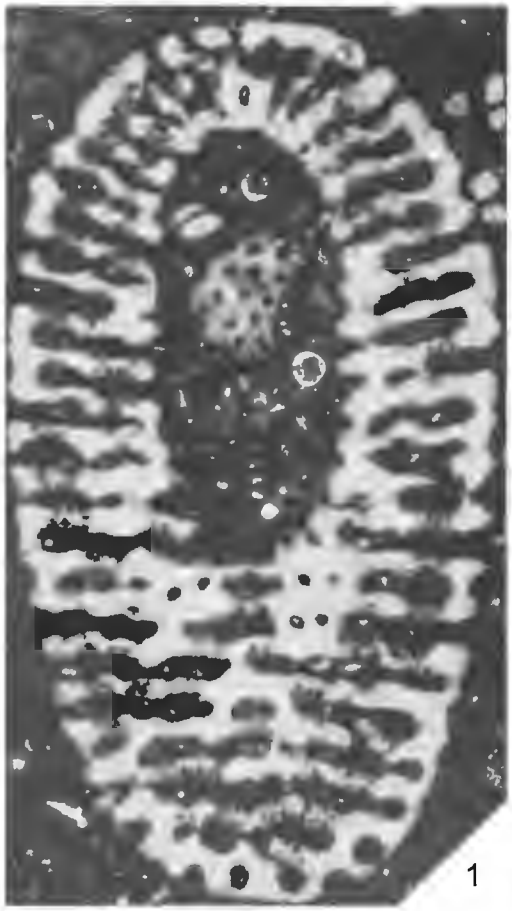
PLATE 1

Figs 1–8: *Zittelina radoicicae* (Bystrický, 1976)

1. Oblique section, thin section 1409; Matejovec-9; × 27.
2. Axial section; 1522; Matejovec-9; × 14.5.
3. Detail of Fig. 2, × 29.
4. Transverse section; 1452, Juríkovci-14; × 14.5.
5. Oblique section; 1683; Juríkovci-14; × 14.5.
6. Transverse section; 1550; Jeruzalem-11; × 14.5.
7. Subaxial section; 1374; Jeruzalem-11; × 14.5.
8. Oblique section; 1452; Jeruzalem-11; × 10.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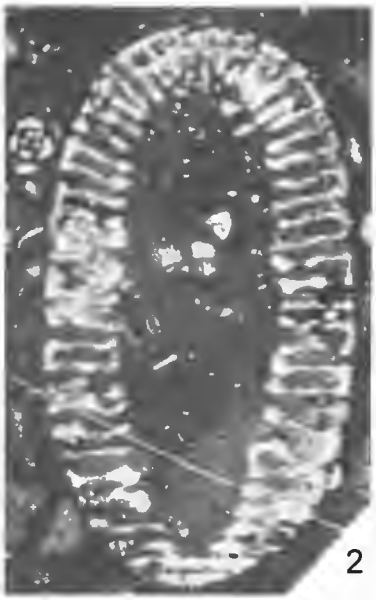
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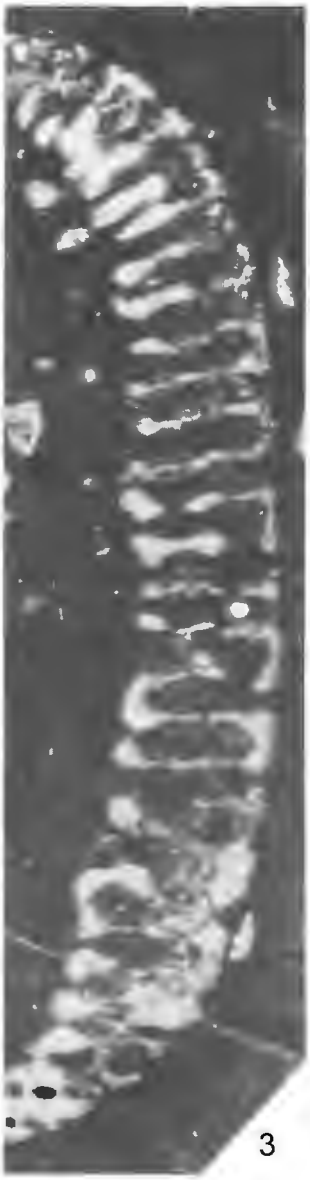
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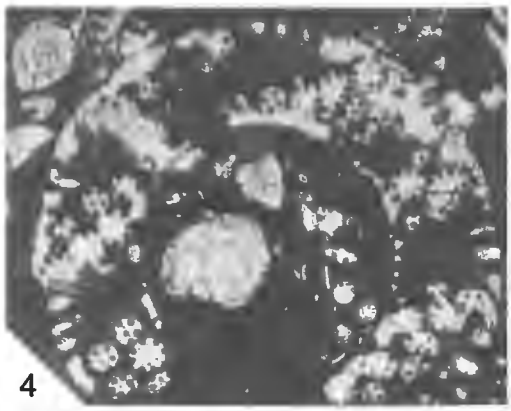
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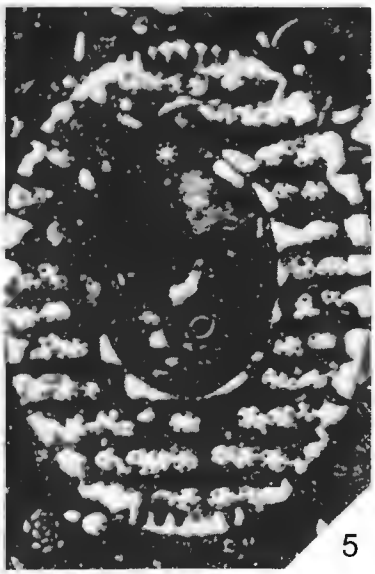
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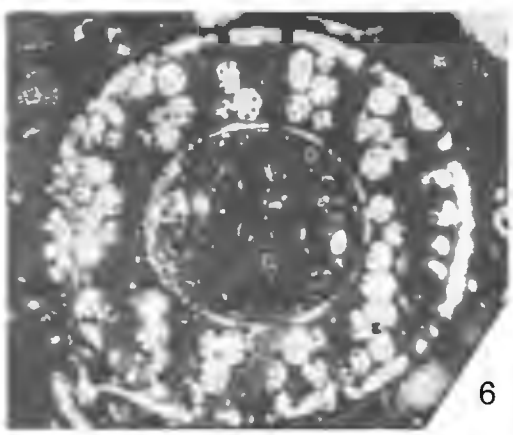
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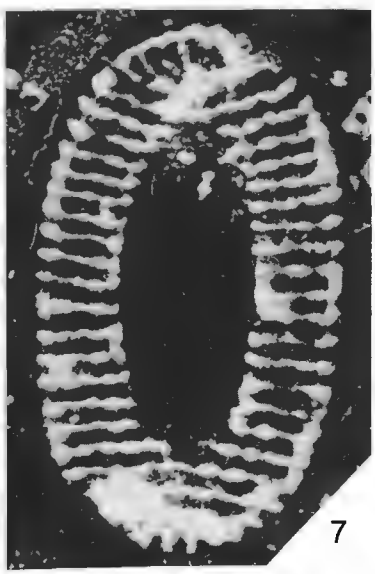
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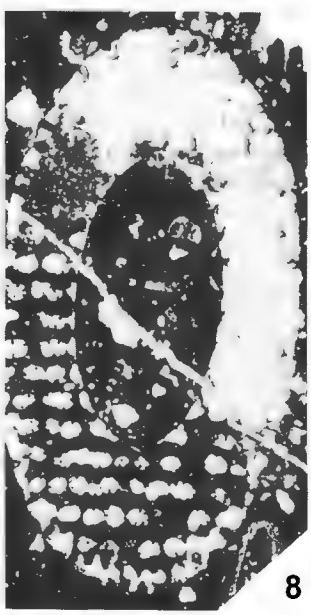
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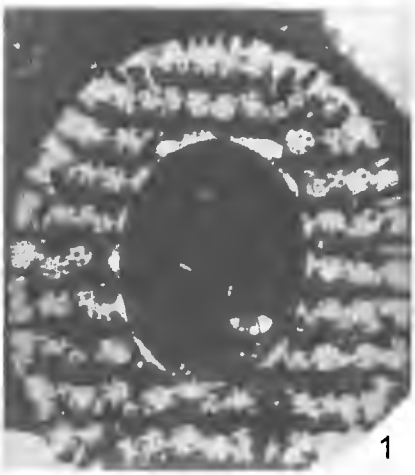
PLATE 2

Figs 1–10: *Zittelina radoicicae* (Bystrický, 1976)

1. Transverse-oblique section; 1682; Juríkovci-14; × 14.5.
2. Oblique section; 1463; Juríkovci-14; × 14.5.
3. Slightly oblique-axial section; 1679; Juríkovci-14; × 15.
4. Tangential section; 1481; Juríkovci-14; × 14.5.
5. Oblique section; 1674; Juríkovci-14; × 14.5.
6. Axial section; 1553; Jeruzalem-11; × 10.
7. Oblique section; 1417; Matejovec-9; × 14.5.
8. Oblique section; 1355; Juríkovci-14; × 14.5.
9. *Zittelina radoicicae*? Slightly oblique-transverse section; 1547; Matejovec-9; × 14.5.
10. *Zittelina radoicicae*? tangential section; 1547; Matejovec-9; × 14.5.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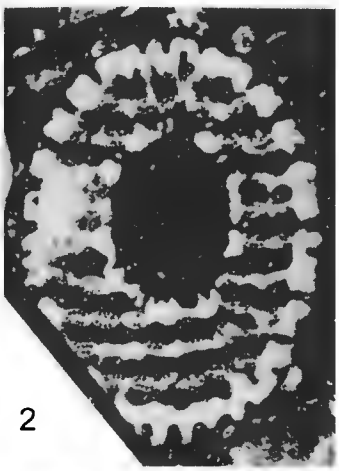
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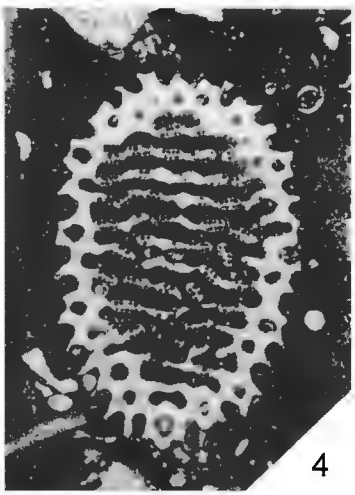
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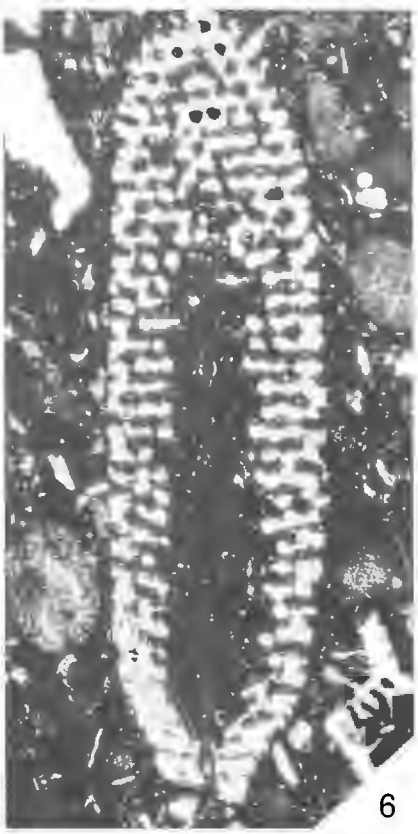
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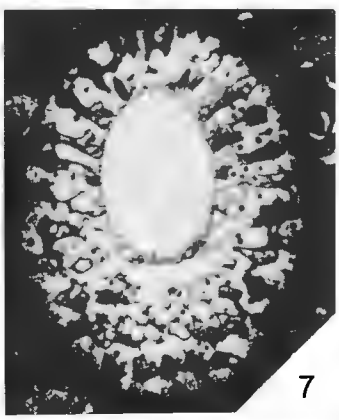
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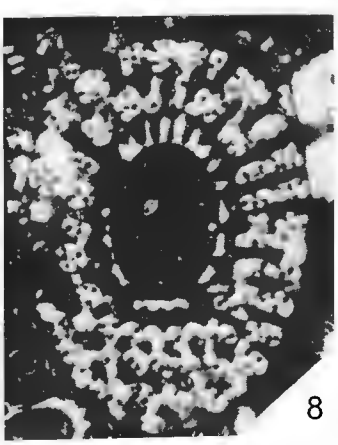
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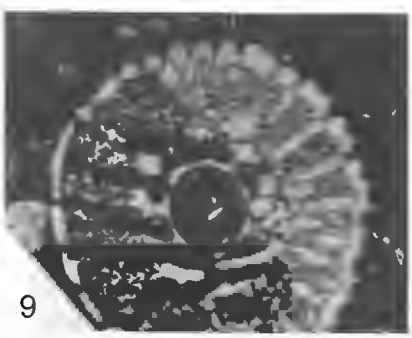
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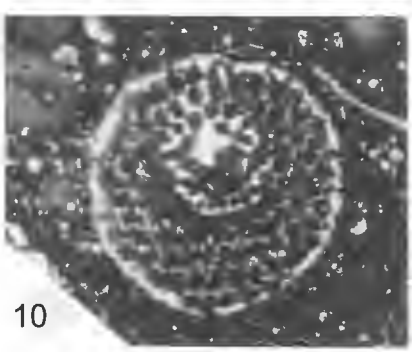
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PLATE 3

Figs 1–2: *Zittelina radoicicae* (Bystrický, 1976)

1. Oblique section; 1247; Jeruzalem-11; × 15.

2. Slightly oblique-transverse section; 1365; Jeruzalem-11; × 15.

Figs 3–9: *Zittelina bystrickyi* (Dieni, Massari et Radoičić, 1983)

3. Oblique section; 1452; Juríkovci-14; × 10.

4. Axial section; 1563; Jeruzalem-12; × 14.5.

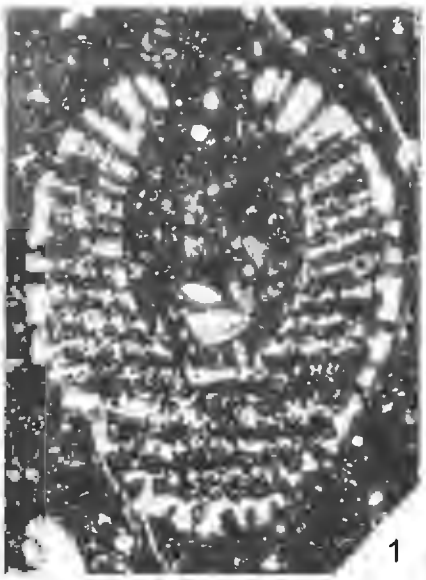
5. Oblique-tangential section; 1314; Jeruzalem-12; × 14.5.

6. Subaxial section; 1526; Matejovec-9; × 14.5.

7. Axial section; 1416, Matejovec-8; × 10.

8. Axial section; 1322; Jeruzalem-12; × 14.5.

9. Axial section; 1427; Matejovec-10; × 14.5.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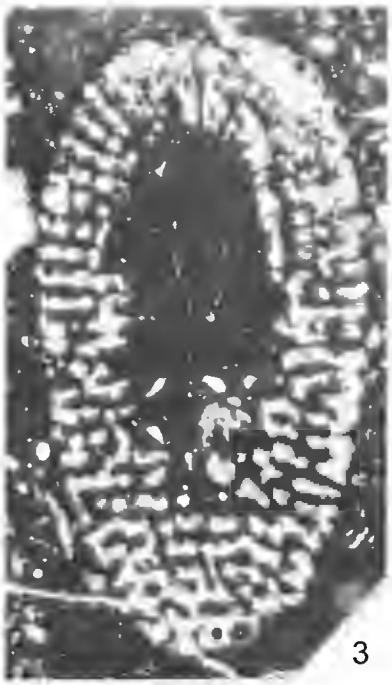
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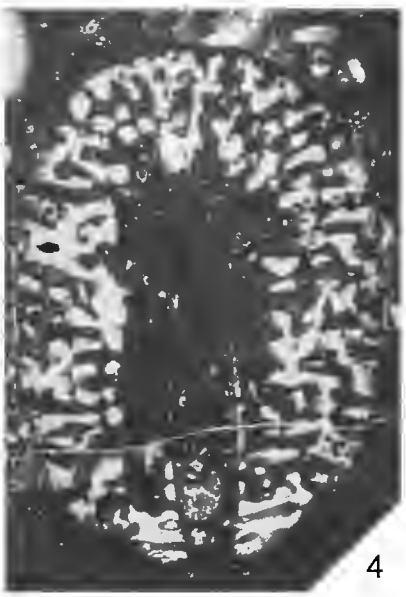
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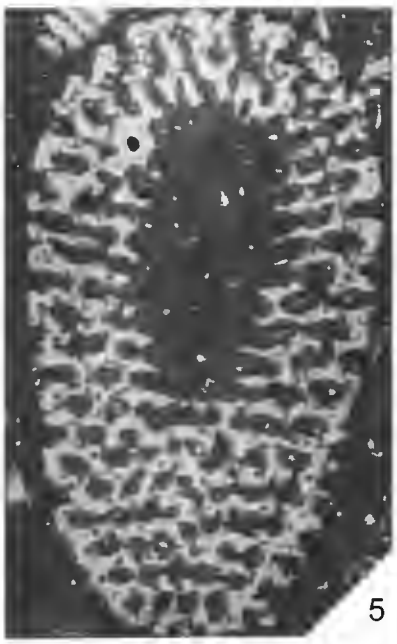
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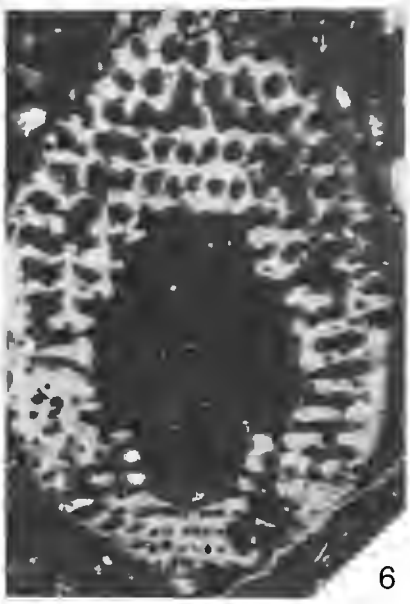
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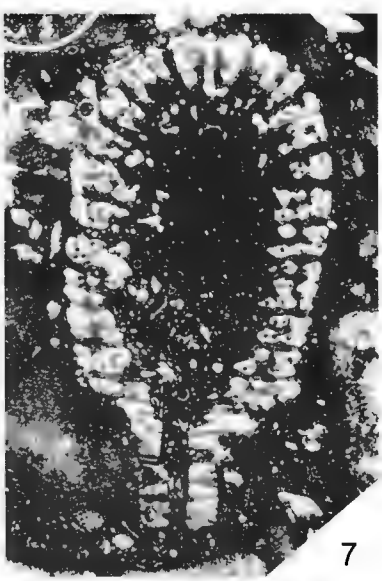
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PLATE 4

Figs 1–7: *Zittelina bystrickyi* (Dieni, Massari et Radoičić, 1983)

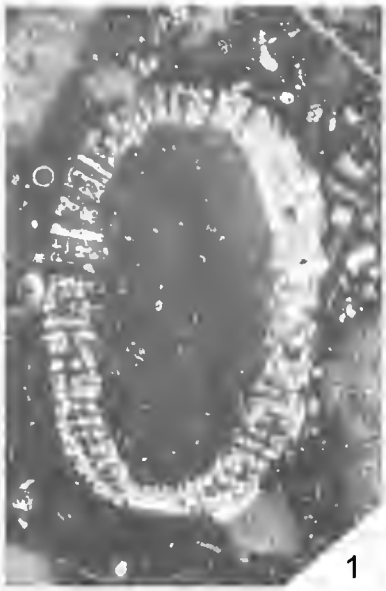
1. Subaxial section; 1565; Jeruzalem-12; × 10.
2. Subaxial section; 1394; Matejovec-9; × 14.5.
3. Oblique section; 1241; Matejovec-8; × 10.
4. Subaxial section; 1331; Matejovec-8; × 14.5.
5. Tangential section; 381; Matejovec-7; × 14.5.
6. Transverse section; 1566; Jeruzalem-12; × 14.5.
7. Oblique-transverse section through isolated main axis tubule; pebble II-2; Jeruzalem-11; × 24.5.

Fig. 8: *Zittelina radoicicae* (Bystrický, 1976)

8. Transverse section through the fragmentary whorl; 1318; Jeruzalem-12; × 29.

Fig. 9: *Triploporella*? sp.

9. Longitudinal section through the basal part of the calcareous body; 1319; Jeruzalem-12; × 24.5.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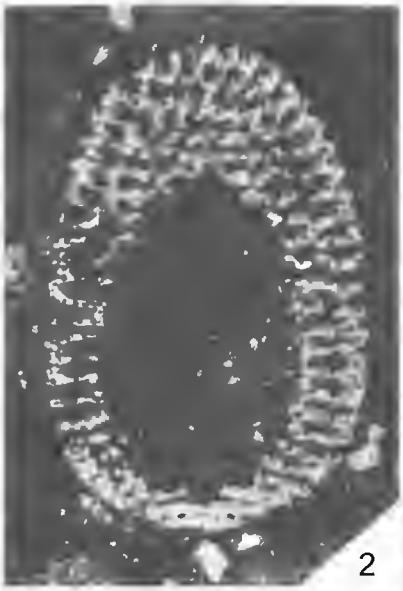
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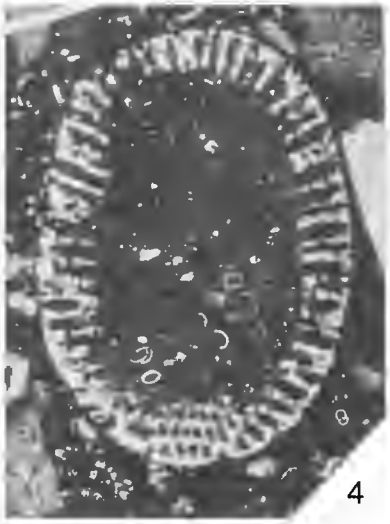
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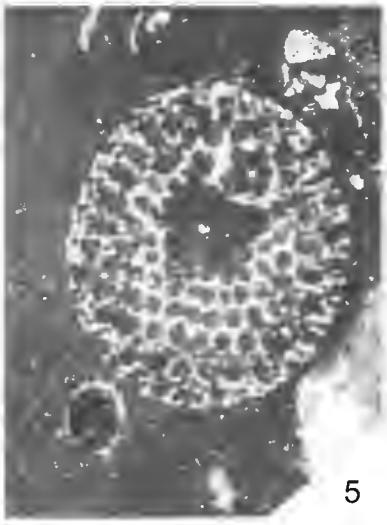
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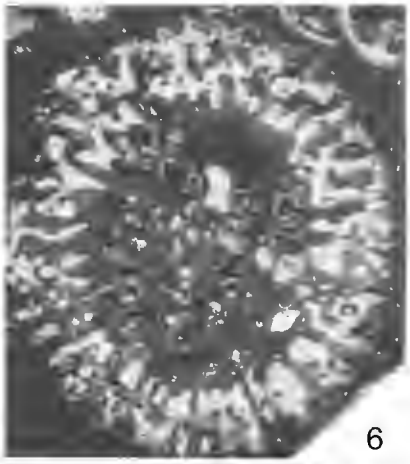
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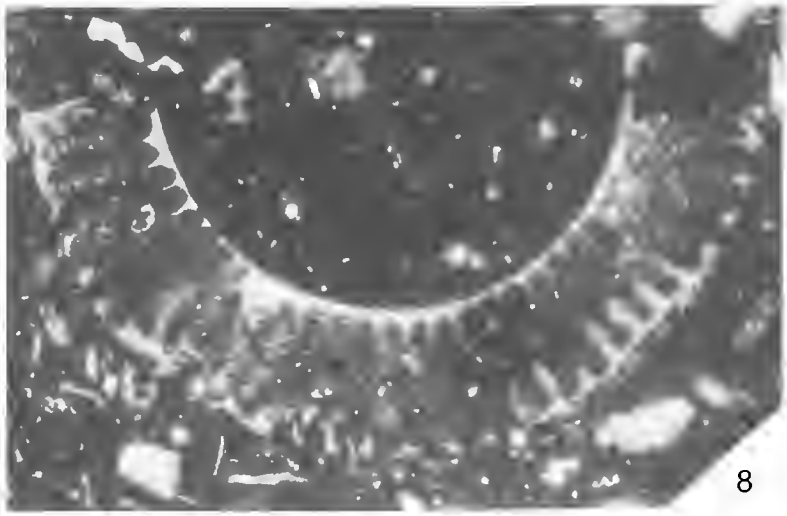
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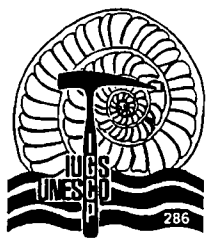

PALEOCENE PALYNOMORPHS FROM THE NW PART OF THE ADRIATIC CARBONATE PLATFORM

Miklos Kedves

Abstract

At the northern end of the Adriatic carbonate platform, in three sections reaching Late Cretaceous to the end of the Paleocene. *Stephanoporopollenites* and other pollen grains were discovered. They are associated to Betulaceans, Myricaceans and Juglandaceans in the Thanetian deposits, and to reworked sporomorphs from the Paleozoic and the Triassic in the K/T transitional beds and in the late Thanetian.

Key words: Palynomorpha, angiosperms, brevaxones, Upper Cretaceous, Paleocene, carbonate platform, Karst, Slovenia, Italy.

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INTRODUCTION

During the Paleocene period several important changes are observed in the composition of the vegetation. The sporae dispersae isolated from the sediments indicate well the most important evolutionary events, in the first place in the angiosperm flora. The extremely intensive diversification of the angiosperms may be followed palynologically by the appearance of the brevaxonate pollen grains. It is necessary to emphasize, that till this time we know not exactly all external and internal factors of these extraordinary differentiations of the angiosperms. The most important palynological characteristics in the Upper Cretaceous, at the K/T boundary and in the Lower Tertiary in Europe may be summarized as follows:

1. Diversity increase of brevaxonate pollen grains.
2. Variation within the form-genera and form-species.
3. Differentiation of paleophytogeographical regions: basic differences have been established between the spore-pollen assemblages of the Southern and the Northern Hemispere. The Upper Cretaceous and Lower Tertiary of Europe and the western part of North America may be characterized by the abundance of the pollen grains of the Stemma Normapolles (Thomson and Pflug, 1953; Pflug, 1953b).

The palynological assemblages of the Paleocene angiosperms represent the following evolutionary grades:

1. Angiosperm pollen taxa of typical Upper Cretaceous types.
2. The evolved Normapolles, within this type there are some form-genera typical to the Paleocene layers, further ones to the more or less whole Paleogene, or at least until the Upper Eocene.
3. The Postnormapolles form-genera with early Amentiflorae origin (Juglandaceae, Myricaceae, Betulaceae).

4. The Longaxones pollen grains of early and advanced types.

For the Upper Cretaceous and Lower Paleogene in Europe the Maastrichtian at its the locality type is important (Kedves and Herngreen, 1980; Herngreen, Felder, Kedves and Meessen, 1986). As regards the K/T boundary, the importance of the Fish Clay from Denmark must be emphasized (Kedves, 1979). The peculiar form-genus of Jarzenipollis Kedves, 1979, is in all probability characteristic for the lowermost Paleocene (Danian) and the uppermost Maastrichtian. Important Paleocene palynological data were published from Belgium by Roche, 1969, from England by Gruas-Cavagnetto, 1976. For the Eocene in Europe, the Paris Basin is the most important (Kedves, 1968a, b etc.; Gruas-Cavagnetto, 1968).

As regards the age determination of the European Paleocene spore-pollen assemblages, the peculiar Normapolles form-genus, *Stephanoporopollenites* is very important. Previously it was believed, that these pollen grains are restricted to the European deposits, because it was never found in the eastern part of North America, in spite of the intensive investigations of the spore-pollen assemblages. But they occur in a relatively small region of North Africa (Meon and Donze, 1983). Several papers were published on *Stephanoporopollenites*: Thiergart (1940), Thomson and Pflug (1953), Pflug (1953b), Krutzsch (1958, 1961, 1967, in Góczán, Groot, Krutzsch and Pacltová), Kedves (1967, 1987). Based on the data of Krutzsch (1967, in Góczán *et al.*) its distribution may be summarized as follows.

Paleogene – Zone subfsp. resp – fsp.	From	max	to
St. praehexaradiatus	3	4	5
St. hexaradiatus minnaensis	4	5–6	7
St. hexaradiatus hexaradiatus	5	6–8	10
St. hexaradiatus semitribinae	7 a	7b–9	10 Basis
St. hexaradiatus tribinae	7 b	8–9	
and		11–12	13 a

NW ADRIATIC REGION

Palynological investigations were carried out as a part of a complex research program in the NW Adriatic region (Pugliese *et al.*, 1995). The samples were collected from Padriciano (Italy), Dolenja vas and Sopada (Slovenia). Alltogether 26 samples were investigated. The samples were treated with HCl-washing — HF-washing — hydrochlorid acid diluted with tartaric acid washing. The organic residues were coloured, and mounted with glycerine jelly hydrated at 39.6 %.

The organic material in the samples investigated is in general not so well preserved, moreover in several samples sporomorphs were not observed. The observations in the light microscope produced following results:

Organisms indicating salt water ecological conditions:

Chitinous Foraminiferae shells: i-4; Hystrichosphaeridae gen. et sp. indet: (Plate 1, fig. 3), i-6, Dolenja vas 58, Sopada 56.

Fresh water algae: *Botryococcus braunii* Kütz.: i-7, i-12, Dolenja vas 58, 60, 64, Sopada 56.

Old Paleozoic reworking: mostly *Trachysphaeridium laminaritum* Timofejew, 1966: (Plate 1, fig. 1), i-4, Dolenja vas 60, 62, 64, 68, 69.

Probably Triassic reworked spore: *Craterisporites* fsp. Plate 1, fig. 2), Dolenja vas 62, 68.

Sporites: Triletes indet.

Pollenties: Gymnospermatophyta: cf. *Classopollis* fsp., *Pityosporites microalatus* (Potonié, 1931b) Thomson and Pflug, 1953, Abietaceae, *Pinus*, *Pityosporites labdacus* (Potonié, 1931b) Thomson and Pflug, 1953, Abietaceae, *Pinus, Cupressacites hiatipites* (Wodehouse, 1933) Krutzsch, 1971, Taxodiaceae v. Cupressaceae, *Cupressacites dorogensis* (Kedves, 1961) Kedves, 1974, cf. Coniferae, *Inaperturopollenites concedipites* (Wodehouse, 1933) Krutzsch, 1971, Taxodiaceae.

Angiospermatophyta: Longaxones *Monocolpopollenites tranquillus*: (Potonié, 1934) Thomson and Pflug, 1953, Palmae, *Dicolpopollis* fsp., Palmae, cf. *Calamus* (Plate 1, fig. 8), *Cupuliferoidaepollenites liblarensis* (Thomson, in Potonié, Thomson and Thiergart, 1950) Potonié, 1960, Fagaceae v. Leguminosae, *Cupuliferoidaepollenites quisqualis* (Potonié, 1934) Potonié, 1960, Fagaceae v. Leguminosae, *Cupuliferoipollenites oviformis* (Potonié, 1931a) Potonié, 1960, Fagaceae cf. Castanea, *Cupuliferoipollenites insleyanus* (Traverse, 1955) Potonié, 1960, Fagaceae, Castanea, *Retitricolporites* fsp., cf. Salicaceae.

Brevaxones: Normapolles: cf. *Complexiopollis* fsp., cf. *Trudopollis* fsp., cf. *Oculopollis* fsp., *Papillopollis* fsp., *Nudopollis* fsp., *Minorpollis* fsps., *Stephanoporopollenites hexaradiatus* (Thiergart, 1940) Thomson and Pflug, 1953 subfsp. *hexaradiatus* (Plate 1, fig. 6), *Stephanoporopollenites hexaradiatus* (Thiergart, 1940) Thomson and Pflug, 1953 subfsp. tribinae Krutzsch, 1961 (Plate 1, fig. 5), *Stephanoporopollenites hexaradiatus* (Thiergart, 1940) Thomson and Pflug, 1953 subfsp. *semitribinae* Krutzsch, 1961 (Plate 1, fig. 4), cf. *Tetrapollis validus* (Pflug, 1953a) Pflug, 1953b (Plate 1, fig. 7), *Minorpollis* fspp., Normapolles fgen. et fsp. indet.

Brevaxones: Postnormapolles: *Triporopollenites* fspp., *Triatriopollenites* fspp., *Subtriporopollenites constans* Pflug, 1953a subfsp. *constans*, *Subtriporopollenites* fsp., *Alnipollenites* fsp., cf. *Graminidites* fsp., Polypodate types.

The most important palynological characteristic features of the localities investigated are as follows.

Padriciano

Sample i-4 contains Normapolles of Upper Cretaceous and Lower Paleogene type (cf. *Oculopollis*, *Papillopollis*, *Stephanoporopollenites hexaradiatus hexaradiatus*).

i-6 — Paleocene: *Stephanoporopollenites hexaradiatus tribinae* with *Minorpollis* fspp.

i-7 — Paleocene: *Stephanoporopollenites hexaradiatus semitribinae*, cf. *Tetrapollis validus*. The occurence of the palm pollen grains of Calamus type are also worth mentioning.

i-11 — Paleocene: Relatively rich in sporomorphs: *Stephanoporopollenites hexaradiatus ? hexaradiatus*, and several pollen grains of Juglandaceae of *Engelhardtia* type, Carya, Palmae, with *Calamus* and *"tranquillus"* type.

1–12 — Paleocene: Rich in sporomorphs: *Stephanoporopollenites hexaradiatus hexaradiatus, Stephanoporopollenties hexaradiatus semitribinae*, with pollen grains of Myricaceae, Betulaceae, Juglandaceae and Palmae.

Sopada

Extremely poor in organic microremains. The occurrences of the most important sporomorphs are summarized on the Table 1.

In conclusion, in the first place the occurrences of the form-genus *Stephanoporopollenites* must be emphasized. In comparison with the published data the Lower Thanetian is the most probable for the samples from Padriciano i-4, 6, 7, 11, 12, and for Dolenja vas 65, 66, 67. But it is necessary to point that further investigations must be carried out with the hope to find well preserved Upper Cretaceous and Lower Tertiary spore-pollen assemblages.

Table 1: The distribution of sporomorphs

Sections	Padriciano					Sopada	Dolenja vas W & E								
	S					58		45	44			23		29	
Drobne No.	1	1	6	19	20	/1	47	A	/6	19	20	b	25	28	30
Kedves No.	4	6	7	11	12	56	58	60	62	64	65	66	67	68	69
Oculopollis	+														
Papillopollis	+														
Steph. hexaradiatus ? hexaradiatus	+		+		+						+	+	+		
Stephanoporopollenites h. tribinae		+									+	+	+		
Minorpollis fspp.		+									+	+	+		
Steph. hexaradiatus semitribinae			+		+						+	+	+		
cf. *Tetrapollis validus*			+												
Calmus type			+												
Engelhardtia				+											
Carya				+											
Palmae				+	+										
tranquillus type				+											
Myricaceae					+						+	+	+		
Betulaceae					+						+	+	+		
Juglandaceae					+						+	+	+		
Trudopollis											+	+	+		
Hystrichosphaeridae gen. et sp. Indet		+				+	+								
Botryococcus braunii			o		o	o	o	o		o					
rework. *Trachysphaeridium laminaritum*	#							#	#	#				#	#
rework. *Craterisporites* fsp.								#						#	
Age after Drobne & Pugliese samples:	Danian				Th	Danian	Maa		Danian					Thanetian	

Dolenja vas

Samples No 65, 66 and 67 only contain stratigraphically significant angiosperm pollen grains of Paleocene age:

— *Stephanoporopollenites hexaradiatus hexaradiatus,*
— *Stephanoporopollenites hexaradiatus tribinae,*
— *Stephanoporopollenites hexaradiatus semitribinae,*
— *Trudopolis*
— *Minorpollis* and
— pollen grains of Betulaceae, Myricaceae and Juglandaceae.

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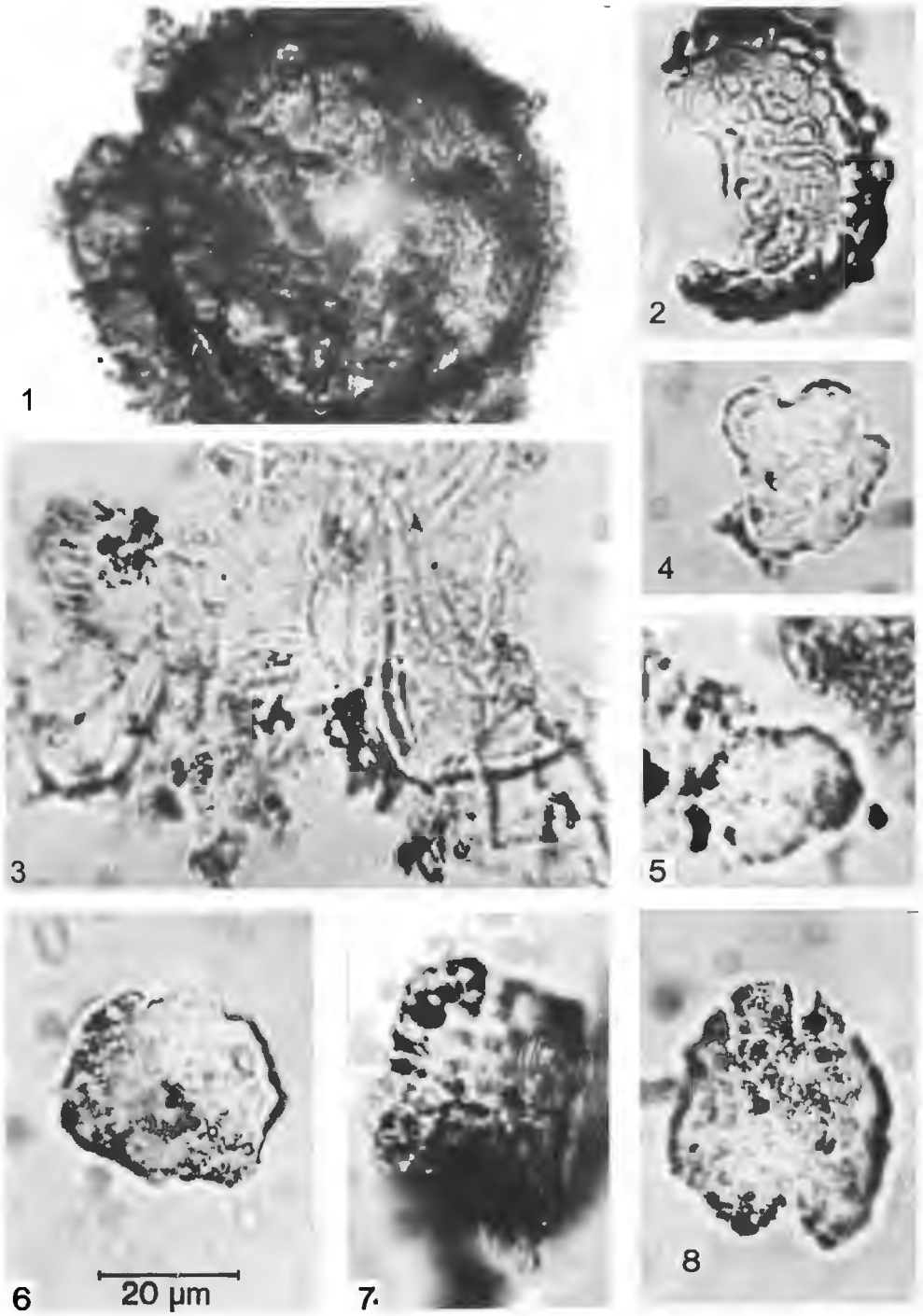

Fig. 1: *Trachysphaeridium laminaritum* Timofejew 1966. Slide: Dolenja vas 60/1; cross-table number: 23.7/111.9.
Fig. 2: *Craterisporites* fsp. Slide: Dolenja vas 62/1; cross-table number: 9.6/133.9.
Fig. 3: Hystrichosphaeridae gen. et sp. indet. Slide: Dolenja vas 58/2; cross-table number: 9.3/132.2.
Fig. 4: *Stephanoporopollenites hexaradiatus* (Thiergart 1940) subfsp. *semitribinae* Krutzsch 1961. Slide: Dolenja vas 66/1; cross-table number: 9.9/128.3.
Fig. 5: *Stephanoporopollenites hexaradiatus* (Thiergart 1940) subfsp. cf. *tribinae* Krutzsch 1961. Slide: i-12/1; cross-table number: 10.5/145.7.
Fig. 6: *Stephanoporopollenites hexaradiatus* (Thiergart 1940) subfsp. *hexaradiatus*. Slide: i-7/1; cross-table number:17.1/149.6.
Fig. 7: Cf. *Tetrapollis validus* (Pflug 1953a) Pflug 1953b. Slide: i-7/2; cross-table number: 19.3/141.9.
Fig. 8: *Dicolpopollis* fsp., Palmae, cf. *Calamus*. Slide: i-7/1; cross-table number: 9.9/128.7.

Dela – Opera SAZU 4. razr.	34/2	65–127	11 Figs	16 Plates	4 Tables	Ljubljana 1998

DASYCLADACEAN GREEN ALGAE AND MICROPROBLEMATICA OF THE UPPERMOST CRETACEOUS-PALEOCENE IN THE KARST AREA (NE ITALY AND SLOVENIA)

Filippo Barattolo

Abstract

The fossil algal content, mainly green algae dasycladales, are described from five uppermost Cretaceous-Paleocene stratigraphical successions restricted to open shelf environments of the Karst area (NE Italy and Slovenia). Eighteen species belonging to 14 genera have been listed. Three species in the upper Maastrichtian versus 17 species in the Danian-Thanetian interval. Two species (*Acroporella chiapasis* Deloffre, Fourcade & Michaud and *Aeolisaccus barattoloi* De Castro) cross the K/T boundary. Two new taxa *Dacastroporella tergestina* n. gen. n. sp. and *Drobnella slovenica* n. gen. n. sp. seemingly appear just above the K/T boundary. A new species, *Microsporangiella buseri* n. sp., is described from upper Danian limestones.

A comparative list of Paleocene algal successions mainly from the Tethyan realm is supplied. The present knowledge on dasycladaleans allows us to prospect a tentative characterization of a benthic biozonation based on algae.

Key words: Micropalaeontology (Dasycladales, microproblematica), Carbonate platform, Karst Area (NE Italy, Slovenia), Latest Cretaceous-Paleocene, central Tethys, central America Middle East, Turkey, India.

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INTRODUCTION

The Upper Cretaceous is to be considered a period of crisis for dasycladaleans. According to stratigraphical evidence the minimal occurrence of dasycladaleans seems restricted to the Cenomanian-Senonian interval. In respect to the Senonian, the Maastrichtian can be considered as a moment of moderate increase for dasyclads. In the Paleocene we see a full and important flourishing of new genera and species (Barattolo, 1991).

In spite of their abundance in shallow water sediments and of their significance in biostratigraphy, the Maastrichtian-Paleocene dasycladaleans are sinadequately used for biostratigraphic purposes. Perhaps the fact that the corresponding sediments are usually scattered, vertically reduced and often lacunar is a possible explanation to it. The Karst area represents a sort of exception in this respect. It is not by chance that the first study on fossil dasycladaleans from this region was published more than sixty years ago (Raineri, 1930). Recent contributions are given by Buser & Radoičić (1987) and Drobne *et al.* (1989).

The present paper supplies further data on the knowledge of this rich and diversified algal assemblage.

STRATIGRAPHIC SEQUENCES

The present algal inventory is based mainly on five stratigraphical sections of the Karst area (fig. 1). Two of them are located in Italy (Colle di Medea, Duino), the other two are placed in Slovenia (Dolenja vas-E, Dolenja vas-W and Sopada). For a stratigraphical description of the Italian series we refer to Martinis (1962) and Cliberto *et al.* (1985) respectively. The Dolenja vas series are treated by Drobne *et al.* (1988), some data on Sopada by Pugliese *et al.* (1995).

An approach to the study of algae of the Slovenian sequences was made by Drobne *et al.* (1989) and Pugliese *et al.* (1995). The stratigraphic distribution of most characteristic algae from Colle di Medea (fig. 2) and Duino (fig. 3) are reported in the present paper.

MATERIAL AND METHODS

The Slovenian material for the present study was collected by colleagues of Ljubljana during the last ten years. The Italian material is mainly the result of a field work achieved by the writer with colleagues of the University of Trieste during the years 1983–1985.

All the algae have been studied in thin section. More than one thousand thin sections from over 250 samples have been examined. Additional thin sections from selected samples have been cut for the present paleontological study.

The samples deposited at the Paleontološki Inštitut Ivana Rakovca, ZRC SAZU Ljubljana are labelled with the letters "Dv" (Dolenja vas sections) and "Sop" (Sopada section). Those deposited at the Department of Paleontology, University of Naples Federico II, are labelled with the letter "A" (De Castro collection) and "BA" (Barattolo collection). Thin sections labelled as "PU" belong to Raineri's material and are deposited in the Sezione di Paleontologia of the Museo Regionale di Scienze Naturali, Turin (Italy).

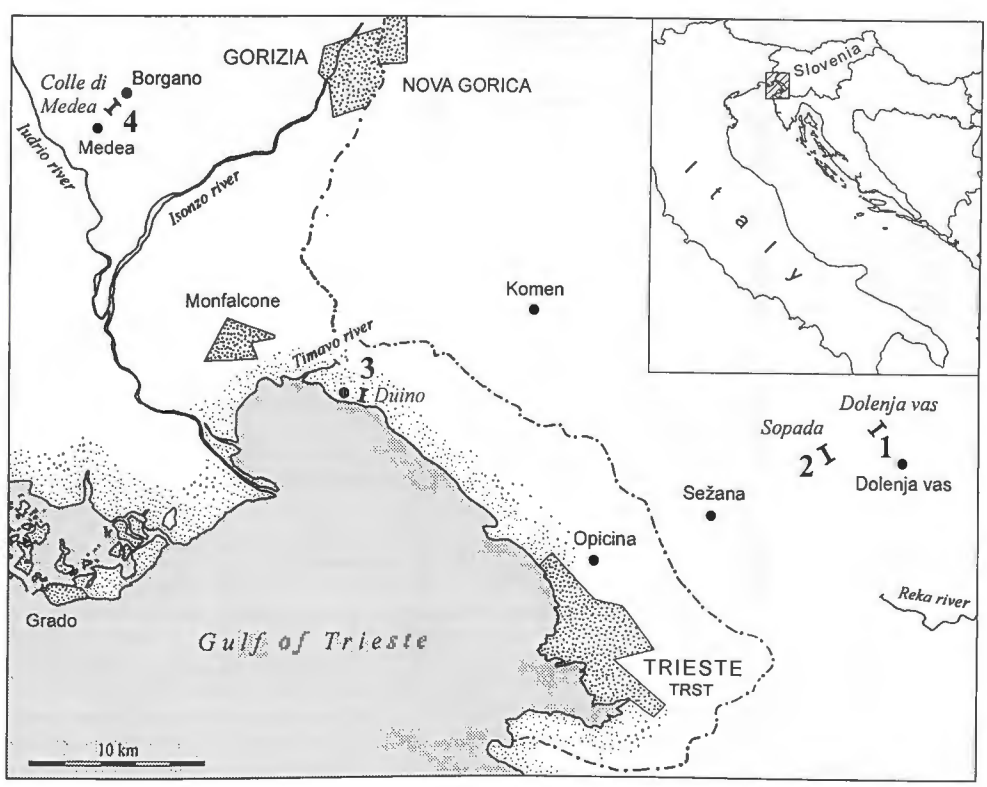


Fig. 1: Location of the stratigraphic sequeces of the Karst area.

1. Dolenja vas E and W;

2. Sopada;

3. Duino;

4. Colle di Medea.

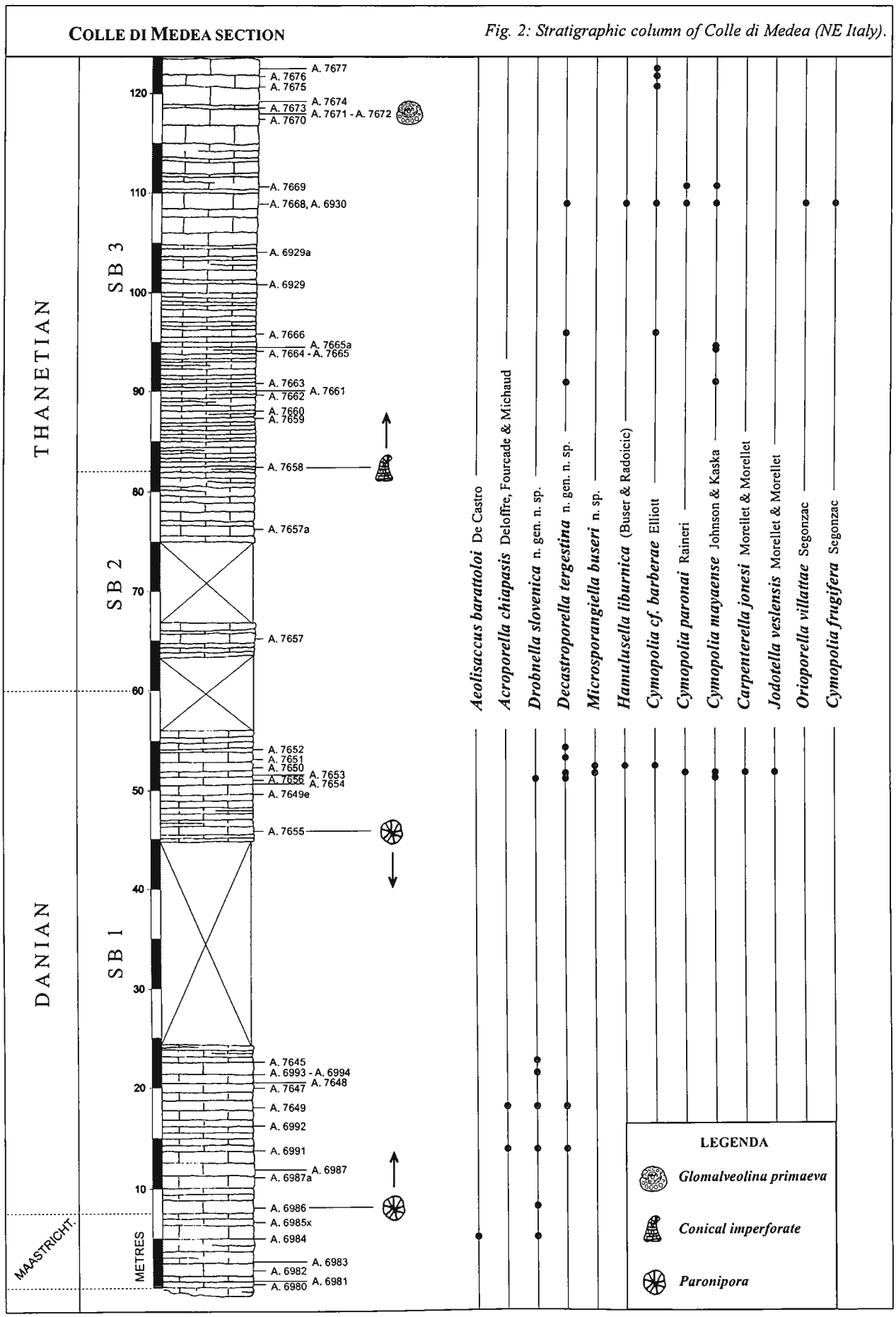
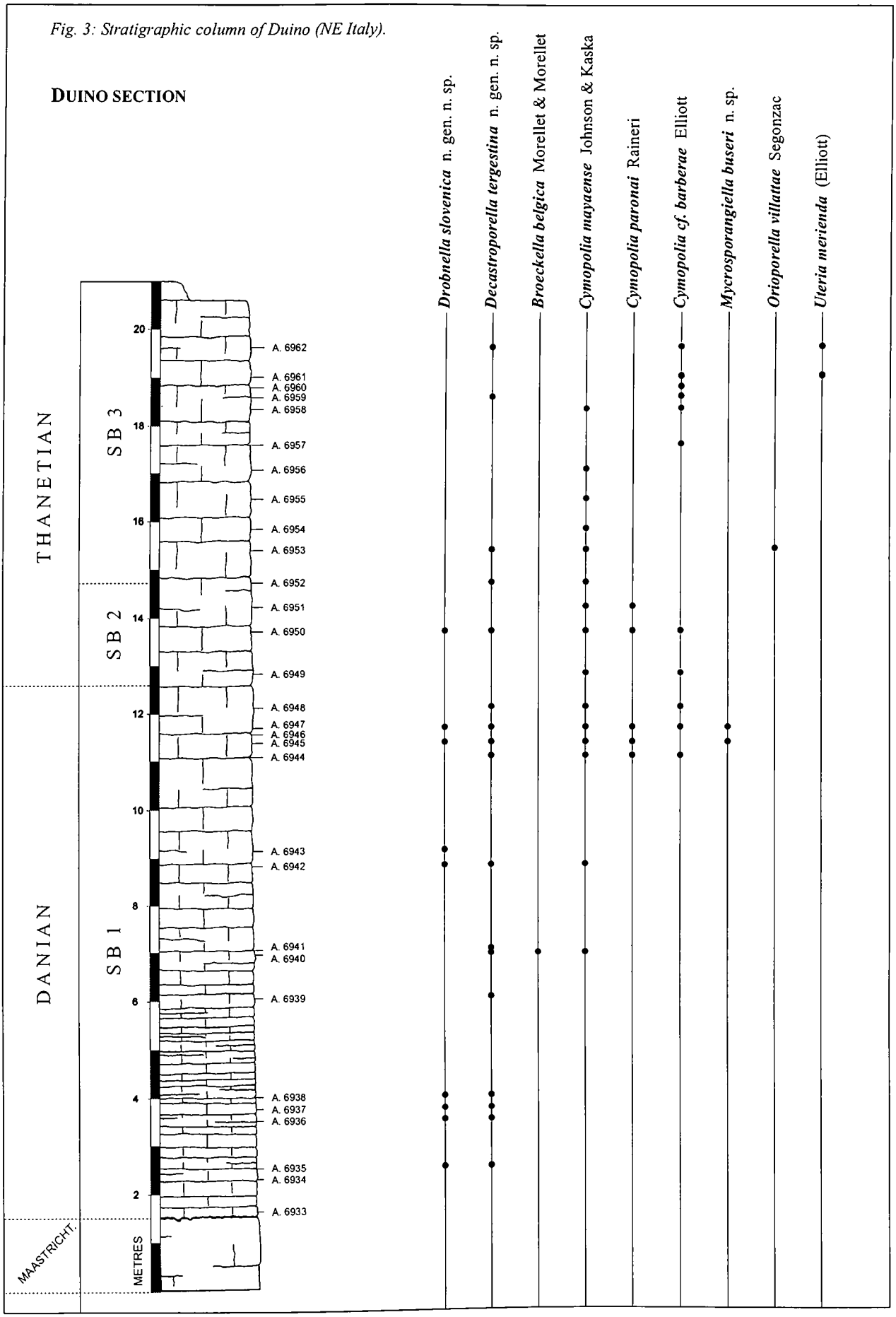


Fig. 2: Stratigraphic column of Colle di Medea (NE Italy).

Fig. 3: Stratigraphic column of Duino (NE Italy).



SYSTEMATIC DESCRIPTIONS
Division Chlorophyta
Order Dasycladales Pascher, 1931

? Family Triploporellaceae (Pia, 1920) Berger & Kaever 1992

Tribe Decastroporelleae nov. tribus.

Type-genus: *Decastroporella* n. gen.

Diagnosis: Euspondyle, club-shaped thalli, coexistence of two types of whorls (fertile and sterile) with a differentiated head. Possible double location of reproductive organs (both in the massive verticils of the stalk and in the head).

Discussion: The occurrence of massive branches in the stalk, most likely reproductive because alternating with thin sterile branches, together with a well developed head is the striking character of this tribe. This fact leads to conclude that representatives of this tribe developed a double strategy of reproduction during their life-history. The reproduction at least in the stalk can be supposed, to be of cladosporate type.

The tribe characters, if considered separately, occur somehow in the diagnoses of several tribes. The alternation of two types (sterile and fertile) of primary branches can be found in Cylindroporelleae Pal 1976, Uterieae (Morellet & Morellet, 1922) Bassoullet *et al.*, 1979; Halicoryneae Valet, 1969. The first two tribes, that belong to the family Triploporellaceae (Pia, 1920) Berger & Kaever, 1992, are characterized by cylindrical and moniliform thalli. The alternation is observed in the same whorl (Cylindroporelleae) or in subsequent close whorls (Uterieae and also Cylindroporelleae). Halicoryneae show spaced whorls but never a stalked thallus. *Rostroporella* Segonzac, a genus of this tribe, holds an ovoid thallus but stalk as well as "sterile" whorls are totally missing.

On the other hand, stalked to club-shaped thalli occur in two tribes of Triploporellaceae, i.e. Coniporelleae Bassoullet *et al.*, 1979 (subtribe Coniporellinae Bassoullet *et al.*, 1979) and Triploporelleae (Pia, 1920) Bassoullet *et al.*, 1979 [subtribe Triploporellinae (Pia, 1920) Bassoullet *et al.*, 1979]. However the taxa belonging to these tribes exhibit verticils of similar branches where there is no alternation of fertile and sterile whorls.

Attribution to family level: According to Berger & Kaever's (1992) classification, the presence of euspondyle branches allows to restrict the attribution to three families: Triploporellaceae, Dasycladaceae and Acetabulariaceae. The alternation of two types of whorls and a cladospore reproduction restrict the choice to Triploporellaceae and Acetabulariaceae. Although the tribe Decastroporelleae has characters shared by both the families, the absence of coronulae, as well as the particular shape of the thallus of the type-genus (a stalked thallus) makes it more reasonable to attribute the new tribe to the family Triploporellaceae rather than to the Acetabulariaceae.

Genus *Decastroporella* n. gen.

Origin of the name: The genus is dedicated to my theacher and colleague prof. Piero De Castro, Dipartimento di Paleontologia, Università di Napoli Federico II.

Type-species: *Decastroporella tergestina* n. gen n. sp.

Diagnosis: Club-shaped thallus with a well differentiated head part. The stalk portion is constituted by stout phloiophorous primary branches ("massive" branches) in spaced whorls; between these whorls thin phloiophorous primary branches ("subtile" branches) are present. The head portion is weakly calcified and shows very thin branches of one order only. The reproduction was probably carried on by the head portion of the thallus and by the "massive" branches of the stalk.

Comparisons: The new genus leaves one perplexed because of its unexpected organization. In fact the alga seems a mixture of two different for distant genera. The stalk is organized as a *Clypeina* Michelin (e.g. *Clypeina inopinata* Favre) but the thallus as a whole, with its stalked shape, recalls *Sestrosphaera* Pia or *Coniporella* Fischer & Thierry. The head, characterized by very thin branches and a thin calcareous wall, looks like that of *Petrascula* or an ellipsoidal body from *Ovulites* Lamarck (Halimediaceae). What is most striking is the coexistence of massive branches along the stalk together with a head. Both of them are commonly related to a reproductive function and have been never reported together in the same thallus. One could hypothesize that reproductive organs are localized in two different parts of the thallus, probably related to different moments of reproduction.

***Decastroporella tergestina* n. gen. n. sp.**
(figs 3, 4, 5; tab. 1; pls. 2–6; pl. 9, fig. 3)

1930 *Neomeris* sp. — Raineri, Mem Ist. Geol. R. Univ. Padova, 8 (7).
1987 *Clypeina* nov. sp. — Buser & Radoičić, Geologija, 28/29 (1985/86), pl. 6, fig. 1.
1989 *Clypeina* n. sp. — Drobne *et al.*, Mem. Soc. Geol. It., 40 (1987), pl. 2, fig. 3–6.
1991a *Clypeina* sp. 2 — Radoičić, Geologija, 34 (1991), pl. 3, fig. 3.

Origin of the name: The specific epithet comes from the city of Trieste (latin: Tergeste).

Holotype: Specimen in axial section figured in pl. 6, fig. 5; detail in pl. 5, fig. 3. Thin section A.6935.2.

Isotypes: Specimens of the samples A.6935 (thin sections A.6935.1–A.6935.14) and A.6937 (thin sections A.6937.1–A.6937.12).

Depository: The material is deposited at the Department of Paleontology, University of Naples Federico II (De Castro collection).

Type-locality: The outcrop is located about 500 m east of Duino village, near Trieste, along the steep coastline.

Type-level: Dark laminated bioclastic limestone (wackestone-packstone to grainstone) with inclusions of several generations of different *Paronipora*. The samples come from the lowest unit of a Paleocene sequence overlying an Upper Cretaceous rudist limestone. This unit, 5 m thick, consists of dark to black bituminous bioturbated mud-supported limestones (fig. 3).

Diagnosis: Club-shaped stalked thallus with a sharp differentiation into a cylindical, perannulated and articled lower portion (the "stalk") and a spherical to slightly ellipsoidal upper portion (the "head"). Each article of the stalk shows a lower part with thin phloiophorous primary branches ("subtile" branches), arranged in great number with an unclear order along the central stem. In the upper part of the article a verticil of 5 to 9 stout phloiophorous primary branches ("massive" branches) are present. The head exhibits very thin branches of only one order calcified along a short extent.

The calcareous skeleton is rather thin, articled in the stalk but continuous in the head. The articles usually break from each other and are the commonest part of the thallus that can be observed in the sediment.

The most significant biometric values are supplied in tab. 1.

General features of the calcareous skeleton: The calcareous skeleton is rather thin and follows the outer shape of the thallus, that is it shows a stalk and a head. The first is articled while the second is continuous.

Each article, 0.43–1.55 mm long, is cylindrical in shape. It is often slightly tapered at both ends, while the swollen part is shifted near the upper end (pl. 4, fig. 3, 5). Most part of an article is pierced by numerous thin pores ("subtile" branches) slightly flaring outwards. In this part the calcification is constituted by two layers in thin section marked by a faint dark line (pl. 2, fig. 12; pl. 3, fig. 11), sometimes substituted by a narrow empty space (pl. 2, fig. 14). The inner layer often is lacking (pl. 3, fig. 12) or discontinuous (pl. 3, fig. 7).

The upper end of the article shows a stronger calcification and holds a verticil of stout pores ("massive" branches).

When the inner layer is well preserved its inner surface is rather smooth. It was probably close to the central stem, so that the shape of the central cavity may be assumed to infer that of the main axis. The central stem most likely was affected by periodical narrowings, each corresponding to the emplacement of the whorl of "massive" pores.

The head is spherical to slightly ellipsoidal. Its diameter (Dh) is 1.4–2.2 mm but with an extremely thin calcified wall (0.028–0.056 mm in thickness), densely pierced by very small pores. The calcified wall becomes stronger in the vicinity of the junction to the stalk (pl. 5, fig. 3; pl. 6, fig. 4).

Branches of the stalk: The branches are arranged in periodical series (articles) consisting of a long part of the main axis crowded by thin branches. The series ends with a single verticil of stout branches. Because of the uncertainty of the role played by the branches of the stalk in the reproduction of the plant here, a mere morphological terminology is prefered for them. Consequently the thin branches are indicated as "subtile" branches while the stout branches are termed "massive" branches.

"Subtle" branches are roughly perpendicular to the surface of the main axis. That is they are set at right angles along most part of the article, but they gently bend downwards in the lower part of the article and slightly upwards at the top of it. The branches are arranged without a clear order (pl. 2, fig. 17; pl. 3, fig. 5) even though in some specimens (pl. 2, figs 14, 18) there can be perceived an arrangement in close and alternate whorls recalls that of *Griphoporella curvata* (Gümbel) Pia (Barattolo *et al.*, 1993). On the other hand, whether the arrangement of the "subtle" branches would be really aspondyle it should be hardly understandable in an undoubtedly euspondyle general context as revealed by the verticils of the "massive" branches: In this case we are logically compelled to assume that "subtle" branches were effecively euspondyle but several factors (e.g. the closeness of whorls, great number of pores in a whorl, natural irregularities) have masked it. This is why in the reconstructions they are drawn in verticils (figs 4–5).

The number of "subtle" branches in a horizontal row as deduced by oblique sections is about 12–24; the height between whorls (or two ideal rows) is about 0.020–0.035 mm. In transversal sections the number of pores is apparently 50–100 % higher. This fact can be only in part imputed to the inaccuracy of the measure from oblique sections; there is some evidence that the closeness of whorls equal to the thickness of the thin section (0.02–0.03 mm), makes two alternating whorls counted as a single one.

Massive branches, except for their tapered inner end, are roughly cylindrical. They are in number of 5–12 per whorl and usually preserved in their proximal part (pl. 4, figs 3–4, 7), but occasionally for a great extent (pl. 3, figs 1, 3–4; pl. 4, fig. 9). In this case their outer ends are enveloped by a thin and delicate calcareous wall. This fact explains the frequent incompleteness of preservation. Massive branches are right and set at 40–60° to the main axis.

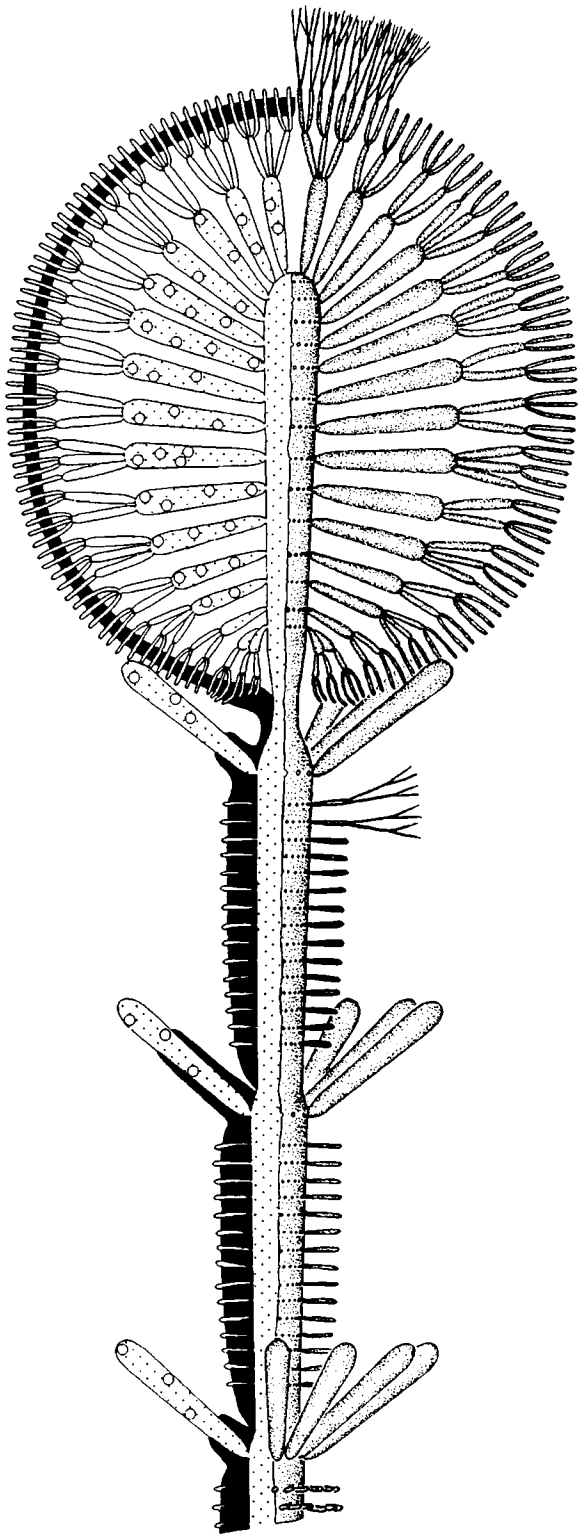


Fig. 4: Decastroporella tergestina *n. gen. n. sp. Reconstruction of the thallus in longitudinal view. Left side: stem, branches and calcification (black) in axial section; branches of the head as well as the kind and/or position of reproductive organs are merely interpretative. Right side: longitudinal view of the branches without calcification and the central stem showing the junctions of primary branches (massive and subtle); a perspective view of the branches is drawn (below). (43.5 ×)*

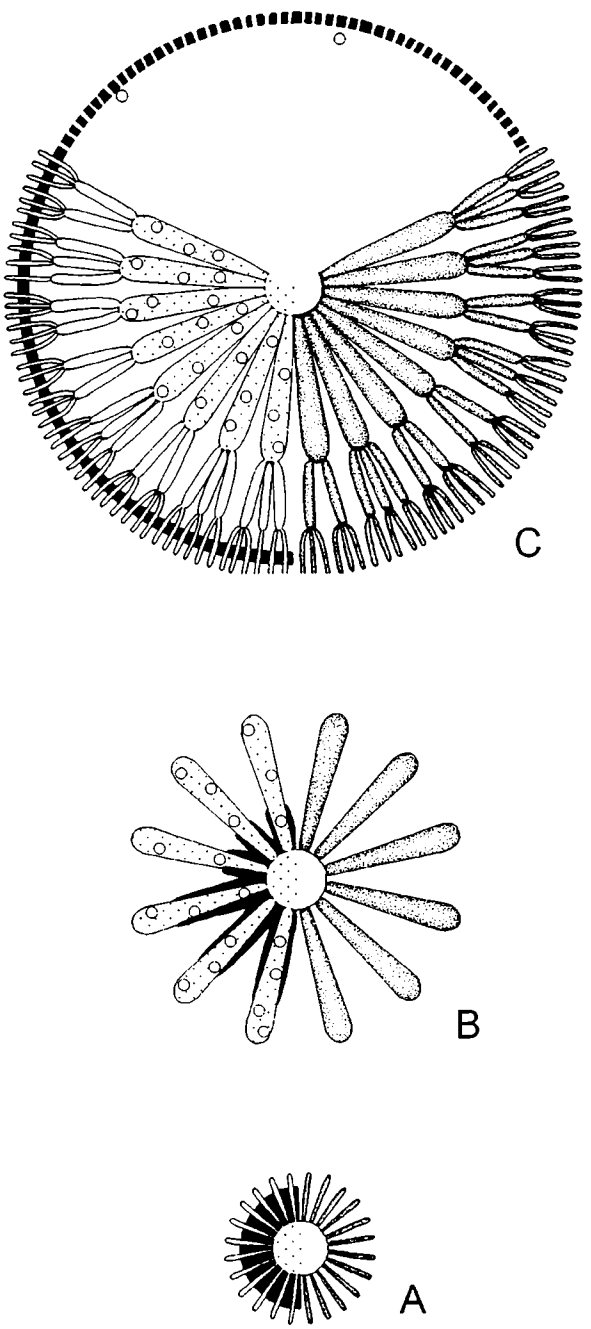


Fig. 5: Decastroporella tergestina *n. gen. n. sp. Reconstructions in transversal view. A: stalked part across subtle branches; B: stalked part across a whorl of massive branches. A–B: left side — stem, branches and calcification (black); right side — half a whorl without calcification and the central stem. C: head; upper side — calcification and possible reproductive organs; lower left side — stem, branches and calcification (black); lower right side — central stem with a sector of a whorl without calcification. (43.5 ×)*

Branches of the head: The branches of the head are calcified for a very little extent (0.014–0.0056 mm; see general features of the calcareous skeleton). In this extremely thin calcified wall, the branches are akrophorous and arranged perpendicularly to the surface of the head. Their diameter is 0.007–0.020 mm, apparently smaller than the "subtle" branches of the stalk. On the vicinity of the connection to the stalk, the branches bend downwards but diverge towards the exterior (pl. 5, fig. 3). In this area, the branches seem inclosed by the calcareous wall (pl. 5, fig. 3), in contrary to what happens elsewhere in the head.

Reproductive organs: No clear traces of reproductive organs have been observed anywhere in the calcareous skeleton. It can be reasonably supposed that massive branches of the stalk, especially if compared to subtile branches, could have carried out a reproductive function. On the basis of their position on the thallus, directly attached to the axial stem, a cladospore reproduction can be inferred for them.

The top, or at least the upper part of the thallus, is where reproduction of dasycladaleans characteristically takes place. This fact is well documented both in extant and fossil representatives. Thus, if the extreme thin calcified wall does not allow to give elements on what type of reproduction was adopted by the head of *Decastroporella tergestina* n. gen. n. sp., a reproductive function of this part of the thallus is highly probable. However small circular corps have been found in the thin calcareous wall or immersed in the early diagenetic aragonitic layer close to the inner surface of the head wall (pl. 6, fig. 1). It is difficult to say whether these bodies can be referred to reproductive stuctures (ampullae ?, cysts ?) or not.

Small globular cavities are also found in the stalk, but very rarely (pl. 4, fig. 1: boundary between 1st and 2nd article from the bottom, and lower left part of 3rd article). Their incorporation in a coherent reproductive scheme is rather difficult.

Reconstruction: The reconstruction of the alga is particularly problematic with most of the problems regarding the head. This fact is mainly due to two orders of factors. The first is the scarcity of information inferable from the extremely thin calcification of the head. Moreover the stalk-head junction of *Decastroporella tergestina,* very sharp, gives no aid either. Elsewhere stalked genera (e.g. *Petrascula, Tersella:* Bernier, 1979; Barattolo & Bigozzi, 1996) exhibit an intergrading connection that can supply elements (e.g. orders of ramifications) for reconstruction. The second is an apparent lacking of fossil allied genera as well as extant counterparts.

At the state of knowledge a lot of different reconstructions can be proposed. What is worse, each of them may influence the algal attribution at family level. Therefore, the present reconstruction (figs 4–5) is one of those possible and merely tentative. It is based on some assumptions, chosen among those most conservative: the head of the thallus carries on a reproductive function. The kind of reproduction is the same in the head and in the stalk. The thin calcified subspherical wall represents a calcification at the outermost part of the head. The central stem continues into the head keeping a size comparable to that of an article from stalk.

Table 1: Main biometric parameters of *Decastroporella tergestina* n. gen. n. sp., from sample A.6935 (only the head, table 1a) and from sample A.6937 (table 1b). For each specimen is supplied the thin section number and the dimensional values. The range (*min.* and *max.*), the number of measurements, the average and the standard deviation for each parameter are given in italics at the bottom of the table. All size parameters are in microns. D_{ext}: outer diameter of the stalked part (subtile branch zone); d_{int}: inner diameter of the stalked part (subtile branch zone); L_{art}: lenght of the article (stalked part); p_s: width of subtile branches; p_{mv}: vertical width of massive branches; p_{mw}: verticillar width of massive branches; l_m: lenght of massive branches; w_s: number of subtile branches per whorl; h_m: height between massive whorls; Dh_{ext}: outer diameter of the head part; *eh*: thickness of calcified wall of the head; *ph*: width of branches in the head.

Decastroporella tergestina n. gen. n. sp. : parameters of the head – Sample A.6935 **Table 1a**

No.	thin section	d int	D ext	L art	ps	pmv	pmw	lm	ws	h m	Dh ext	eh	ph
1	A.6935.1										1442	32.2	14
2	A.6935.1										1554	30.8	14
3	A.6935.2										1204	28	7
4	A.6935.2										2226	42	14
5	A.6935.3										924	14	7
6	A.6935.3										952	14	4.2
7	A.6935.3										1064	28	9.8
8	A.6935.7										1708	35	7
9	A.6935.7										2086	42	16.8
10	A.6935.7										2170	42	16.8
11	A.6935.12										1610	28	9.8
12	A.6935.14										910	28	7
13	A.6935.14										2002	42	16.8
14	A.6935.14										1386	42	14
	Min										*910*	*14*	*4.2*
	Max										*2226*	*42*	*16.8*
	Number										*14*	*14*	*14*
	Average										*1517*	*32.000*	*11.300*
	St. Deviation										*472.30*	*9.6973*	*4.3746*

Decastroporella tergestina n. gen. n. sp. **Table 1b**

No.	thin section	d int	D ext	L art	ps	pmv	pmw	lm	ws	hm	Dh ext	eh	ph
1	A.6937.8	182	294		24				16				
2	A.6937.8	98	168		17								
3	A.6937.8	168	336	1008	28	84	63	210		1316			
4	A.6937.8	112	168		14				16				
5	A.6937.8	140	210		17								
6	A.6937.8	196	336		42								
7	A.6937.8	112	210										
8	A.6937.8	210	378		42								
9	A.6937.8	168	280		14								
10	A.6937.8	196	308		42								
11	A.6937.8	154	322		35								
12	A.6937.8	238	350		21								
13	A.6937.8	105	182										
14	A.6937.8	98	196										
15	A.6937.8	98	182		28								
16	A.6937.8	154	224		21								
17	A.6937.8	196	350		28		112						
18	A.6937.8	224	308										
19	A.6937.8	196	266		14								
20	A.6937.8	224	336		28				24				
21	A.6937.8	154	378										
22	A.6937.8	182	252			98							
23	A.6937.8	224	294		28		70						
24	A.6937.8	182	322		28								
25	A.6937.8	210	308	1022	28		84						
26	A.6937.8	266	350		28								
27	A.6937.8	84	154						13				
28	A.6937.8	168	280		21								
29	A.6937.8	196	280		21		70						
30	A.6937.8	168	322		28				24				
31	A.6937.8	126	210		14		63						
32	A.6937.8	112	182										
33	A.6937.8	70	140										
34	A.6937.8	224	322		24		98						
35	A.6937.8	238	364		28								
36	A.6937.8	196	308		21								
37	A.6937.8	238	378		31								
38	A.6937.8	140	210		21								
39	A.6937.8	168	280		14				24				
40	A.6937.8	280	420		21								
41	A.6937.8	98	238		28		70						
42	A.6937.8	252	406			70							
43	A.6937.8	224	350			84							
44	A.6937.8	154	294		28								
45	A.6937.8	196	350	1218	28	84		168		1260			
46	A.6937.8	140	350		28								
47	A.6937.8	210	350										
48	A.6937.8	196	280		21		63						
49	A.6937.8	280	420		35								
50	A.6937.8	126	266		28								
51	A.6937.8	336	490		42								
52	A.6937.8	210	364		28								
53	A.6937.8	182	280										
54	A.6937.8	224	434		21								
55	A.6937.8	98	154		28								
56	A.6937.8	182	336			112							
57	A.6937.8	252	378										
58	A.6937.8	196	364	1260	21								
59	A.6937.8	238	371		28								
60	A.6937.8	210	350										
61	A.6937.12										1428	28	10
62	A.6937.12										1806	42	10
63	A.6937.12										2198	56	28
64	A.6937.12										1512	32	28
65	A.6937.12										1540	35	28
66	A.6937.12										1694	28	28
67	A.6937.12										2100	42	28
	Min	*70*	*140*	*1008*	*14*	*70*	*63*	*168*	*13*	*1260*	*1428*	*28*	*10*
	Max	*336*	*490*	*1260*	*42*	*112*	*112*	*210*	*24*	*1316*	*2198*	*56*	*28*
	Number	*60*	*60*	*4*	*44*	*6*	*9*	*2*	*6*	*2*	*7*	*7*	*7*
	Average	*181.65*	*299.72*	*1127*	*25.773*	*88.667*	*77*	*189*	*19.5*	*1288*	*1754*	*37.571*	*22.857*
	St. Deviation	*55.590*	*78.970*	*130.58*	*7.5139*	*14.459*	*17.5*	*29.698*	*5.0498*	*39.598*	*298.27*	*9.9976*	*8.7831*

As regards to order of ramification and shape of branches it has been supposed that primary branches were similar to those massive of the stalk, but their number equalled that of subtle branches. According to this, the crowded fine pores of the head could be justified with three orders of ramifications, if the tuft of secondaries and tertiaries was composed of 5 branches in average.

Comparisons: The stalk of *Decastroporella tergestina* n. gen. n. sp. looks like *Clypeina haglani* Radoičić (1990), but differs from it by a far lower number of branches (massive branches) in a whorl (5–12 versus 18–22), and a smaller outer diameter of the fertile whorl (whorl of massive branches) (*Dm* = 0.25–0.83 mm versus 0.88–1.12 mm).

However, one specimen of *C. haglani* (Radoičić, 1990: pl. 3, fig. 5) somehow resembles the stalk part of the new taxon more closely except for the subtile branches that are not visible. Moreover this specimen shows fertile branches shorter than the others of the same species. Thus, if we suppose that the traces of subtile branches have been secondarily obscured, as it happens in *D. tergestina.* Thus, the attribution of Radoičić's mentioned specimen to *D. tergestina* cannot be excluded.

Stratigraphic and palaeoecological distribution: The new species is found in SBZ1–SBZ3 biozones. Its appearance seems to coincide to the beginning of Danian beds (*Acroporella chiapasis* interval). It occurs in several microfacies contexts. Taking into account the paleoenvironmental reconstruction made by Drobne *et al.* (1988, fig. 3) the alga probably populated the shallow marine ponds and the intertidal flat. Secondarily it could occur in the restricted shallow lagoon and in bioclastic deposits.

Family Triploporellaceae (Pia, 1920)
Berger & Kaever, 1992

Tribe Triploporelleae (Pia, 1920) Bassoullet *et al.*, 1979

Genus *Acroporella* (Praturlon, 1964)
Praturlon & Radoičić, 1974

***Acroporella chiapasis* Deloffre, Fourcade et Michaud, 1985**
Pl. 1, figs 1–6

1985 *Acroporella chiapasis* Deloffre, Fourcade et Michaud, Deloffre, Fourcade & Michaud, pp. 115–125, fig. 3, pls. 1–2
1989 Microproblematicum (Dasycladacean algae?), Drobne *et al.*, pl. 2, fig. 7

This is a small-sized dasyclad species, originally found in the Chiapas region (Mexico) in the uppermost part of the Ocozocuautla Fm. This unit, 70 m thick, consists of biomicrite and biosparite containing abundant rudist shells and large foraminifera such as *Pseudorhapydionina* sp., *Chubbina jamaicensis* Robinson, *Chubbina* cf. *macgillavryi* Robinson, *Kathina delseota* Smout, *Smoutina* cf. *cruysi* Drooger. According to the fossil content a Maastrichtian age can be inferred for the type level.

In the Karst area the alga is recorded in the Dolenja vas sections (E and W) and in Sopada section, from uppermost Maastrichtian to lower Danian beds (lower part of SBZ1 biozone). The species occasionally occurs in the Colle di Medea section, but only in Danian beds up to the first appearance of *Cymopolia* spp. assemblage (SBZ1 biozone).

Acroporella chiapasis occurs in wackestones with a poorly diversified association, especially in the Cretaceous (indetermined dasycladaleans). In Paleocene beds it is associated to *Decastroporella tergestina* n. gen n. sp. and *Drobnella slovenica* n. gen n. sp. The alga is often found in fragments and in bad state of preservation. The inner part of the primary branches is visible with some difficulty. Secondary branches have never been observed.

Genus Suppiluliumaella Elliott 1968

***Suppiluliumaella* sp.**
Pl. 1, fig. 7

At first sight the general shape of the alga and the primary branches recall *Neogyroporella servaisi* Michaud, a Maastrichtian species from Mexico. However the Karst species differs from this taxon for the general smaller size and for the clear presence of secondary branches.

The fact that primary branches show a peduncular inner part and a swollen outer part, and that secondary branches are phloiophorous allow to attribute the taxon to the genus *Suppiluliumaella.*

The species is found in uppermost Maastrichtian wackestones from the Sopada section, and are anyway very rare.

Genus *Broeckella* Morellet et Morellet, 1922

***Broeckella belgica* Morellet et Morellet, 1922**
Pl. 12, fig. 9

This is a widespread alga of the Paleocene Tethyan domains, usually recorded from reefal environments (Deloffre & Génot, 1982) or from cobbles of similar facies. Its stratigraphic range is restricted to Lower-Middle Paleocene (Danian-Thanetian). Actually the alga is known from the upper Danian (Montian) of Mons (type locality). It has also been found in a Thanetian sequence (Majevica, Bosnia) associated to *Anatoliella ozalpiensis* Sirel, *Idalina sinjarica* Grimsdale, *Mississippina binkhorsti* (Reuss) and *Rotalia provalis* (Terquem) (Radoičić, 1992).

In the Karst area the alga occurs with rare specimens in a sample, Danian in age (upper part of SBZ1 biozone), from the Duino section. The scarce occurrence of this species is probably due to the unfavourable, restricted environmental conditions.

Tribe Dissocladelleae Elliott, 1977

Genus *Dissocladella* Pia in Rao & Pia, 1936

***Dissocladella gracilis* Radoičić, 1991**

Pl. 10, fig. 1

1991b *Dissocladella gracilis* Radoičić, Radoičić, pp. 309–313, pls. 1–2

I refer to this taxon a minute dasyclad alga from the Danian (upper part of SBZ1 biozone) of Colle di Medea section that shows squat primary branches and strongly divergent phloiophorous secondary branches. The alga constitutes a minor component within the *Cymopolia* interval where it occurs. Its real abundance could be biased by its resemblance to sterile articles of some *Cymopolia* (e.g. *Cymopolia mayaense* Johnson & Kaska and *Cymopolia* cf. *barberae* Elliott).

Dissocladella gracilis has been reported from the Thanetian of Bosnia where it occurs in facies similar to those of the Karst (Radoičić, 1991b, 1992).

Tribe Thyrsoporelleae (Pia, 1927) Elliott ,1977

Genus *Thyrsoporella* Gümbel, 1872

***Thyrsoporella longa* Radoičić, 1990**

Pl. 16, fig. 8

The taxon is found only in the Sopada section (SBZ4 biozone) associated to *Distichoplax biserialis* Dietrich. The species shows three orders of branches like in *Thyrsoporella longa* and similar in size and shape of branches. It is usually badly preserved so that the specimens are ascribed to this taxon with a certain degree of doubt.

Thyrsoporella longa first was described in three boreholes in the Iraqi desert. Its stratigraphic position is referred to Danian p.p.-Thanetian (Radoičić, 1990: p. 93). Here the species is known to occur with another thyrsoporellid, *Thyrsoporella turgidipora* Radoičić. The differences between the two algae, comparable in size, are rather smalls and, according to the author, are based on the shape of the branches.

Family Dasycladaceae Kützing, 1843

Tribe Dasycladeae Pia, 1920

Genus *Cymopolia* Lamouroux, 1816

The genus (Cretaceous-Recent) is characterized by an articulated thallus. The variously cylindrical, barrel-like to subspherical articles hold a number of verticils of primary branches. One primary divides into one ampulla and three to eight phloiophorous secondary branches embracing the ampulla.

Cymopolia is the best represented dasyclad genus in the Karst area, both in diversity (number of species) and richness (abundance of specimens). The taxa recognized occur in the SBZ1 (upper part)–SBZ3 biozones, only one in SBZ4. With all of them we have problems of taxonomical attribution. These are mainly due to their poor descriptions, and illustrations in a genus where heteromorphosis (sterile and fertile articles, strong variability in article shape etc.) is frequent and further complicates the study. Therefore, a detailed study on the *Cymopolia* species is necessary, but not in the context of the present paper, wich only gives some observations on the most significant taxa recognized.

***Cymopolia mayaense* Johnson et Kaska, 1965**

Pl. 11, figs 1–6; Pl. 12, figs 1–2;
Pl. 13, fig, 1; Tab. 2

1930 *Cymopolia elongata* Defrance, Raineri, p. 7, figs 2–3

1989 *Cymopolia mayaense* Johnson et Kaska, Drobne *et al.*, pl. 1, fig. 1

The alga was established by Johnson & Kaska (1965) on material from Guatemala. The sample was collected 3 km NE of San Luis in the El Petén region and probably belongs to Petén Fm. (Paleocene-Lower-?Middle Eocene). The marine limestones of the formation contain *Borelis floridiana*, *B. gunteri*, *Lituonella elegans*, *Rhapidionina limbata*, *Coskinolina elongata*, *Fabularia matleyi* and *"Pellatispirella" nassauensis* (Johnson & Kaska, 1965: p. 4).

The material is rather poor as well as the specimens figured. Johnson & Kaska (1965) give the following diagnosis: *"Thallus develops as branching segmented stems. The segments are cylindrical or nearly so with rounded ends. The segments studied had lengths ranging from 1.6 to 2.9 mm and maximum diameters from 0.8 to 1.38 mm. Each segment contains a cylindrical central stem from which regular whorls of short, primary branches develop. Each primary branch bears a tuft of usually four secondary branches surrounding an egg-shaped sporangium. A fairly thick shell of calcium carbonate surrounds the central stem and extends outward to the ends of secondary branches, or nearly that far. Thus the fossil formed is a calcified cylindrical segment with the surface covered with circular pits representing the ends of the secondary branches."* Dimensional measurements are summarized in tab. 2.

The Karst species fully corresponds to the diagnosis of *C. mayaense*, and a good correspondance is shown by the dimensional parameters. The number of primaries in a whorl (*w*) seems higher than in *C. mayaense* (15–25 versus 14–16). Actually the datum of *C. mayaense* is de-

duced from two small specimens and probably is shifted to the lower limit of variability. In fact a value of 27–28 can be estimated for the holotype (Johnson & Kaska, 1965: pl. 18, fig. 1).

The ampullae of the Karst material are a little smaller than the ones from Guatemala. Actually the size of the ampullae of the Karst alga is not constant from an article to another as well as in a same article. A great amount of articles are sterile (pl. 11, fig. 16). The others show from minuscule immature (pl. 11, fig. 3 — right middle side) to well developed mature ampullae (pl. 13, fig. 1, 3). Moreover, problems arise when one wants to fix a dimensional limit with the ampullae of the closest species *Cymopolia paronai* (see below).

Table 2: Biometric parameters of some *Cymopolia* compared with *Cymopolia mayaense* from Karst region (sample BA.1511). * = values deduced from original photos; 1 = misprinted as *D* in the original paper; 2 = misprinted as *d* in the original paper; 3 = misprinted as *L* in the original paper. All size parameters are in millimeters. *L*: lenght of articles; *D*: outer diameter of the calcareous skeleton; *d*: inner diameter of the calcareous skeleton; *p*: diameter of primary branches; *w*: number of primary branches per whorl; *h*: height between whorls; *p'*: diameter of secondary branches; *da*: diameter of ampullae; *la*: lenght of ampullae; *w'*: number of secondary branches per tuft.

	Cymopolia mayaense Johnson & Kaska 1965	sample BA.1511	*Cymopolia heraki* Gušić 1967	*Cymopolia elongata* (Defrance), from Morellet & Morellet 1913	*Cymopolia elongata* (Defrance), from Génot 1978
L	1.6–2.9	3.1–4.9	(1) 1.45–4.51	1.5–12	max 8.08
D	0.8–1.4	0.50–1.4	(2) 0.49–1.752	0.75–2.5	0.5–2.8
d	0.3–0.6	0.22–0,69	(3) 0.29–0.943	0.25–1.75	0.21–1.89
p	0.023–0.030	0.021–0.049	0.02–0.08		0.030–0.061
w	14–16 (28*)	15–25	20–35		18–32
h	0.13–0.16	0.14–0.21	0.10–0.17		0.19–0.32
p'	0.016–0.032	0.014–0.042	0.02–0.095		0.016–0.030
da	0.75–0.12	0.04–0.11	0.05–0.085		0.073–0.171
la	0.12–0.16	0.04–0.15			
w'	4*	4–5.	4		3–8.

Comparisons: Deloffre & Radoičić (1978) considered *Cymopolia heraki* Gušić, a Maastrichtian species from Croatia, as junior synonym of *C. mayaense* for the two share secondary branches longer than primaries. Actually *C. heraki* shows many similarities with *C. mayaense* both in morphology and biometry (see tab. 2) but the diameters of primary and secondary branches seem in average higher in *C. heraki* than in *C. mayaense* (p = 0.02–0.08 mm versus 0.023–0.030 mm; p' = 0.02–0.095 mm versus 0.016–0.032 mm). It is possible that a more detailed comparative study could reveal more important differences to improve the definition of *C. heraki*. Anyway, this taxon is still considered valid apart from *C. mayanse* by Radoičić (1991a: pgs. 112, 120).

According to Deloffre & Génot (1982, p. 63) *C. mayaense* differs from *C. elongata* (Defrance) by a lesser number of secondary branches per tuft (4 versus 3–8) and by a stronger aspect of secondary branches if compared with the primary ones. In fact, *C. mayaense* has primary and secondary branches of similar diameter (p = 0.023–0.030 mm versus p' = 0.016– 0.032 mm) while *C. elongata* shows primary branches stouter than secondary ones (p = 0.030 –0.061 mm versus p' = 0.016–0.030 mm).

***Cymopolia paronai* Raineri, 1930**

Pl. 11, figs 7–8; Pl 12, figs 5, 7; Pl. 13 fig, 2

1989 *Cymopolia paronai* Raineri, Drobne *et al.*, pl. 1, fig. 5

In 1930 Raineri studied the algal content of some thin sections from a foraminiferal grey limestone collected at Colle di Medea. The material was given to C.F. Parona who first studied it (Parona, 1928). The material once belonged to the Institut of Geology, University of Turin, now it is housed at the Sezione di Paleontologia (Museo Regionale di Scienze Naturali, Turin), nr. PU19595.

Less than ten years ago the material was found and recognized by Dr. Franca Campanino, curator at the Museo di Paleontologia (Dipartimento di Scienze della Terra, University of Turin) and temporarily lent to the author for the study.

The diagnosis is the following (translation by Deloffre & Génot, 1982, in italics):

"I have only a good transversal section, well preserved, through a whorl. *Around a central cavity, almost circular, radiate 16 to 18 primary branches, club-shaped, becoming slightly narrow at the base* (very few of them are preserved). *Each primary branch bears a large oval sporangium with a slightly truncated base. Under the sporangium, on a primary branch, the secondary branches are inserted, probably 4, for 3 are visible in a thin section which does not give any idea of space; this number*

is certainly larger in reality. The secondary branches are a little longer than the sporangium and terminate towards the outside in a cup-shaped widening.

Measurements:

whorl diameter:	mm **1200** × 1245
inner diameter:	mm **415** × 430
thickness of the calcareous skeleton:	mm **400** × 415
lenght of primary branches:	mm 110
sporangium size: mm 250 lenght,	mm 165 diameter

I have no idea on the external shape, for the alga is enclosed in the rock and visible only in section. Therefore I cannot deduce the shape and lenght of articles nor can I know wheather the articles are annulated or the annuli, corresponding to a verticil, are fused together."

The couple of values of the first three parameters given by Raineri (1930) probably refer to measurements taken along the short and long axes of the specimen (Raineri, 1930, fig. 1). Therefore only minor values must be considered (those here written in bold types).

Radoičić (in Buser & Radoičić, 1987) emended the description of the alga on interpreting the Raineri's drawing. In particular she thinks that the primary branches are cylindrical and not club-shaped. Moreover, the pore of an ampulla appears secondarily wider for including also the ones of the surrounding secondary branches.

An examination of type material (pl. 11, fig. 7) partly confirms Radoičić's interpretations. This fact is also strenghtened by the abundant material coming from the type-locality (Colle di Medea) and the other sections. The primary branches appear roughly cylindrical but they often show a gently widening at their inner part. The holotype is represented by a slightly inclined transverse section, thus the three small ampullae cavities indicated by Radoičić (in Buser & Radoičić, 1987, p. 78) can be interpreted as the result of a cut tangential to the lower side of a verticil. However, the value of the ampulla lenght is lower than Raineri's (1930) (*la* = 0.22 mm versus 0.25 mm) but the diameter is comparable. Anyway the holotype gives the impression that the ampullae are laterally compressed. This fact seems confirmed by another transversal section, referable to *C. paronai*, found in the type material (pl., fig. 8) where strongly compressed ampullae are visible.

Further data on *Cymopolia paronai* are given by Radoičić (1991a). The author also points out the main differences with the associated *Cymopolia elongata* (here referred to as *C. mayaense*).

In the Karst area *Cymopolia poronai* is usually worse preserved than *C. mayaense* and far less frequent; a similar behaviour has been noted by Radoičić (1987, 78) in the Kras section. In spite of the available abundant material and geographically wide-spread occurrence of *Cymopolia paronai* this species still remains uncompletely known. This hampers the distinction of the two species by quatitative methods. Considering the many specimens with a morphology intermediate between the characters used to distinguish the two so-called species, we can not exclude the possibility that, in fact, we are dealing with a single, highly variable population. To solve the problem, biometrical studies on the two species will be necessary. These will have to be supported by a systematic review of the other, closely related species of *Cymopolia (C. elongata, C. mayaense* and *C. heraki)*.

Cymopolia frugifera Segonzac, 1976

Pl. 12, fig. 8; Pl. 14 fig, 1

The alga is characterized by elongated to squat articles bearing whorls of oblique, distally widened primary branches. Each primary branch gives rise to two ampullae and a number of secondary branches. The author does not indicate an indisputable number of secondary branches per tuft. The number of two, mentioned in the diagnosis, most likely refers to sectioned specimens. Génot (1987, tab. 35) draws three per primary branch.

The species differs from canonical specimens by two ampullae instead of one. Segonzac (1976) probably funded the generic attribution on the moniliform shape, of the thallus rather than on characters of reproductive organs and branches. In fact, the most closely related genus *Indopolia* Pia groups species with a cylindrical thallus and a tuft of two secondaries.

Radoičić (1991a) illustrates an alga [*Cymopolia* sp. 2M (gr. *C. frugifera* Segonzac)] that differs from *C. frugifera* by primary branches wich are not enlarged distally and which exhibit spherical ampullae oriented in a different way.

Although uncertain due to the scarse type material, the alga from the Karst area shows most characters of the Pyrenean species. It slightly differs from the latter by thinner inner parts of the primary branches and by an outer part wich is more pronounced. In the studied area it has been found in the biozonal interval SBZ1 (upper part)–SBZ3. In the French Pyrenees, according to Tambareau's (1972) data, it occurs from Thanetian to lower Ilerdian (Segonzac, 1976).

Cymopolia cf. *barberae* Elliott, 1968

pl 12, figs 3–4, 6

This species is established from a single figured specimen from Iraq (Kolosh Fm., Paleocene-Lower Eocene). Here, we tentatively refer to it a small to medium sized *Cymopolia* (D = 0.5–0.8 mm) characterized by inclined short cylindrical primary branches dividing into four secondary ones that surround a large ampulla. Sterile articles or fertile articles bearing sterile verticils (without ampullae) at their ends have been observed. The larger-sized specimens could be confused with small-sized ones

of *C. paronai*. The alga occurs from SBZ1 (upper part) to SBZ4. According to the ranges observed in the Karst series, it is the only species of *Cymopolia*, among the four, that survives the interval SBZ1 (upper part)–SBZ3 (*Cymopolia* assemblage).

Genus *Neomeris* Lamouroux, 1816

Neomeris sp.
Pl. 14, figs 2–3

This alga is represented by rare fragments characterized by a few subsequent or isolated rings of calcified ampullae, squared in axial section (pl. 14, fig. 3). The attribution of our material to this genus is doubtful because clear data are lacking on the number and arrangement of secondary branches.

The alga is recorded within the SBZ1–SBZ3 biozone interval at Colle di Medea and Duino sections.

Tribe Parkerelleae (Morellet & Morellet, 1922) Génot, 1980

Genus *Microsporangiella* Segonzac, 1979

In the Karst area a little dasyclad, usually broken in articles, has been detected in two sites (Dolenja vas, Colle di Medea). At first sight the taxon shows similarities with two species referred to as many genera: *Microsporangiella langi* Segonzac and *Jodotella sloveniaensis* Deloffre & Radoičić. The former species, found in the Thanetian of Esperaza (Aude, France) is the type-species of *Microsporangiella*, a genus characterized by the following diagnosis: "Parkerelleae présentant des groupes d'ampoules fertiles disposées latéralement aux ramifications. Ces ampoules sont groupées en touffes pédoncules convergent ensemble et simultanément vers l'extérieur du thalle. Les verticilles ont leur touffe propre et il n'y a pas de vis-à-vis des ampoules entre deux verticilles". Deloffre & Génot (1982) give the following English translation: "Parkerelleae showing groups of fertile ampullae set out laterally to branches. These ampullae are grouped in tufts on fertile branches alternating with sterile branches, and their peduncles converge simultaneously towards the exterior of the thallus. The verticils have their own tuft and there is no vis-à-vis of ampullae between two verticils."

Deloffre & Génot (1982) declare their perplexity on the genus. According to these authors the organization of the alga, as deduced by the generic diagnosis and the description of its type-species, is unclear. In particular the convergent attachment of the tuft of ampullae to the swollen distal end of the branches is not visible in the poor and insufficient material supplied by Segonzac (1979).

Actually what can be deduced by the three sections figured by Segonzac (1979, pl. 3, figs 2–3, 5) is that the alga holds a cylindrical calcareous skeleton showing eu-spondyle primary branches, maybe swollen at their distal end, set roughly perpendicularly to the central stem. Between the whorls of primaries, tufts of 4 ampullae occur. The tufts are slightly shifted towards the outer surface of the calcareous skeleton.

Moreover we also agree with Deloffre & Génot (1982) on considering necessary a supplementary study of *M. langi* on more abundant material. On the other hand, the new species here described partly fits with Segonzac (1979)'s description of *Microsporangiella* except for the presence of sterile and fertile branches. A character, this last, that anyhow is not surely deducible from Segonzac's (1979) photos.

Taking into account the necessity of a re-study of the type-species of *Microsporangiella*, that possibly may open new solutions, here the following tentative description of *Microsporangiella* is prospected: "cylindrical thallus, distally widened primary branches set in verticils. Primary branches bear laterally a number of ampullae, usually two to six, attached to the outer end of primary branches, in the vicinity of its cortical swelling."

According to the present interpretation the genus *Microsporangiella* should differ very little from *Parkerella* Morellet & Morellet and *Carpenterella* Morellet & Morellet. The main difference from both of them is set on the junction point of the ampullae (in the vicinity of the swollen part of primary branches versus the inner/middle part of the branches (primaries?). To such a character, kept alone, a generic level can be hardly attributed. On the other hand the poor calcification does not show clearly the shape and the orders of branches in *Parkerella* (probably only primary) and *Carpenterella*. The doubts on the real structure of these two genera make hazardous, at the state of knowledge, to consider *Microsporangiella* a younger synonym of *Parkerella* or *Carpenterella*. Moreover the number of ampullae per branch is very variable in the *Microsporangiella*-like species [a tuft of 4–6 in *M. langi* Segonzac, 1–2 ampullae in *M. buseri* n. sp., and two tufts, one above and one below, in *M. sloveniaensis* (Deloffre & Radoičić)]. Thus at the moment it seems more prudent to still retain the genus *Microsporangiella*.

Jodotella sloveniaensis Deloffre & Radoičić, from the Paleocene of the Soča Valley (Slovenia), shows calcified primary branches, the secondary branches are supposed not preserved, and the ampullae are attached at the distal part of the primary branch. For the supposed presence of the secondary branches the authors accordingly referred the species to the genus *Jodotella*. Actually Deloffre & Radoičić (1978: pl. 4, fig. 1) show a specimen with primary branches regularly swollen outwards. Therefore it might be hypothesized that the branches are only primary and phloiophorous and make a cortex at their distal end. For this reason it is considered better to transfer the taxon to the genus *Microsporangiella*.

Microsporangiella buseri n. sp.									
No.	**thin section**	**D ext**	**d int**	**da**	**p**	**pwc**	**li**	**h**	**w**
1	BA.1511.16	182	77						
2	BA.1511.16	231	105						
3	BA.1511.16	273	133						
4	BA.1511.16	210	126	32					
5	BA.1511.16	280	126						
6	BA.1511.16	217	91						
7	BA.1511.16	231	105		21	98	49		7
8	BA.1511.16	168	91		18		35		
9	BA.1511.16	224	119	42	18		42		
10	BA.1511.16	266	140						
11	BA.1511.16	280	133	38			49		
12	BA.1511.16	238	105						
13	BA.1511.16	280	140						
14	BA.1511.15	224	112	42	21		46		
15	BA.1511.15	266	126						
16	BA.1511.15	182	112						
17	BA.1511.15	210	98	32					
18	BA.1511.15	252	98						
19	BA.1511.15	238	112						
20	BA.1511.15	210	84						
21	BA.1511.15	238	140		28		42		
22	BA.1511.15	252	140						
23	BA.1511.15	266	133	28			42		
24	BA.1511.15	238	112	42					
25	BA.1511.15	280	147	49			42		
26	BA.1511.15	266	126		24	112	46		
27	BA.1511.15	287	140	46					
28	BA.1511.15	259	126		31		56		
29	BA.1511.15	259	112	38					
30	BA.1511.15	378	161	70	35		84		
31	BA.1511.14	252	112	35	24		52		
32	BA.1511.14	252	98						
33	BA.1511.14	231	112						
34	BA.1511.14	238	105	32					
35	BA.1511.14	294	147	46	35		70		
36	BA.1511.14	210	119		21		42		
37	BA.1511.14	224	154		14		35		6
38	BA.1511.14	294	140	56					
39	BA.1511.14	280	147						
40	BA.1511.14	196	112	28					
41	BA.1511.12	224	119						
42	BA.1511.12	252	126	42					
43	BA.1511.12	280	126	46	24		52		
44	BA.1511.11	196	105		17	98	35		7
45	BA.1511.11	224	112	42	21		35		
46	BA.1511.11	252	126	46	28				
47	BA.1511.11	294	168				42		
48	BA.1511.11	336	140	42	32				
49	BA.1511.11	238	133	38	14				
50	BA.1511.11	238	126						
51	BA.1511.11	224	91	42	14				
52	BA.1511.11	231	126	35	21		49		
53	BA.1511.11	224	119	42	28		35		
54	BA.1511.11	238	112	49					
55	BA.1511.11	238	140	28	18		42		
56	BA.1511.11	350	154	77	32		70		
57	BA.1511.11	154	98		14				
58	BA.1511.11	336	182	52					
59	BA.1511.11	280	126	42	28		49	140	
60	BA.1511.11	266	147	42					
	Min	*154*	*77*	*28*	*14*	*98*	*35*	*140*	*6*
	Max	*378*	*182*	*77*	*35*	*112*	*84*	*140*	*7*
	Number	*60*	*60*	*31*	*25*	*3*	*24*	*1*	*3*
	Average	*248.85*	*123.20*	*42.613*	*23.240*	*102.67*	*47.54*		*6.67*

***Microsporangiella buseri* n. sp.**
Figs 6–7; Tab. 3; Pl. 15, Pl. 16, figs 1–6

1992 Parkerelleae genus ? — Radoičić, Radovi Geoinstituta, 26 (1992), p. 227, pl. 7, figs 3–5.

Origin of the name: The species is dedicated to Prof. Dr. Stanko Buser, Department of Geology University of Ljubljana, Ljubljana, Slovenia.

Holotype: Specimens in axial section figured in pl. 16, fig. 3. Thin section Dv11.13 (= BA.1511.13)

Isotypes: Specimens of the sample Dv11. The sample is labelled also as BA.1511 (Barattolo collection): thin sections BA.1511.1–BA.1511.16. Other material is constituted by two samples A.7650 (thin sections A.7650.1–A.7650.4) and A.7653 (thin sections A.7653.1–A.7653.6).

Depository: The material BA.1511 is deposited at the Department of Palaeontology, University of Naples Federico II (Barattolo collection), the one labelled as Dv11 is deposited at the Ivan Rakovec Institut of Palaentology ZRC SAZU Ljubljana. The material labelled as A.7650 and A.7653 is deposited at the Department of Palaeontology, University of Naples Federico II (De Castro collection).

Type-locality: Dolenja vas W section (sample Dv11).

Type-level: Dark bioclastic limestone (wackestone-packstone to grainstone) bearing *Paronipora*.

Diagnosis: Cylindrical thallus. Only primary branches, set in moderate by spaced verticils. The primary branches are phloiophorous. The inner part of each branch is short but stout, akrophorous or slightly swelling outwards. The outer part is distinctly and abruptly flared out. Primary branches constitute a cortex at their distal ends. Cortical meshes are in the shape of vertically elongated polygons (hexhagons ?). A single to a couple of twin-set ampullae are attached laterally to the branch by mean of a peduncle. The point of attachment is placed near the inner/outer part boundary of the branch.

The calcareous skeleton is strong but often broken into articles by a thin irregular surface of discontinuity. This is placed in the middle part between two verticils. The calcification envelopes the axial stem, the reproductive organs and the primary branches up to the inner side of their cortical swelling.

The most significant biometric values are supplied in tab. 3.

General features of the calcareous skeleton: The calcareous skeleton is strong and cylindrical but broken in articles. The calcification surrounds all parts of the thallus (stem, branches and reproductive organs).

The inner surface is always smooth and regular (e.g. pl. 15, figs 2, 6, 16; pl. 16, figs 2–3). It indicates that calcification touched the main axis. The outer surface sometimes displays an irregular pattern (e.g. pl. 15, fig. 15; pl. 15, fig. 8: upper part). More often the outer surface is regularly scallopped (pl. 15, figs 2, 4, 7) in transversal section. This fact can be observed also in longitudinal section but in a less distinct way by a wider ondulation (pl. 16, figs 3–4). The scallopped pattern is related to the cortical swelling of the primary branch at its distal part.

The original elongated cylindrical calcareous skeleton is often broken into segments by thin irregular surfaces of discontinuity that occur between two whorls, so that each segment (article) contains a single verticil. In tangential section the discontinuity appears like an irregular to zigzagging dark line (pl. 15, fig. 16; pl. 16, fig. 1). In longitudinal section the dark line (pl. 16, fig. 4) appears to be broken at an almost 90° angle. If in this kind of section, the dark line set amid two articles is straight and thicker, it hardly can be discerned from a primary pore of a whorl (pl. 16, fig. 3). In other specimenes the calcareous skeleton is unsegmented but so badly preserved, especially its outer surface, that sometimes also its attribution to this taxon may be problematic.

The outer diameter of the calcareous skeleton (D) is 0.15–0.38 mm, the inner diameter (d) is 0.08–0.18 mm.

Primary branches: The branches are arranged in moderately spaced whorls (h = 0.14–0.22 mm), 6–9 per whorl and are set at 80–90° to the main axis. The available specimens supply no data on the arrangements (alternate or in continuity) of the branches between two verticils. The primary branches are phloiophorous. The inner part of a branch is short (li = 0.035–0.084 mm) but stout (p = 0.014–0.035 mm), akrophorous or slightly swelling outwards. It is circular in transversal section. Some branches show a rather thin inner part. This fact is apparently without relation to the algal size (pl. 15, figs 1, 15). The outer part distinctly and abruptly flares out. In the verticillar section of the branch, the surface of the outer part is set nearly at right angle to the inner part (e.g. pl. 15, figs 2, 7). The surface gradually bends on coming into contact with the adjacent branches. The distal size of pores in their verticillar width (pdw) is 0.10–0.12 mm. In vertical section the outer part appears wider than in the verticillar one (pl. 16, fig. 4). Rare tangential-oblique

Table 3: Main biometric parameters of *Microsporangiella buseri* n. sp. For each specimen is supplied the thin section number and the dimensional values. The range (*min.* and *max.*), the number of measurements, the average and the standard deviation for each parameter are given in italics at the bottom of the table. All size parameters are in microns. D_{ext}: outer diameter of the calcareous skeleton; d_{int}: inner diameter of the calcareous skeleton; *da*: diameter of ampullae; *p*: diameter of primary branches (akrophorous part); p_{wc}: verticillar cortical width of primary branches; *li*: lenght of primary branches at the inner part; *h*: height between whorls; *w*: number of primary branches per whorl.

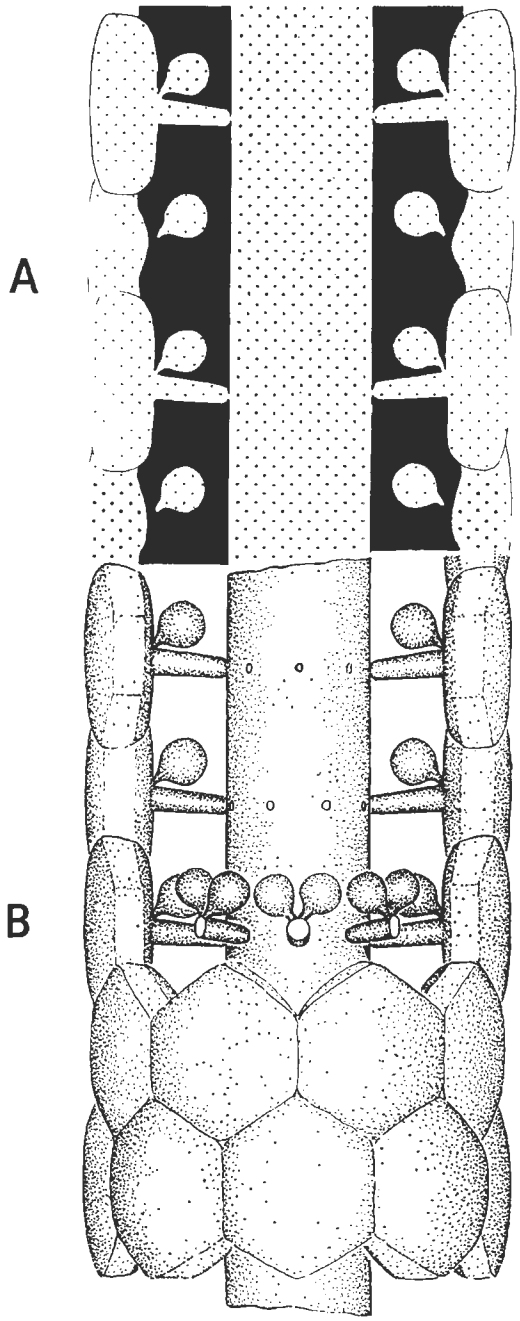


Fig. 6: Microsporangiella buseri *n. sp. Reconstruction of the thallus in longitudinal view. A: stem, primary branches, ampullae and calcification (black) in axial section. B: longitudinal view of the thallus without calcification; the central stem shows the junctions of primary branches; in the lower part a perspective view of the branches, the ampullae and the cortex is drawn. (57 ×)*

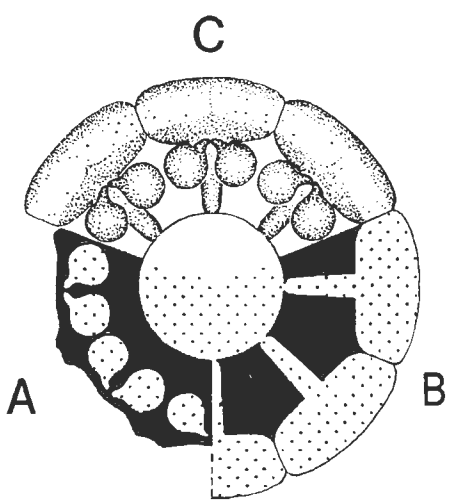


Fig. 7: Microsporangiella buseri *n. sp. Reconstruction in transversal view. A: transversal section between two whorls showing the ampullae and calcification (black). B: transversal section at whorl level showing primary branches and calcification (black). C: primary branches, ampullae and the central stem without calcification. (57 ×)*

sections confirm it, in fact vertically elongated pores can be seen. They represent transversal sections of branches at their swollen distal part. Primary branches thus constituted a cortex at their distal end in shape of vertically elongated polygons (hexagons?).

Reproductive organs: Reproductive organs are of choristosporate type and consist of ampullae set aside to the branches. Ampullae are subsphaerical to drop-like in shape, 0.028–0.077 mm in diameter (da), and are joined to the branches by a long thin peduncle. The latter is sometimes attached to the distal end of the akrophorous part of the branch (pl. 16, fig. 1). Other times it is attached to the inner end of the swollen part (pl. 16, fig. 5). The two cases can occur in a same specimen (pl. 16, fig. 3: upper and lower whorls).

Ampullae are in number of one (pl. 15, figs 5–6) or two (pl. 15, fig. 8) per branch. Single ampullae per branch usually occur in small specimens; single larger ampullae are observed in large specimens. Paired ampullae mainly occur in large specimens. The peduncles of the paired ampullae converge to a same junction point (pl. 15, figs 8–14).

All ampullae of a whorl are set on one side only, indifferently on the upper or lower side (pl. 15, figs 9, 14). In a same specimen they retain the side from one whorl to another (pl. 16, figs 3–5).

Reconstruction: Thanks to the strong calcification that reaches from the stem to the swollen part of primary branches, most elements of the thallus can be recognized. Only the outer cortical end of the branches, the top and the bottom of the thallus are not preserved. Here it is assumed that they are similar to *Neomeris* for the following similarities between the two genera: phloiophorous branches, choristosporous reproduction, cylindrical thallus.

Comparisons: The closest taxa are *Microsporangiella langi* Segonzac and *Microsporangiella sloveniaensis* (Deloffre & Radoičić) nov. comb.

From a dimensional point of view *M. buseri* n. sp. is rather close to *M. langi* (*D* is 0.15–0.38 mm versus

0.20–0.43 mm; *d* is 0.08–0.18 mm versus 0.11–0.22 mm), but its primary branches appear stronger and with a well defined swollen part (e.g. pl. 15, figs 2, 4 versus pl. 3, figs 3, 5 in Segonzac, 1979). The number of ampullae per branch and their arrangement is significantly different. There is one or a pair of ampullae per branch set on one side (upper or lower) per whorl in *M. buseri* versus a single tuft of 4–6 ampullae per branch in *M. langi*.

Several characters allow to distinguish the new taxon from *M. sloveniaensis*. It exhibits a general smaller size (*D* is 0.15–0.38 mm versus 0.4–0.64 mm; *d* is 0.08–0.18 mm versus 0.20–0.27 mm), but its whorls are more widely spaced. The ampullae of *M. buseri* n. sp. are set on a single side (lower or upper) of the verticil, instead of on both sides as in *M. sloveniaensis*. The number of branches per whorl (*w*) is remarkably lower (6–9 versus 18 or more).

Stratigraphic and palaeoecological distribution: The new species is found in the *Cymopolia* assemblage (upper part of SBZ1–SBZ3 biozones). It occurs in several microfacies contexts. Taking into account the paleoenvironmental reconstruction made by Drobne *et al.* (1988, fig. 3) the alga probably populated the shallow marine ponds and the intertidal flat. Secondarily it could occur in the restricted shallow lagoon and in bioclastic deposits.

Genus *Carpenterella* Morellet & Morellet, 1922

The genus is usually constituted by calcified hemispherical little bodies in which radially arranged pores open in a small area placed amid the truncated part. Morellet & Morellet (1922) considered the fossils representing this genus as isolated ampullae and the pores as cysts, like a *Terquemella*. The writer agrees with Génot (1980, 1987) who interprets it as a tuft of ampullae of a weakly calcified parkerellid.

At present a large part of the plant is unknown like in the allied genus *Parkerella*. In the two genera calcification is restricted to reproductive organs so that nothing, or nearly so, can be inferred about numbers and orders of branches. According to Génot (1987) *Carpenterella* differs from *Parkerella* because it shows independent tufts of numerous ampullae instead of a tuft of paired ampullae.

Carpenterella is recorded only in the Paris Basin and Brittany from Thanetian to Bartonian (Génot, 1987). The present paper establishes its first occurrence in the Danian.

Carpenterella jonesi Morellet & Morellet, 1922

Pl. 14, figs 6–15

The species is a rare algal component in the stratigraphic succession but when present it can be moderately abundant in the sediment. The general measurement of the calcified little bodies and the ampullae are closely comparable to the material from France (Morellet & Morellet, 1922; Génot, 1987). The number of ampullae is probably greater.

In the Karst material the corpuscules are sometimes grouped together. Two or three of them form a small arc (pl. 14, fig. 14). This can be interpreted as tufts of ampullae belonging to the same whorl.

In other cases, two little bodies may be joined with their hemispherical surface (pl. 14, figs 7, 10). This case can be explained as resulting from two tufts set in the space between subsequent verticils. The junction between the bodies may be marked by a thin, dark, scalloping line (pl. 14, fig. 13). These characters are well known and described from the French material by Génot (1987).

Carpenterella jonesi, the most widespread species of the genus, is recorded in the Paris Basin and Brittany from Thanetian to Bartonian (Génot, 1987). In the Karst area it occurs in Danian fenestral algal wakestones (SBZ1 upper part) of Dolenja vas and Colle di Medea.

Carpenterella sp.

Pl. 14, figs 4–5

The alga has been found only in the Colle di Medea section (upper part of SBZ1 biozone). It consists of tufts of few ampullae (5–6). Each isolated calcified little body enveloping a singe tuft is roughly polyhedral in shape. In longitudinal sections the calcareous corpuscule shows a pentagonal shape with inside two spherical ampullae, whose peduncles converge toward a corner of it. In transverse section it looks like an irregular quadrangle containing a few pores (ampullae) arranged in circle (tuft). Two calcified corpuscules can be joined side by side making a small arc (part of a whorl). The poor available material does not allow to produce further significant informations.

Family Acetabulariaceae (Endlicher) Hauck, 1885
Tribe Acetabularieae Decaisne, 1842

Genus *Orioporella* Morellet & Morellet

Orioporella malaviae Pia in Rao & Pia, 1936

Pl. 10, figs 7–8

1936 *Orioporella malaviae* n. sp. — Pia in Rao & Pia, Paleont. Indica, 21, mem. 4: 26–28, figs 32–34, 43, pl. 2, figs 4–9

1967 *Orioporella villattae* n. sp. — Segonzac, Boll. Soc. géol. France, 9, 5: 784–788, pl. 30, figs 4–7, pl. 31, figs 1, 3, 8

1980 *Orioporella villattae* Segonzac — Deloffre., Bull. Cent. Rech. Explor.-Prod. Elf-Aquitaine, 4, 2: 628, pl. 3, figs 5–6.

1980 *Miniacina multiformis* Scheibner — Deloffre, Bull. Cent. Rech. Explor.-Prod. Elf-Aquitaine, 4, 2: pl. 3, figs 4.
1985 *Orioporella villattae* Segonzac — Dieni *et al.*, Mem. Sci. Geol., 38: 22, pl. 18, figs 1–8
1989 *Orioporella villattae* Segonzac — Deloffre *et al.*, Rev. Micropal., 32 (1): 8, pl. 3, fig. 5.
1989 *Orioporella vilattae* Segonzac — Drobne *et al.*, Mem. Soc. geol. It., 40 (1987), 76, pl. 1, fig. 3
1990 *Orioporella villattae* Segonzac — Radoičić, Bull. Acad. Serbe Sci Arts, Cl. Sci mat. nat., Sci nat., 102: pl. 11, fig. 1
1991a *Orioporella malaviae* Pia in Pia & Rao — Radoičić, Geologija, 34 (1991), pp. 59–60, fig. 2a, pl. 2, pl. 3, fig. 1.
1991 *Orioporella malaviae* Pia in Pia & Rao — Deloffre *et al.*, Geobios, 24 (1991), p. 529, pl. 3, figs 7–8.
1993 *Orioporella villattae* Segonzac — Kuss & Herbig, Bull. Soc. Paleont. It., vol sp. 1, p. 270, pl. 4, figs 1–5.

The species was first described in Danian beds of the Trichinopoly district (India; Pia in Pia & Rao, 1936). In 1967 Segonzac established *O. villattae* from the Thanetian limestone from the French Pyrenees. This species is rather similar to *O. malaviae* and differs from it by a slightly smaller size and by a lower number of ampullae per disc. But the strongest difference is based on the occurrence of perforations of the calcareous wall separating the ampullae (vertical partitions), lacking in *O. villattae* (see Deloffre & Génot, 1982). Many authors (Deloffre & Génot, 1982; Dieni *et al.*, 1985; Radoičić, 1991a) stressed the close affinities between the two species. As to the perforations of the vertical partitions, Dieni *et al.* (1985), Radoičić (1991a) and Deloffre *et al.* (1991) have already debated on the significance of this character. This and further evidence on the disc shape and the number of ampullae per disc made Radoičić (1991a) and Deloffre *et al.* (1991) to propose *O. villattae* as a junior synonym of *O. malaviae*. The opinion of these authors is here accepted: *O. villattae* cannot be differentiated well enough by its morphological and biometrical characters. In addition most of the biometrical data from *O. malaviae* are deduced from very few tangential or oblique sections and probably overestimated. Deloffre *et al.* (1991) consider also *Tibetipora sinensis* Yu-Jing, a taxon from Paleocene-Lower Eocene of China, as a junior synonym of *O. malaviae.*

The species occurs in the Thanetian of the Middle East (Radoičić, 1990) from subsurface samples containing *Anatoliella ozalpiensis* Sirel. This species (sub *O. malaviae*) is recorded by Radoičić (1991a) in the Thanetian of Bosnia assembled with *Anatoliella ozalpiensis*, *Idalina sinjarica*, *Mississippina binkhorsti*.

In the French Pyrenees the species is reported in a Thanetian sequence containing *Periloculina slovenica* and *Ranikothalia sindensis* below levels with *Glomalveolina levis* (Tambareau *et al.*, 1994). The species has been also found in Danian beds of W Aquitaine from reef facies (Deloffre, 1980, see also: comparative distribution of Paleocene green algae).

In Mexico it occurs in an Upper Paleocene-Lower Eocene sequence containing *Neomurciella butterlini* Fleury & Fourcade, *Raadshoovenia* aff. *guatemalensis* Van Den Bold, *Pseudorhapydionina limbata* (Van Den Bold), *Fissoelphidium nassauensis* (Applin & Jordan) and *Storrsella haastersi* (Van Den Bold).

In Greece (Klokova section, Epyrus) Deloffre *et al.* (1991) point out the species from Lower Paleocene (maybe corresponding to the upper part of SBZ1 biozone: see comparative distribution of Paleocene green algae).

In the Karst area *O. malaviae* is found in the SBZ1 (upper part)–SBZ3 interval. The species becomes more frequent upwards. Its occurrence is occasional but constantly observed in all the studied sequences. It can be considered a characteristic component of the *Cymopolia* assemblage.

Tribe Clypeineae Elliott, 1968

Genus *Hamulusella* Elliott, 1978

The genus was erected for a species from the Paleocene of Kurdistan (*H. sadalanensis* Elliott, 1978). The alga is characterized by primary branches only, set in widly spaced whorls. The branches show a short proximal portion below the connection with the axial stem and a longer distal portion above it. Primary branches are opened outwards.

As observed by Deloffre & Génot (1982) the alga exhibits affinities with the genus *Clypeina* Michelin. Accordingly the two authors put the genus in the family Acetabulariaceae.

A distinction from *Clypeina* could be founded on the shape of the primary branches, particularly on the short proximal portion below the junction point. This character, not visible or recorded in the type-species of *Clypeina* (Génot, 1987: fig. 61; pl. 26, figs 8–10), can be consistent (generic discriminator) if interpreted as an outgrowth related to a lower coronula. Such an interpretation is not self-evident: similar morphologies have been observed in other taxa wich have no or distant relations to acetabulariaceans. I refer for example to *Selliporella donzelli* (Sartoni & Crescenti) (Barattolo *et al.*, 1992) and *Pseudoclypeina distomensis* (Barattolo & Carras, 1990).

Hamulusella can be also compared to the genus *Actinoporella* Gümbel, but differs from it because the primary branch exhibits only a lower proximal portion ("lower outgrowth") instead of two, a lower and an upper outgrowth.

In the present paper *Hamulusella,* with some reservations, is considered a valid genus by supposing the lower proximal portion to be possibly related to a lower coronula.

In the literature at least two species are known to exhibit the characters of *Hamulusella*, i.e. primary branches with only a lower proximal portion. The first, *Actinoporella durandelgai* (Fourcade & Jaffrezo), is recorded from the lowermost Cretaceous of Spain and Italy (Sardinia). The species (lectotype designed by Bassoulet *et al.* 1978, p. 27) was at first placed in the genus *Clypeina* by Fourcade & Jaffrezo (1973) and subsequently transferred to the genus *Actinoporella* by Conrad *et al.* (1975).

The second, *Clypeina liburnica* Radoičić in Buser & Radoičić, is known in Paleocene beds of the Karst area (Slovenia). The two species are here ascribed to the genus *Hamulusella* that ranges accordingly from Cretaceous to Paleocene.

Hamulusella liburnica (Radoičić in Buser & Radoičić) nov. comb.

Figs 8–9; Pl. 10, figs 2–6

1987 *Clypeina liburnica* n. sp., Radoičić in Buser & Radoičić, pp. 72–73, 77, pls. 1–2

In the Paleocene beds of the studied sequences the alga occurs in the SBZ1 (upper part)–SBZ3 interval. When present it always is a minor component of the algal assemblage, usually dominated by *Cymopolia.*

There is a good correspondance with the description of this species given by Radoičić (in Buser & Radoičić, 1987). Further details on the branches, detected thanks to the moderately rich and well preserved material as well as to some oriented sections (e.g. axial sections, oblique sections of a single verticil), can be added here.

The distinctly phloiophorous primary branches show a small thin portion below the junction point to the axial stem (lower outgrowth). This one is inclined at 150°–180° to the main axis. In oblique section the lower portion of the primary pores appear somewhat convex like in *Clypeina jurassica,* as observed by Radoičić (in Buser & Radoičić, 1987: p. 177).

The part of the branch over the junction point gradually swells outwards. Some times this branch is straight and set at 50° to the vertical axis (pl. 10, fig. 4). Some other times it is sharply curved, and a first inner part of it is set at 30° while a second orthogonal outer part (pl. 10, fig. 6) can be recognized.

A very thin calcareous wall envelopes and closes the distal end of the primary branch (pl. 10, figs 2, 4, 6). Its occurrence seems a mere matter of preservation, lacking in branches of specimens (pl. 10, fig. 6), where other branches show it.

A thin and delicate calcareous wall surrounds the main axis (pl. 4, figs 4, 6). The specimen at pl. 10, fig. 6 even

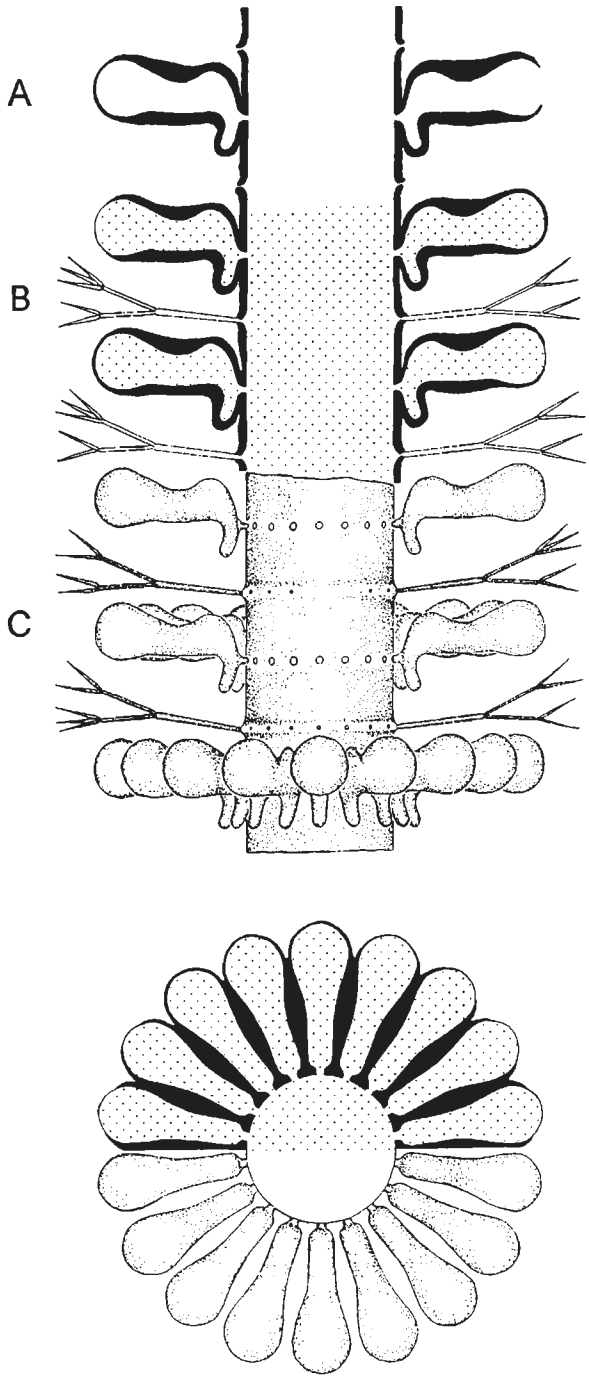


Fig. 8: Hamulusella liburnica *(Radoičić). Reconstruction of the thallus in longitudinal view. A: calcification. B: stem, fertile branches and calcification (black) in axial section, possible whorls of sterile branches are also drawn. C: longitudinal view of the thallus without calcification; the central stem shows the junctions of fertile and sterile branches; in the lower part a perspective view of fertile branches is drawn. (43 ×)*

Fig. 9: Hamulusella liburnica *(Radoičić). Reconstruction in transversal view. Up: transversal section at whorl level showing fertile branches and calcification (black). Below: half a whorl of fertile branches without calcification. (43 ×)*

shows constantly a modest swelling in between fertile whorls which corresponds at times a small pore. This fact can be most likely related to sterile whorls alternated to fertile ones as happens in the genus *Halicoryne*. A possible reconstruction of the alga is supplied in figs 8–9.

The presence of a clear and well defined lower portion below the junction point (lower outgrowth) obliges us to transfer the species from *Clypeina* to the genus *Hamulusella* Elliott.

Division Rhodophyta

In the studied series only very occasional red algae are recorded in the interval from the uppermost Maastrichtian to the Danian (up to SBZ2 biozone). Only crustose, non geniculate corallinaceans (pl. 16, fig. 7) are found whithin the SBZ1 biozone (upper part).

From SBZ3 biozone onwards the environment shows a significant increase in water-energy. This fact leads to a re-appearance of *Sporolithon* and other corallinacean genera (Drobne *et al.*, 1988, pl. 22, fig. 2), *Pseudolithothamnium album* Pfender (Drobne *et al.*, 1989, pl. 2, fig. 1) as well as the appearance of *Elianella elegans* Pfender & Basse (Drobne *et al.*, 1988, pl. 20, fig. 1) and *Pycnoporidium levantinum* Johnson (Drobne *et al.*, 1989, pl. 2, fig. 2).

In the SBZ4 biozone the appearance of *Distichoplax biserialis* (Dietrich) Pia is recorded. As to this widespread species, known from Cuba (Beckmann & Beckmann, 1966) to Borneo (Baadve & Kundal, 1988), it is said to range from Paleocene to Middle Eocene (Denizot & Massieux, 1965). In the French Pyrenees the alga first appears at the lower Thanetian (Tambareau *et al.*, 1994)

Microproblematica
Division Chlorophyta or Charophyta?

Genus *Drobnella* n. gen.

Origin of the name: The genus is dedicated to the colleague Katica Drobne, Paleontološki Inštitut Ivana Rakovca, ZRC SAZU Ljubljana, for her contributions to the knowledge of paleontology of the Karst region.

Type-species: *Drobnella slovenica* n. gen n. sp.

Diagnosis: The calcareous body is made by an empty (central cavity) cylindrical stem. Whorls of elongated pores ("main pores"), tapered at their distal ends, start from it. Except the tapered extremity of main pore wall, the calcareous sleeve is constantly pierced by irregular pores ("blind" pores), smaller than main pores, that get narrower and narrower inwards and usually close inside the calcareous wall, not reaching the central cavity.

Taxonomic attribution: At first sight, fragments of the stem and main pores can be confused with dasyclads, and blind pores misunderstood for the pores of the branches. The fact that the blind pores do not usually communicate with the central cavity as well as their irregularity excludes any veritable organic function and has to be considered a mere but highly characteristic kind of calcification.

Inferences on the algal nature are based on the inner cavity of the calcareous skeleton (stem and main pores) and pores communicating with it. Difficulty in the systematical attribution depends to the interpretation of the intercommunicating calcified framework as primary (an originally siphonate structure) or as secondary (e. g. a mould of a pluricellular organism). Thus, the same fossil organization (stem with spaced whorls of main pores) can be ascribed to different taxonomic groups. Although the character of the calcified wall of *Drobnella* is peculiar, in the first case one may take it for granted the attribution to dasycladaleans; in the second case the taxon could be referred tentatively to charophytes.

If dasyclad hypothesis should be accepted, the new genus could be put in the family Triploporellaceae (tribe Salpingoporelleae, subtribe Oligoporellinae) or Acetabulariaceae (tribe Clypeineae) for some morphological similarities (spaced whorls of trichophorous primary branches) with the Permo-Triassic genera *Oligoporella* Pia and *Physoporella* Pia, and the Meso-Cenozoic genus *Clypeina* Michelin [e. g. *Clypeina sulcata* Maslov] respectively.

If the charophyte nature of *Drobnella* would be recognized, it could be very problematic or even impossible to define a more precise position of it inside the group. In fact fossil charophytes are classified according to characters of gyrogonites, i.e. calcified oogonia (Feist & Grambast-Fessard, 1991), but no structure more or less assignable to gyrogonites has been found so far in *Drobnella*. On the other hand extant genera are classified by the characters of the plant (Wood & Imahori, 1965), most of which are not or very rarely preserved as fossil. However *Drobnella* does not exhibit any trace of a cortex along the main axis (uncorticated internodes ?), as well as no traces of structures referable to stipulodes alternated to branchlets (main pores) or reproductive organs and bract-cells along the branchlets have been observed. For these characters, although negative, *Drobnella*, according to the charophyte hypothesis, could show some morphological similarity with the extant genus *Nitellopsis* Hy, known also in the Tertiary with the subgenus *Tectochara* Grambast (Feist & Grambast-Fessard, 1991, p. 195–196). Thus, accordingly, the alga would belong to the order Charales.

Drobnella slovenica n. gen. n. sp.

Figs 10–11, Tab. 4, Pls. 7–9

1987 Dasycladacean DS1 (nov. gen. nov. sp.) — Buser & Radoičić, Geologija, 28/29 (1985/86), pl. 6, fig. 2.

Origin of the name: The species comes from the country of Slovenia.

Holotype: Specimens in longitudinal section figured in pl. 8, fig. 2; detail in pl. 9, fig. 2. Thin section Sop37.2 (= BA.1513.2).

Isotypes: Specimens of the sample Sop37. The sample is labelled also as BA.1513 (Barattolo collection): thin sections BA.1513.1–BA.1513.8.

Depository: The material BA.1513 is deposited at the Department of Palaeontology, University of Naples Federico II (Barattolo collection), the one labelled as Sop37 is deposited at the Paleontološki Inštitut Ivana Rakovca ZRC SAZU, Ljubljana.

Type-locality: Sopada section, about 7 km ENE of Sezana, Slovenia.

Type-level: Dark mud or grain-supported limestones with repeted stromatolitic, bioturbated (birds-eye) and laminated layers from the Danian, SBZ1 (Pugliese *et al.*, 1995).

Diagnosis: The fossil species is represented by a long calcareous cylindrical stem, internally empty (central cavity). From the stem spaced whorls of elongated pores (main pores), tapered and sharp pointed at their distal ends. The main pores are set orthogonal to the stem axis but they distally curve upwards like a hook. Few main pores per whorl (nine) have been esteemed. Both the stem and the whorls are built by a variously important calcareous wall. The calcareous sleeve is constantly pierced (except the tapered extremity of main pores) by irregular pores ("blind" pores) that get narrower and narrower inwards and usually close inside the calcareous wall, so that they do not reach the central cavity.

The most significant biometric values are supplied in tab. 4.

General features of the calcareous skeleton: The calcareous skeleton is represented by a continuous calcareous layer that encrusts separately the stem and the main pores. It becomes thinner at the stem-whorl junction (pl. 7, fig. 4) as well as toward the distal end of main pores. The calcareous layer is densely pierced by pores ("blind" pores) closed inward, on the contrary the tapered end of main pores are enveloped by compact lime (pl. 8, figs 8–9).

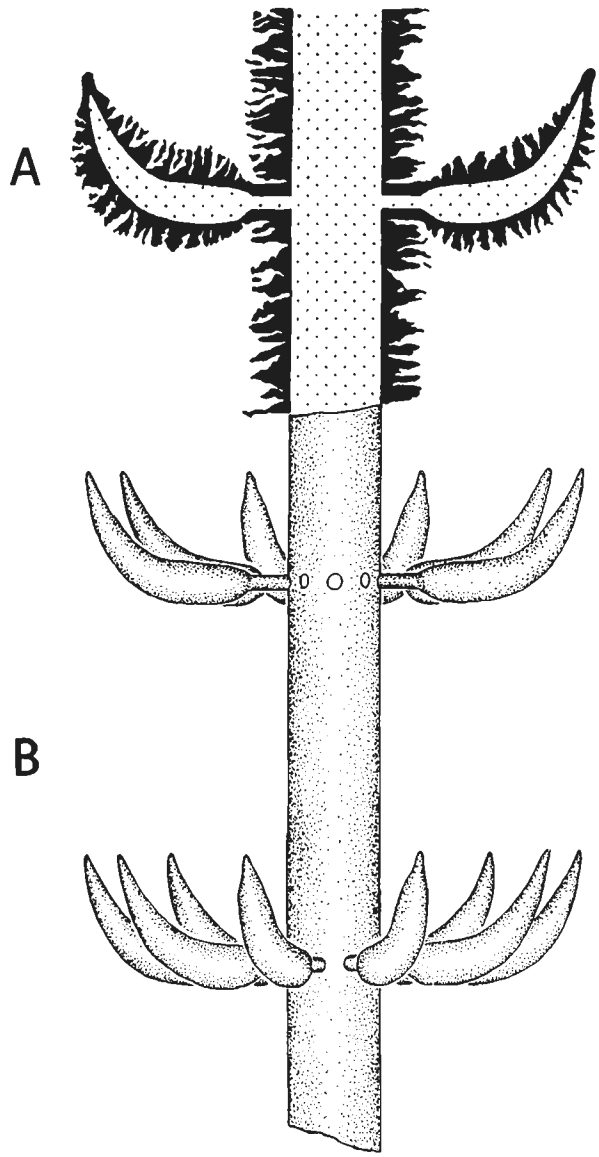


Fig. 10: Drobnella slovenica *n. gen. n. sp. Reconstruction in longitudinal view. A: stem, main pores and calcification (black) in axial section; the calcareous wall is pierced by "blind" pores (white). B: longitudinal view of the thallus without calcification; the central stem shows the junctions of main pores; in the lower part a perspective view of main pores is drawn. (30 ×)*

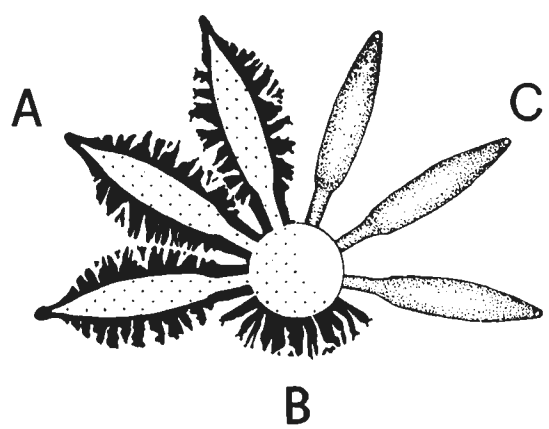


Fig. 11: Drobnella slovenica *n. gen. n. sp. Reconstruction in transversal view. A: calcification (black) across the stem. B: transversal section at whorl level showing main pores and calcification (black). C: main pores and the central stem without calcification. (30 ×)*

The inner surface of the calcareous skeleton, whatever part we consider, appears sometimes smooth sometimes rather irregular (pl. 7, figs 2, 5–7). A smooth inner surface can be explained by a more closeness of the calcareous skeleton to soft parts.

Depending on diagenesis, the calcareous skeleton (most likely sparry calcite) appears yellow (e.g. in the type material) or white. At the optical microscope its color or nature seems the same as that of the assembled dasycladaleans (mainly *Decastroporella tergestina*).

The species is usually found broken in pieces, each element representing a fragment of the stem or isolated main pores. In thin section, main pores are often indistinguishable from parts of the stem, but elements of very small size (inner diameter mainly less than 0.16 mm) and those showing one tapered end (pl. 8, figs 3–9) are most likely referable to them.

Drobnella slovenica rarely becomes an important component of the sediment. But occasionally the fragments, accompanied with very small pieces of the weakest part of the calcareous wall, may become the major fossil constituent in some lithotypes (mainly wackestone; pl. 9, fig. 3).

The width of a verticil is 1.8–2.6 mm. The inner diameter (*d*, i.e. central cavity or main pores) is 0.056–0.66 mm, the outer diameter (*D*, width of the calcareous sleeve of stem or main pores) is 0.27–1.12 mm.

Central cavity and pores: The central cavity of the calcareous skeleton is cylindrical in shape (pl. 8, figs 1–2). The main pores take origin from the central cavity at the same level (verticil) in small number (probably nine). The whorls are rather spaced. The value of distance between whorls (*h*) is found on a small number of complete specimens, it ranges from 0.37 to 2.2 mm, mainly in the interval 1.7–2.0 mm. The central cavity-main pore communication is operated by a cylindrical proximal pore (pl. 7, figs 3–4) crossing trough the calcareous wall of the stem. Here the calcareous wall is fused to that of the main pore or it is separated from it by a narrow space. Whatever the connection is, the calcareous wall always shows a reduced thickness.

The main pores are elongated, they show a slight swelling in their middle part and are tapered and sharp pointed in the distal ends (pl. 7, fig. 1; pl. 9, fig. 2). The main pore ends with a subtle needle-like pore (pl. 7, fig. 1; pl. 8, fig. 9) usually encrusted by compact lime (without blind pores). The inner part of the main pore is set perpendicularly to the stem, afterwards it gradually curves upwards. In such a way the main pore looks like a hook.

All sections surely referring to main pores do not show any trace of lateral ramifications. However rare medium-sized fragments (stem?, main pores?) may present lateral pores. For this uncertainty the presence of lateral secondary pores cannot be completely excluded.

Blind pores: All the calcareous skeleton is pierced by radial and irregular pores, opened outwards and diminishing in diameter inward; usually they close before reaching the central cavity. The pores cut transversely show a subcircular shape in their inner part and irregularly lobate to subrectangular in their outer part (pl. 8, fig. 1). The characters of pores (density, size and thickness of their calcareous wall) greatly vary from one specimen to another. The blind pores do not seem to have had a particular function in the living organism but probably represent only a particular kind of calcareous skeleton.

Table 4: Main biometric parameters of *Drobnella slovenica* n. gen. n. sp. For each specimen is supplied the thin section number and the dimensional values. The range (*min.* and *max.*), the number of measurements, the average and the standard deviation for each parameter are given in italics at the bottom of the table. All size parameters are in microns. D_{ext}: outer diameter of the calcareous skeleton (stem and branches); d_{int}: inner diameter of the calcareous skeleton (stem and branches); bp_i: inner diameter of blind pores; bp_d: distal diameter of blind pores; p_i: inner diameter of branches; *h*: height between whorls; *w*: number of branches per whorl.

Drobnella slovenica n. gen. n. sp.								
No.	**th. section**	**D ext**	**d int**	**bpi**	**bpd**	**pi**	**h**	**w**
01	BA.1513.6	1120	406	21	84			7
02	BA.1513.6	476	182	30.8	63			
03	BA.1513.6	994	280	28	70		700	
04	BA.1513.6	504	196		56			
05	BA.1513.6	1050	658	42	84	49		
06	BA.1513.6	770	280		112			
07	BA.1513.6	882	238		126			9
08	BA.1513.6	630	140		126			
09	BA.1513.6	448	112					
10	BA.1513.6	560	168	21	98			
11	BA.1513.6	532	154		49			
12	BA.1513.6	350	84	21	70			
13	BA.1513.6	602	238		84			
14	BA.1513.6	308	112		42			
15	BA.1513.6	588	140		42			
16	BA.1513.6	392	140		42			
17	BA.1513.6	280	84		35			
18	BA.1513.6	448	210	28	84			
19	BA.1513.6	616	196		70			
20	BA.1513.6	280	56		42			
21	BA.1513.6	728	294		112	56		
22	BA.1513.6	462	182	35	56			
23	BA.1513.6	714	280	28	112			
24	BA.1513.6	518	112	21	91			
25	BA.1513.6	266	70					
26	BA.1513.6	490	350	30.8	98			
27	BA.1513.6	560	280		70			
28	BA.1513.6	1120	336	28	154			
29	BA.1513.6	490	154	14	70			
30	BA.1513.6	364	147					
31	BA.1513.6	322	70		42			
	Min	*266*	*56*	*14*	*35*	*49*	*700*	*7*
	Max	*1120*	*658*	*42*	*154*	*56*	*700*	*9*
	Number	*31*	*31*	*13*	*28*	*2*	*1*	*2*
	Average	*576.26*	*204.81*	*26.815*	*78.000*	*52.500*	*700.00*	*8*
	St. Deviat.	*244.21*	*123.04*	*7.27*	*30.821*	*4.950*		

Reproductive organs: No traces of structures referable to reproductive organs have been observed anywhere in the fossil.

Reconstruction: A reliable reconstruction of soft parts of *Drobnella* is rather problematic. The elements detected on the basis of the calcified wall do not allow even a firm systematical position (see taxonomical attribution), thus only the reconstruction of the general view of *Drobnella slovenica* is proposed (figs 10–11). On the other hand the particularly good conditions of preservation have permitted to understand the verticillar organization of the alga among the generalized fragmentary state of the fossil. A fact that can be considered exceptional.

Comparisons: The character of the calcareous wall is particularly unusual. Its taxonomic weight is not enough, if kept alone, to define an algal genus, but it is at the specific level. However such a character does not seem has been recorded before in more or less similar fossil algae.

Division Cyanophyta

***Aeolisaccus barattoloi* De Castro**
Pl. 1, fig. 8

1989 *Aeolisaccus barattoloi* n. sp. — De Castro, Mem. Soc. Geol. It., 40 (1987), pgs. 111, 113, pls. 1–2

The taxon consists of cylindrical hollow tubular segments mostly less then 0.033 mm wide and differs from *Aeolisaccus kotori* Radoičić, an Upper Cretaceous species, by a smaller outer diameter and a thinner calcareous wall.

It has been recorded in Colle di Medea and Dolenja vas sections. It ranges from Maastrichtian to Danian (lower part of SBZ1 biozone) beds. The species is moderately frequent and sometimes very abundant in the Maastrichtian, becoming less and less frequent upwards.

COMPARATIVE DISTRIBUTION OF PALEOCENE GREEN ALGAE

The present chapter tries to list the main Paleocene algal sequences and compares their content with respect to the facies or environmental conditions, stratigraphical distribution and foraminiferal assemblage. The list is not complete nor exhaustive but it is an attempt to organize the data from a ponderous and varied paleontological literature, often detached from a stratigraphical, biostratigraphical and environmental framework. The analysis is limited to those better known or significant regional situations that exhibit closer relations with the studied algal flora. For an easy description the sites are grouped into facial and regional contexts.

Breccias and conglomerates

They probably are the commonest geological context where a rich and diversified Paleocene dasycladalean assemblage is recorded. The rocks, mainly of Eocene to Miocene age, are derived from destroyed marginal belt sequences of shallow-water areas (Radoičić, 1991a, p. 230). Although not exclusive and often paleoenvironmentally difficult to interpret, margin and open platform facies are well represented among the Paleocene clasts. Such sediments were widely spread in the Tethyan domain (e.g. Deloffre & Radoičić, 1978, Slovenia; Gušić, 1973, Croatia; Dieni *et al.*, 1990, Sardinia; Zuppetta *et al.*, 1984, Southern Italy; Bistricky, 1976, Slovakia; Deloffre *et al.*, 1990, Greece; personal data, Central Turkey, environs of Krikkale).

Margin and open platform facies

Examples of nearly continuous marginal sequences are rather rare. A great amount of open platform facies exhibit a predominance of red algae but where green algae are scarce or totally absent.

Dasycladaleans possibly flourishing in these environments are *Broeckella belgica* Morellet & Morellet, *Orioporella malaviae* Pia, *Sandalia multipora* Dieni, Massari & Radoičić, *Oroseina solaris* Dieni, Massari & Radoičić[1], *Cymopolia edwardsi* Morellet & Morellet, *Cymopolia frugifera* Segonzac, *Jodotella veslensis* Morellet & Morellet, *Jodotella sloveniaensis* Deloffre & Radoičić, *Triploporella apenninica* Baretti as well as most bornetellids (*Zittelina*, *Dactylopora*), uteriids (*Uteria*) and thyrsoporellids (*Thyrsoporella*, *Trinocladus*). Thyrsoporellids preferentially occupied open environment (Beckmann & Beckmann, 1966, p. 10; Elliott, 1968, p. 96), although their occurrence in more protected facies is well documented by Kuss & Herbig (1993).

France (W Aquitaine). Deloffre (1980) recorded *Broeckella belgica* Morellet & Morellet, *Orioporella villattae* Segonzac (= *O. malaviae* Pia) and bornetellids (*Digitella jacquei* Deloffre and *Dactylopora* sp.) from a reef limestone deposit, about 80 m thick, known in subsurface. The reef facies develops in the upper part of a

[1] This alga is doubtfully ascribed to udoteaceans by Dieni, Massari & Radoičić (1985). However it looks like an isolated calcified ampulla of a dasyclad alga, the single aperture being interpreted as the peduncle of the ampulla. Actually *Neomeris radiata* Morellet & Morellet 1922, from the Lutetian of the Paris Basin, shows thin radial canalicules that cross the calcareous wall of the ampullae (see Génot 1980, pl. 10, figs 5–6) like in *O. solaris*. A character similar to *N. radiata* is shown also by *Neomeris avellanensis* (Segonzac) (Deloffre & Génot 1982). On the basis of these affinities *Oroseina solaris* is referred to dasycladaceans and the attribution to the genus *Neomeris* could be a matter of discussion.

Danian sedimentary succession. On the basis of the stratigraphical data mentioned above the assemblage could be tentatively referred to SBZ1 (upper part).

Italy (Abruzzi). A few meter thick limestone sequence bearing *Triploporella apenninica* Baretti and *Broeckella belgica* Morellet & Morellet with other dasycladaceans and corallinaceans (Barattolo, 1982). The age Danian-Montian merely is deduced from the occurrence of *Broeckella belgica.*

Turkey (Antalya region). About 50 meters of a margin to open platform sequence from Maastrichtian to upper Thanetian (*Glomalveolina primaeva* zone) outcrop (personal data, under study).

(Central Anatolia). Some successions or parts of them described in the next facies (see below) show diffuse grainstone-packstones. Further sedimentological studies could refer these washed limestones to open-shelf environments.

Lagoonal and restricted platform facies.

This is a typical habitat for dasycladaleans that populate subtidal environments as well as, but less frequently, intertidal ones. The dasyclad coenoses are usually less diversified than in the previous environments. Thanks to the euryhaline habit of the group, dasyclads can be found also in brackish water, thus they can be helpful in stratigraphy when other fossil markers are absent.

Mexico (Chiapas). Deloffre *et al.* (1989) illustrate a paleoflora consisting of *Uteria mexicana* Deloffre, Fleury, Fourcade & Michaud, *Orioporella villattae* Segonzac (= *O. malaviae* Pia), *Acicularia* sp. and *Neomeris* sp.[2] The algal flora occurs in an upper Paleocene-Lower Eocene sequence containing *Neomurciella butterlini* Fleury & Fourcade, *Raadshoovenia* aff. *guatemalensis* Van Den Bold, *Pseudorhapydionina limbata* (Van Den Bold), *Fissoelphidium nassauensis* (Applin & Jordan) and *Storrsella haastersi* (Van Den Bold) (Deloffre *et al.*, 1989, p. 4).

Guatemala. Johnson & Kaska (1965) point out two dasycladaleans (*Cymopolia mayaense* Johnson & Kaska and *Acroporella occidentalis* Johnson & Kaska) probably from the upper part of El Peten Fm (Paleocene-Lower-?Middle Eocene). The formation bears in the marine limestones *Borelis floridiana, B. gunteri, Lituonella elegans, Rhapydionina limbata, Coskinolina elongata, Fabularia matleyi* and *"Pellatispirella" nassauensis* (Johnson & Kaska, 1965: p. 4).

Cuba (Oriente province). A Paleocene-Eocene sequence contains abundant red algae but green algae are common in back reef limestones (Beckmann & Beckmann, 1966). Dasyclads are represented by *Clypeina elliotti* Beckmann & Beckmann, *Cymopolia* cf. *kurdistanensis* and *Terquemella globularis* Elliott. The Paleocene-Lower Eocene interval contains *Lituonella* cf. *floridana* Cole, *Coskinolina floridana* Cole, *C.* cf. *elongata* Cole, *Dictyoconus cookei* (Moberg), *Borelis gunteri* Cole, *Rhapydionina* sp., *Amphistegina lopeztrigoi* Palmer, *Eoconuloides wellsi* Cole & Bermudez, *Boreloides cubensis* Cole & Bermudez, *Eofabiania irregularis* (Keijzer), *E. grahhami* Küpper, *Ranikothalia antillea* (Hanzawa), *R. bermudezi* (Palmer), *Discocyclina barkeri* Vaughan & Cole and *D. weaveri* Vaughan.

France (French Pyrenees). Limestone outcrops of lower Thanetian-lower Ilerdian age (referable to SBZ2–SBZ5 biozonal interval Tambareau, 1972). About twenty dasycladaleans have been recorded from this region (Segonzac, 1976, 1979), 60 % of them are recognized in other Tethyan localities. A great number of taxa occurs for a short range, probably or partly due to their spotted presence and abundance in the sediment.

In the following lines the Pyrenean taxa have been tentatively inserted in the SBZ biozonal scheme according to literature data.

SBZ2: *Cymopolia paronai, Cymopolia mayaense, Cymopolia inflataramosa, Microsporangiella langi, Dissocladella lunata, Belzungia silvestri, Trinocladus atacis, Uglasiella aurigerensis.*
SBZ2–SBZ4: *Orioporella villattae* (= *O. malaviae*), *Rostroporella oviformis.*
SBZ2–SBZ5: *Cymopolia frugifera.*
SBZ3: *Acicularia valeti, Acroporella occidentalis, Belzungia terquemi, Clypeina elliotti, Cymopolia morelletorum, Jodotella volpensis, Neomeris avellanensis.*
SBZ3–SBZ4: *Sarosiella feraemollis.*
SBZ3–SBZ5: *Acroporella anceps.*
SBZ5: *Ovulites maillolensis* (halimedaceans).

France–Belgium (Paris and Mons basins). The algae are known since the beginning of this century by Leon and Jean Morellet's classic works. A monograph by Génot (1987) and Génot (1993) supply complete and updated informations on them.

Nine Danian-Montian and eleven Thanetian species have been recorded. Apart from uncertain occurrences, only one species (*Montiella macropora* Morellet & Morellet) covers the Danian-Thanetian interval. 80 % of dasycladaleans are endemic. Only *Broeckella belgica* (Montian), *Carpenterella jonesi* and *Jodotella veslensis* (Thanetian), and maybe also *Cymopolia elongata* and *Parkerella montensis* are recorded elsewhere in coeval terrains.

The short ranges of the Paris basin algae contrast

[2] Although re-crystallized the taxon figured by Deloffre et al. (1989, pl. 3 fig. 6–7) could belong to *Cymopolia mayaense.*

with the longer ranges of algae from the Thetyan realm. This fact, together with the high degree of endemism leads to the hypotesis that Paleocene algae successively colonized the Paris and Mons basins. Their periodical radiation interrupted by mass extiction due to regressive events.

Slovenia. Buser & Radoičić (1987) illustrate a section near Slivje where 60 m of Kozina Limestone (lower Paleocene) and 53 m of Miliolid Limestone (middle Paleocene) crop out. Algae occur in the latter formation. The earliest assemblage consists of *Clypeina* nov. sp. (= *Decastroporella tergestina* n. gen. n. sp.), DS-1 (= *Drobnella slovenica* n. gen. n. sp.) and DS-2. *Cymopolia elongata* (= *C. mayaense*) and *C. paronai* appear less than ten meters higher.

Bosnia. Radoičić (1992) describes the Kamenjak section consisting mainly of Maastrichtian-Paleogene terrigenous sediments locally alternating with Thanetian reworked limestones (wackestone to grainstone). The algal limestones bear the following foraminifers: *Anatoliella ozalpiensis* Sirel, *Idalina sinjarica* Grimsdale, *Mississippina binkhorsti* (Reuss) and *Rotalia provalis* (Terquem).

Greece. Two Maastrichtian-Thanetian sections (Klokova and Skolis sections), belonging to the Gavrovo-Tripolitza carbonate platform, have been described by Deloffre *et al.* (1991). Klokova section, the thickest, exhibits Maastrichtian mudstones and dolstones (130 m) containing *Rhapydionina liburnica* and *Laffitteina mengaudi*. The last 15 m bear no significant microfossils. Thirty meters of similar facies as before (probably referring to SBZ1) show charophytes and *Microcodium*, and dasycladaleans somewhat higher. The dasyclads are *Indopolia satyavanti*, *Jodotella sloveniaensis*, *Oriporella malaviae*, *Cymopolia* cf. *elongata*, *Clypeina elliotti*, *Triploporella* cf. *apenninica* and *Terquemella* sp. 60 m of packstones (probably referable to SBZ3) containing at the base *Ranikothalia*, in the middle part *Miscellanea* and in the higher part *Ranikothalia sindensis*, *Discocyclina seunesi*, *Glomalveolina primaeva* and *Fallotella alavensis*. According to Deloffre *et al.* 1991 the Paleocene flourishing is related to the diastrophic events that involved the Gavrovo-Tripolitza area.

Morocco (Atlas). *Acicularia* sp., *Cymopolia elongata* and *Neomeris* sp., co-occurring with halimedaceans (*Halimeda nana*, *Halimeda* sp. and *Ovulites arabica*) have been recorded (Kuss & Herbig, 1993) in Thanetian beds from tidal flat to open lagoon environments.

Egypt (NE). A rich microflora (18 dasycladaleans and halimedaceans species) is documented by Kuss & Herbig (1993) from the Thanetian (*Alveolina levis* zone = SBZ4). Seven taxa pass the Paleocene/Eocene boundary; two taxa appear in the Eocene. The main Thanetian green algae recorded are *Clypeina merienda*, *Clypeina occidentalis*, *Orioporella villattae* (= *O. malaviae*), *Belzungia silvestri*, *Cymopolia elongata*, *Dissocladella deserta*, *Furcoporella diplopora*, *Neomeris plagnenesis*, N. cf. *tyrrhenica*, *Thyrsoporella longa*, *Halimeda nana*, *Ovulites arabica* and *O. morelleti*. A detailed paleoenvironmental distribution of the algae is also given by the two authors.

Turkey[3]. Sivas area: Gölköy section was examined. It probably belongs to the homonymous formation (Danian-lower Thanetian) composed of limestone, clayey and tuffaceous limestone, tuffite and sandstone alternations (Terlemez *et al.*, 1980). It passes laterally and upwards to the Igdir Fm. (Inan *et al.*, 1992). *Cymopolia* spp., *Halimeda* spp., *Oroseina solaris*, *Orioporella malaviae*, *Broeckella belgica*, *Jodotella veslensis*, *Thyrsoporella* cf. *longa*, ?*Sarosiella feraemollis*, *Russoella* sp. and *Terquemella* sp. can be reported among the green algae. The red algae are represented by *Pseudolithotamniun album*, *Sporolithon* sp. and other corallinaceans.

Haymana-Polatli zone: the algal content of three sections (Bahçecik, Çaldag and Erif I) have been screened.

Bahçecik section (Sirel *et al.*, 1986, p. 390, fig. 4b; Sirel, 1992). The lower part (Danian) is referred to Çaldag Fm.–Kartal Fm. interfingering and shows few algae (sample B.9: *Sarosiella feraemollis* and *Neomeris* sp). The upper part (Thanetian) is referred to the Çaldag Fm. and rich in algae. Presently no clear stratigraphic differentiation can be noticed in the algal composition. *Terquemella*, *Halimeda*, *Ovulites*, *Neomeris* and *Cymopolia* are the best represented taxa. Frequent thalli of *Pseudolithothamnium album*, *Elianella elegans* and corallinaceans (usually *Sporolithon*) are also observed. *Trinocladus* sp., *Thyrsoporella* sp., *Oroseina solaris*, *Orioporella malaviae*, *Jodotella veslensis*, *Acroporella* cf. *anceps*, and *Uteria* sp. are occasionally found. Of particular interest is the occurrence of *Uglasiella aurigerensis* Segonzac (sample S.10), but this needs a further confirmation.

Çaldag section (Sirel et al, 1986, p. 388, fig. 3a; Sirel, 1992). The lower part consists of upper Maastrichtian Beyobasi Fm. beds containing red algae (*Sporolithon* and *Pseudolithothamnium album*) and encrusting acervulinids (*Solenomeris*). The middle and upper parts consist of Çaldag Fm. limestones of Danian-Thanetian. Their microflora looks like that of the Bahçecik section. In addition the occurrence of *Broeckella belgica* (sample C.I.17) has to be pointed out.

[3] The data from Turkey are the result of personal observations on Sirel's material achieved during my visit in Ankara on september – october 1992 for attending the Third Meeting of IGCP Project n. 286 — Early Paleogene Benthos (8–13 october 1992). I would like to express my sincerest thanks to dr. Ercüment Sirel for having permitted a preliminary study on algae of the sections here indicated. My gratitude goes also to Dr. Sirel and collaborators of MTA of Ankara for the courtesy and disponibility shown.

Erif I section (Sirel, 1992). The sequence is lithologically similar to the Çaldag section. Green algae are represented by *Terquemella* spp., *Halimeda* spp., *Cymopolia* sp. and *Oroseina solaris*. Red algae consist of *Pseudolithothamnium album*.

Iraq. Fourtheen species [*Broeckella belgica*, *Clypeina merienda*, *Cymopolia kurdistanensis* (= *Cymopolia elongata*), *C. barberae*, *Dissocladella deserta*, *D. savitriae*, *Furcoporella diplopora*, *Ovulites maillolensis*, *Indopolia satyavanti*, *Pagodaporella wetzeli*, *Terquemella bellovacensis*, *T. globularis*, *Thyrsoporella silvestri*, *Trinocladus perplexus*] have been found by Elliott (1968) from the Kurdistan and other localities of the Middle East. The algae come from the Kolosh Fm. and the Sinjar Fm. aged Paleocene-Lower Eocene (Elliott, 1968: p. 96–97). According to Elliott (1968, p. 88) the algae show no consistent stratigraphical differentiation throughout. According to Van Bellen (1959) the Kolosh Fm. is composed of: **a**. 144 m of limestones and marls with *Miscellanea miscella*. **b**. 30 m of limestones with *Dictyokathina simplex*. **c**. 113 m of limestones similar to **b** but without *D. simplex*. **d**. 6 m of limestones with *Saudia labyrinthica*. **e**. ≅ 470 m of blue shales and green sands with small forams (among them *Globigerina bulloides*, *Globorotalia angulata*). The Sinjar limestone formation (Van Bellen, 1959, p. 279) consists of 176 m of yellowish limestone bearing *Alveolina globosa*, *A. primaeva*, *Dictyoconus arabicus*, *Dictyokathina simplex*, *Idalina sinjarica*, *Miscellanea miscella*, *Nummulites atacicus*, *Opertorbitolites* sp., *Saudia labyrinthica*, *Taberina daviesi*.

Radoičić (1990) studied the algal content of two boreholes from the Western Iraqi Desert. The most significant algae are *Clypeina haglani*, *C. occidentalis*, *C. socaensis*, *Cymopolia* cf. *heraki*, *Orioporella villattae* (= *O. malaviae*), *Terquemella macrocarpus*, *Thyrsoporella longa*, *T. turgidipora*, *Uteria merienda*, *Halimeda praemonilis* and *Ovulites morelleti*. The algal sediments are referred to the Thanetian for the presence of *Anatoliella ozalpiensis* Sirel.

Iran (Nakhlak and Yazd regions). Deloffre *et al.* (1979) illustrate a Paleocene algal flora mainly consisting of *Acroporella* cf. *anceps*, *Cymopolia heraki*, *Neomeris plagnenesis* and *Halimeda praemonilis*. The sediments bearing the algae are usually represented by marly limestones with *Miscellanea miscella* and *Kathina*.

India (South India, Trichinopoly district). It is a classical algal locality essentially known by the paper of Rama Rao & Pia (1936). In this paper the first author described the Niniyur group (= Niniyur beds) stratigraphy where a rich flora (red algae and dasycladaleans) was found. The best exposed outcrop is located near Sendurai village. Over greenish-yellow and white, unfossiliferous sands and clays referable to the underlying Ariyalur formation follows an argillaceous gritty limestone (indicated as A. G. limestone) crowded with fossils. Upwards the rock passes into a white compact, sub-crystalline, higly fossiliferous limestone (= Lucina Limestone). This interval can be laterally silicified (flints and cherts). A lower unit (= algal limestone), more or less conglomeratic, can be recognized. The upper unit is characterized by a fine-grained, compact limestone crowded with fossils (corals, bryozoans, bivalves). Noteworty is the occurrence of *Nautilus danicus* (= *Hercoglossa danica*) in the Lucina Limestone that would indicate a Danian age.

Niniyur beds of the Trichinopoly area correspond to the *Nerinea* beds of the Pondicherry area (Krishnan & Jacob, 1959). The Algal Limestone of the Pondicherry Formation, underlying the Discocyclinid Limestone, where *Discocyclina ramaraoi* Samanta occurs (Samanta, 1967), is referred to Landenian p.p. (Rajagopalan, 1964).

Most significant dasyclad taxa studied by Pia (in Rao & Pia, 1936) are *Dissocladella savitriae*, *Indopolia satyavanti*, *Acicularia dyumatsenae* and *Orioporella malaviae*. The greatest amount of them comes from a silicified algal limestone (lower unit of Lucina Limestone) cropping out near Nattagooly village, about 4 km NE of Niniyur. The Nattagooly outcrop, whose thickness is not indicated, is 200 m long and 10 m wide.

ALGAL ASSEMBLAGES AND BIOEVENTS THROUGH THE MAASTRICHTIAN-THANETIAN IN THE KARST AREA

According to the stratigraphical evidence in the Karst area (Dolenja vas W and E, Sopada, Duino and Colle di Medea sections) it is possible to recognize different algal assemblages. Some floristic changes are probably linked to variations in the water energy. Such an ecological factor can be invoked, for example, to explain the rather sharp change from the ***Cymopolia assemblage*** to the ***corallinacean assemblage*** (Dolenja vas W section).

Below this boundary the sequence shows an environmental homogeneity in respect to the algal content. This means that environmental modifications as emersion episodes, more or less restricted circulation, variation in salinity, did not influence significantly the algal composition. On the other hand the Sopada section exhibits more homogeneous environmental conditions over its whole extension so that it could give more founded indications about the floral (dasycladacean) change in the middle-upper parts of the Paleocene (SBZ3–SBZ4). The Colle di Medea and Duino sections show a moderate increase in water energy in the SBZ3 biozone, otherwise suitable for dasycladaleans.

At the present level of knowledge it is difficult to judge how far the data from the Karst area can be generalized. However they may constitute a first step to un-

derstand the wide-spread changes observed in this period of Earth history. In the Karst area during the Maastrichtian-Thanetian interval, two general traits are recognized:

a) a marked increase in algal diversity (both at generic and specific level)

b) the absence of a sharp K/T boundary floral change, since some surviving species are recorded.

The lowest assemblage (corresponding to the *Acroporella chiapasis interval* of Pugliese *et al.* 1995) is always oligotypic. Very small, thin walled tubes usually occur; they can be probably referred to calcified stem parts of charophytes. Rare thalli of *Thaumathoporella* as well as filaments of *Aeolisaccus barattoloi* De Castro can also be observed. An infrequent but characteristic dasyclad is *Acroporella chiapasis* Deloffre, Fourcade & Michaud. Other dasyclads occasionally reported in this interval of the Karst area are *Acicularia* sp. and *Clypeina* (?) sp. nov. Probably limited to the lower part of this assemblage is *Suppiluliumaella* sp. Inside this assemblage two new taxa appear (*Decastroporella tergestina* n. gen. n. sp. and *Drobnella slovenica* n. gen. n. sp.). Their appearance seems to be located very close to the K/T boundary.

The end of this assemblage is marked by an "explosion" of new species, most of them recorded in Paleocene and younger deposits.

The middle assemblage (corresponding to the *Cymopolia interval* of Pugliese *et al.* 1995) is particularly diversified and widely occurs in the whole Karst area with similar characters as well as with some changes in several areas of the Tethyan realm (e.g. French Pyrenees). The algal assemblage is dominated by *Cymopolia* (*Cymopolia paronai* Raineri, *Cymopolia mayaense* Johnson & Kaska, *Cymopolia frugifera* Segonzac, *Cymopolia* cf. *barberae* Elliott).

Other dasycladaleans appearing in this interval are *Microsporangiella buseri* n. sp., *Jodotella veslensis* Morellet & Morellet, *Carpenterella jonesi* Morellet & Morellet, *Carpenterella* sp., *Orioporella malaviae Pia in Rao & Pia* and *Hamulusella liburnica* (Radoičić).

Other algae as *Broeckella belgica* Morellet & Morellet, *Uteria merienda* (Elliott), *Pycnoporidium levantinum* Johnson, *Pseudolithothamnium album* Pfender, *Sandalia multipora* Dieni, Massari & Radoičić, *Neomeris* sp., *Parkerella* sp., *Terquemella* sp., *Pseudocymopolia* sp. and *Zittelina* sp. occasionally can be observed. Particularly remarkable is the persistence of *Decastroporella tergestina* n. gen. n. sp. and *Drobnella slovenica* n. gen. n. sp. in this assemblage.

In the Dolenja vas W section, the middle assemblage is substituted upwards with one consisting mainly of red algae (usually corallinaceans but also solenoporaceans and squamariaceans: *Corallinacean interval* in Pugliese *et al.* 1995), both in massive thalli (*Elianella elegans* Pfender & Basse, *Pycnoporidium levantinum* Johnson) and in crustose to subramose thalli (*Pseudolithothamnium album* Pfender, *Sporolithon* sp. and other non-geniculate corallinacean genera); even geniculate corallinaceans are recorded in this assemblage.

The youngest algal assemblage (= *Thyrsoporella longa interval* in Pugliese *et al.* 1995) is present in the Sopada section. It consists mainly of *Cymopolia* cf. *barberae* Elliott continuing from the previous assemblage (*Cymopolia interval*), *Distichoplax biserialis* Dietrich and the index taxon *Thyrsoporella longa* Radoičić. It is not excluded that also this assemblage, like the Corallinacean interval, is the result of ecological factors. In fact *D. biserialis* and *T. longa* are probably recorded elsewhere in older deposits.

CONCLUSION

An analysis of the algae in their stratigraphical context allows to indicate the vertical distribution of the algae from upper Maastrichtian to Paleocene.

As regards the dasycladaleans at the upper Maastrichtian-lower Danian interval, their range can be observed only in very few sites (e. g. Karst area, Greece, Turkey), according to which the restricted facies shows a fundamental poverty in the algal content if compared to similar, younger Paleocene facies. Evidence of a moderately rich and diversified Maastrichtian microflora are recorded in open shelf/margin facies (e. g. Parente, 1994).

Most of the widespread algal communities of the Paleocene can be ascribed to an upper Danian or Selandian-Thanetian interval. Most of the dasycladaleans are distributed throughout this interval. Shorter ranges of some endemic species are supposed to be induced by regressive/transgressive episodes in locally circumscribed basins (e. g. Paris basin). Widespread and long ranging species may show locally a shorter range by ecological changes or biased by their occasional occurrence in the sediment.

Mainly on the basis of the data from the Karst area, a tentative correlation of the dasyclad ranges with the SB zonation is proposed as follows:

— **Upper Maastrichtian**: presence of *Acroporella chiapasis* Deloffre, Fourcade & Michaud before the appearence of *Decastroporella tergestina* n. gen. n. sp. and *Drobnella slovenica* n. gen. n. sp

— **SB1 The lowest part of SBZ1**: presence of *Decastroporella tergestina* n. gen. n. sp., *Drobnella slovenica* n. gen. n. sp and *Acroporella chiapasis* Deloffre, Fourcade & Michaud before the appearance of the *Cymopolia* assemblage

— **SB1 The upper part of SBZ1 up to SBZ3**: presence of the *Cymopolia* assemblage.

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PLATE 1

Figs 1–6: *Acroporella chiapasis* Deloffre, Fourcade & Michaud, oblique sections, × 60, Dolenja vas E section.

Figs 1–3, 6: Uppermost Maastrichtian.

Figs 4–5: Danian (lower part of SBZ1).

1. (BA.1509.1 = Dv43.1),

2. (BA.1509.1 = Dv43.1),

3. (BA.1509.2 = Dv43.2),

4. (Dv45a–9097),

5. (Dv45a–9101),

6. (Dv43/4–5065).

Fig. 7: *Suppiluliumaella* sp., oblique section, (Sop70–11203), × 60, Sopada section, uppermost Maastrichtian.

Fig. 8: *Aeolisaccus barattoloi* De Castro, microfacies, (A.6974.1), × 100, Colle di Medea section, Maastrichtian.

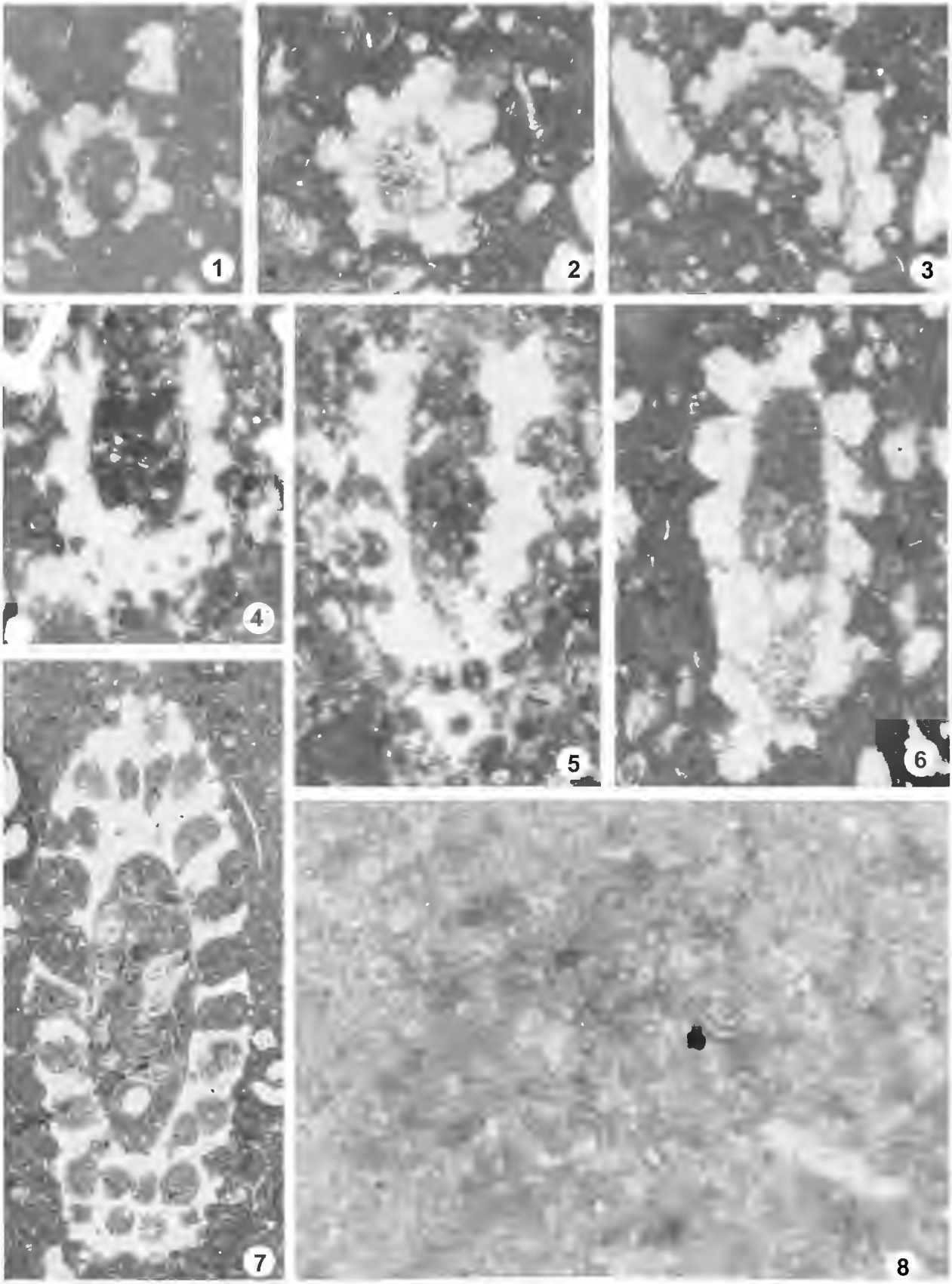
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PLATE 2

Figs 1–18: *Decastroporella tergestina* n. gen. n. sp., isotypes, Duino section, Danian (lower part of SBZ1 biozone). **1–17.** × 60, **18.** × 96.
1. (A.6937.2),
2. (A.6937.7),
3. (A.6937.1),
4. (A.6935.14),
5. (A.6935.2),
6. (A.6935.9),
7. (A.6937.9),
8. (A.6935.1),
9. (A.6937.2),
10. (A.6937.12),
11. (A.6937.4),
12. (A.6937.9),
13. (A.6937.6),
14. (A.6937.6),
15. (A.6937.9),
16. (A.6937.6),
17. (A.6935.13),
18. (A.6935.9).

Figs 1–4: Transversal sections cutting the part of the article bearing subtile branches.

Figs 5–10: Transversal to slightly oblique sections cutting the whorl of massive branches.

Figs 11–13: Oblique sections from the part of the article bearing subtile branches.

Figs 14–17: Oblique sections cutting the lower end of the article.

Fig. 18: Tangential section of an article showing phloiophorous subtile branches making a sort of cortex.

Figs 4, 12, 15: Their calcareous skeleton is marked by a faint, concentric dark line, while in **2, 14.** the line is substituted by a narrow empty space.

Fig. 17: Contrary to what usually happens (see **18**), subtile pores seem to be slightly trichophorous.


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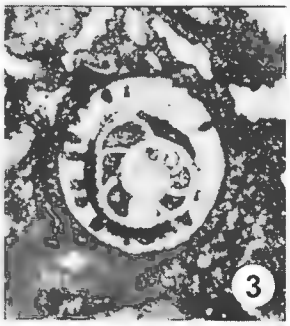
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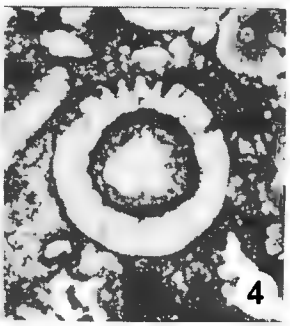
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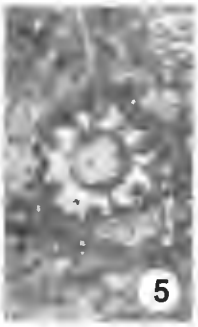
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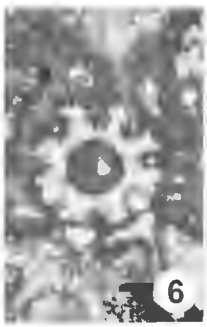
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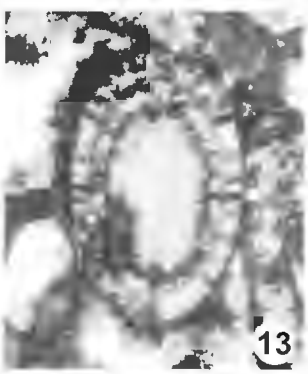
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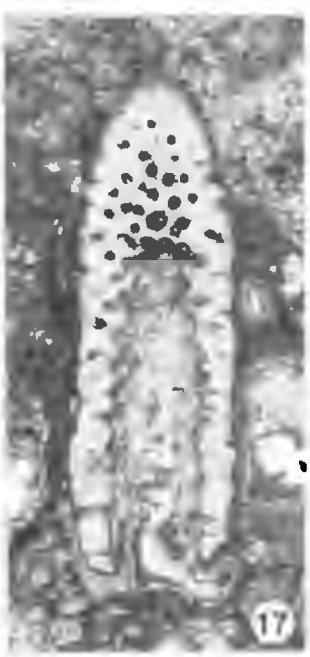
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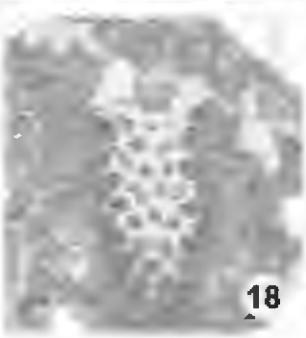
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PLATE 3

Figs 1–12: *Decastroporella tergestina* n. gen. n. sp., isotypes, Duino section, Danian (lower part of SBZ1 biozone), × 60.
1. (A.6935.9),
2. (A.6935.6),
3. (A.6935.14),
4. (A.6935.6),
5. (A.6935.9),
6. (A.6937.6),
7. (A.6937.7),
8. (A.6937.2),
9. (A.6937.6),
10. (A.6937.2),
11. (A.6937.1),
12. (A.6935.13).

Figs 1–4: Oblique sections of articles showing one or two whorls of elongated massive branches.

Figs 5–7: Oblique sections cutting articles with whorls of short massive branches (calcified in their inner end).

Figs 8–12: Tangential sections of articles that show the part bearing subtile branches and the whorl of massive branches at the top.

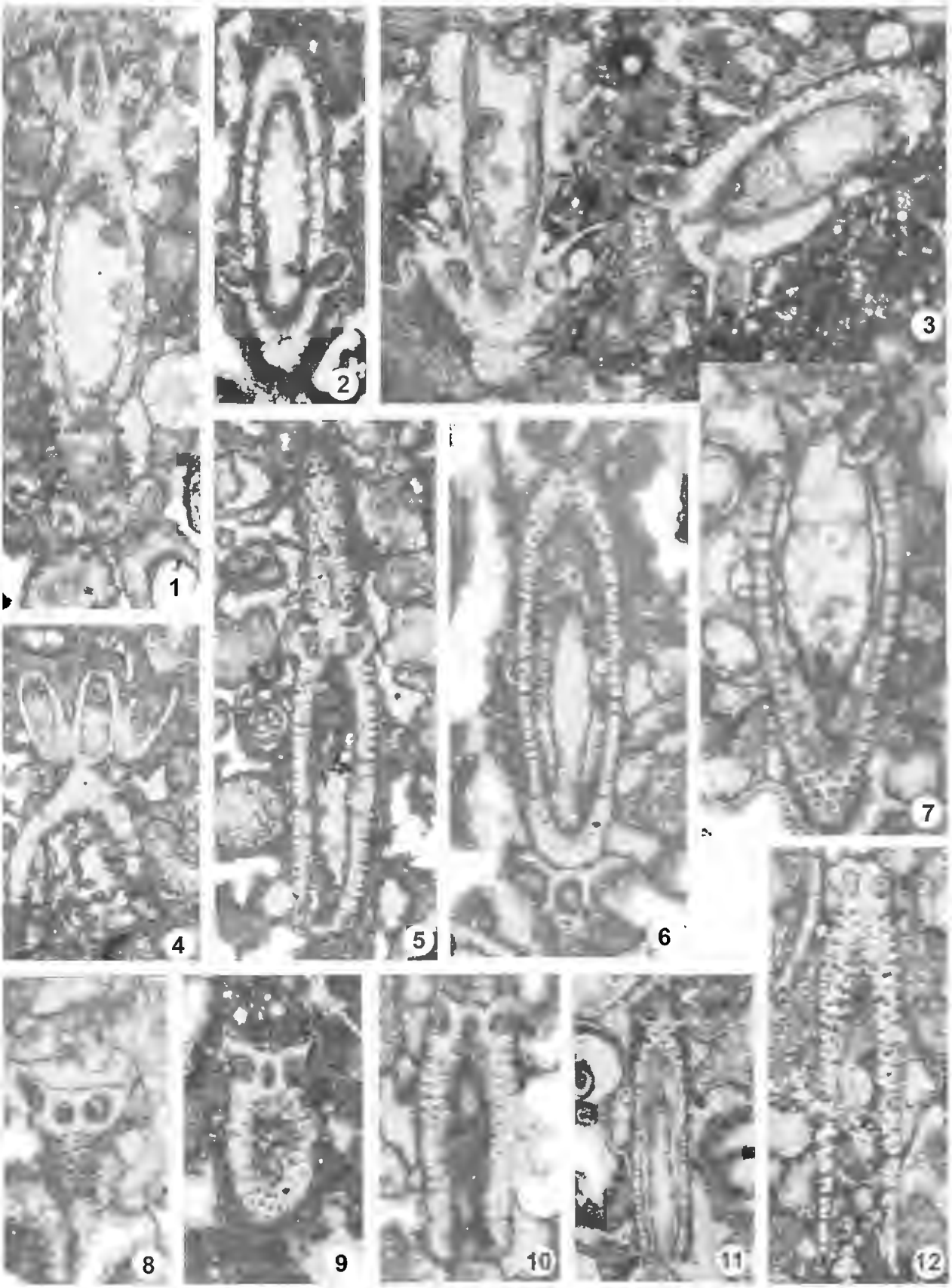
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PLATE 4

Figs 1–9: *Decastroporella tergestina* n. gen. n. sp., isotypes, Duino section, Danian (lower part of SBZ1 biozone), × 60.
1. (A.6935.7),
2. (A.6935.4),
3. (A.6937.8),
4. (A.6937.1),
5. (A.6937.8),
6. (A.6935.9),
7. (A.6937.9),
8. (A.6937.9),
9. (A.6935.13).

Figs 1–9: Longitudinal to axial sections of articles (stalked part of the thallus). Notice the extreme variation in lenght of the articles.

Fig. 3, 5: The specimens show the irregular inner part of the calcareous skeleton.

Fig. 4: Two articles in longitudinal section lacking (not preserved) subtile branches.

Fig. 9: Fragments of two articles in longitudinal section showing a well preserved elongated massive branch.

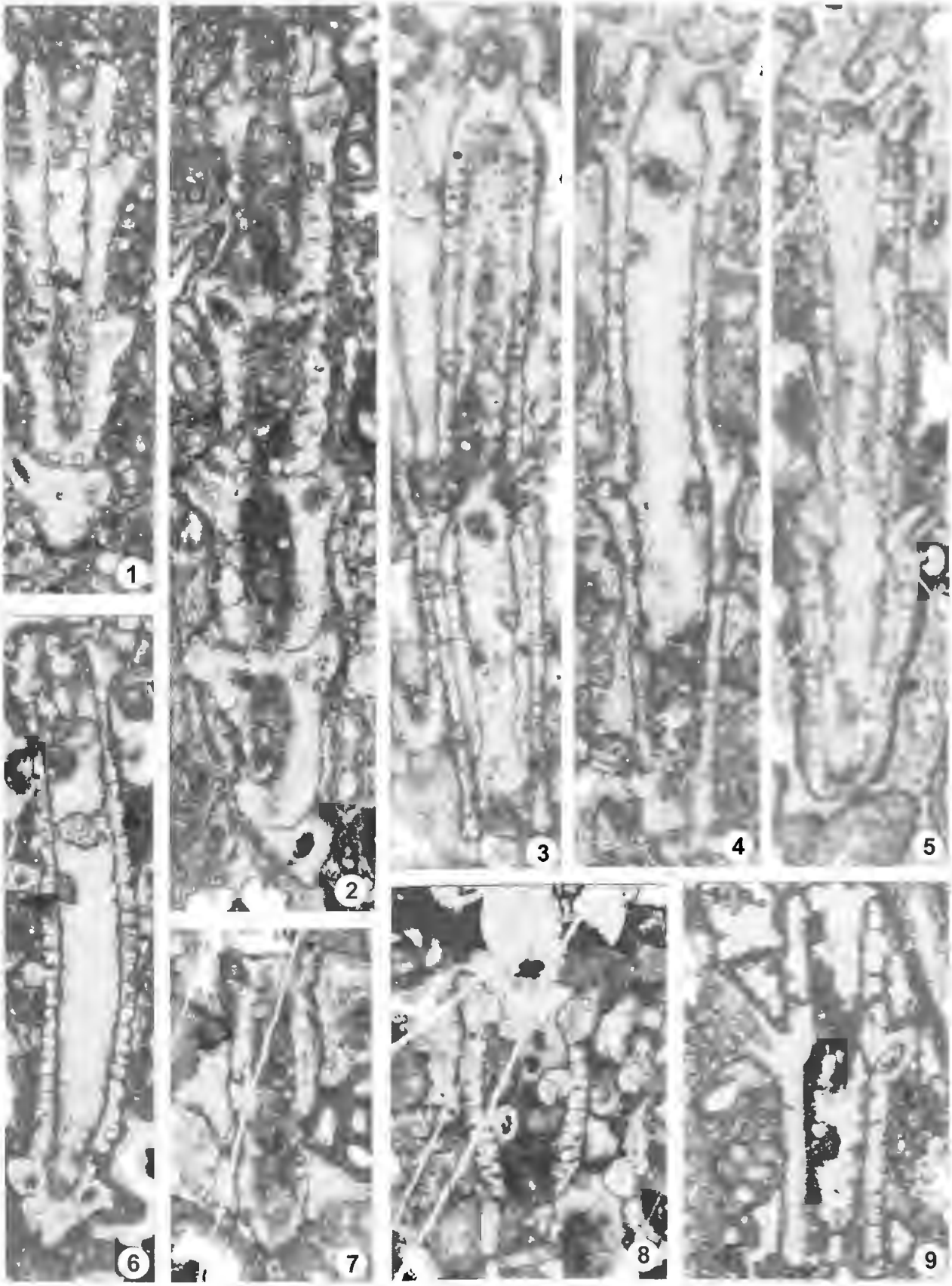
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PLATE 5

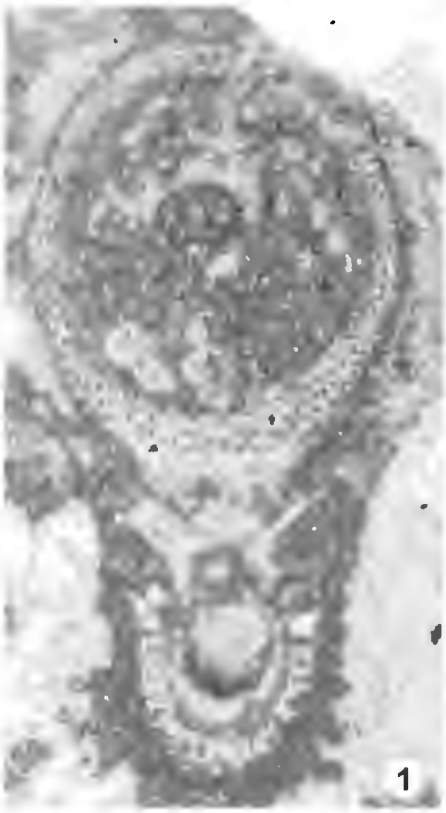
Figs 1–4: *Decastroporella tergestina* n. gen. n. sp., Duino section, Danian (lower part of SBZ1 biozone), × 60. **1–2, 4.** isotypes, **3.** holotype.
1. (A.6937.7),
2. (A.6935.1),
3. (A.6935.2),
4. (A.6935.1).

Figs 1, 3: Oblique and axial sections respectively cutting both the stalked part and the head of the thallus.

Figs 2, 4: Oblique and transversal section respectively accross the head of the thallus.

Fig. 2: Notice the thickening of the calcareous skeleton showing longer thin pores as well in the lower part of the figure. This fact can be explained with a cut in the vicinity of the junction between the stalk and the head (see **3**).

Fig. 3: Detail of pl. 6, fig. 5 showing the junction between the stalk and the head. Notice how the calcareous skeleton of the head is thicker and the pores are longer near the junction.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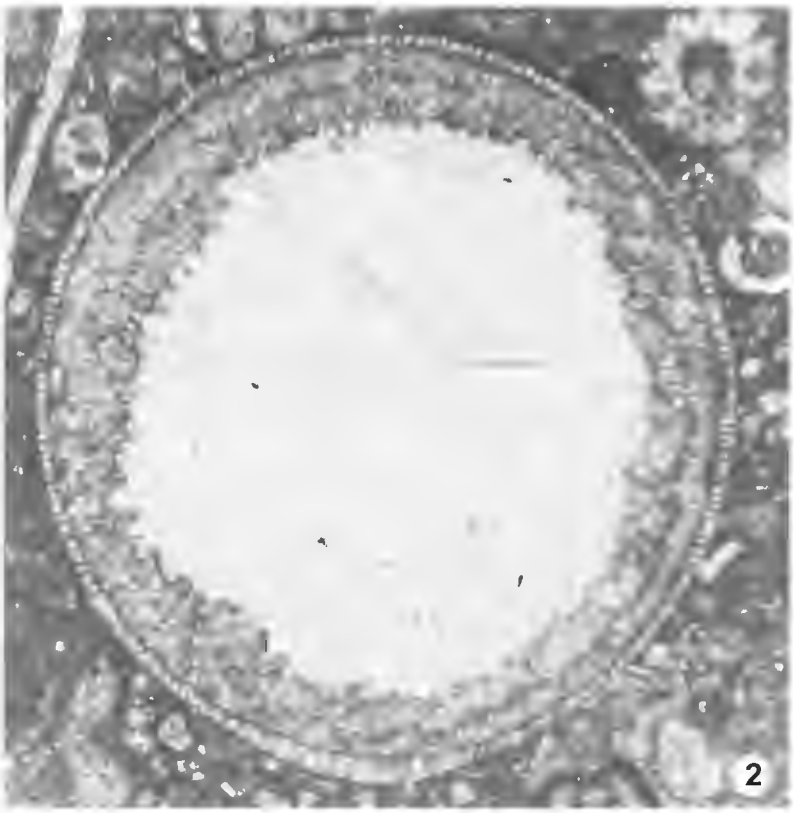
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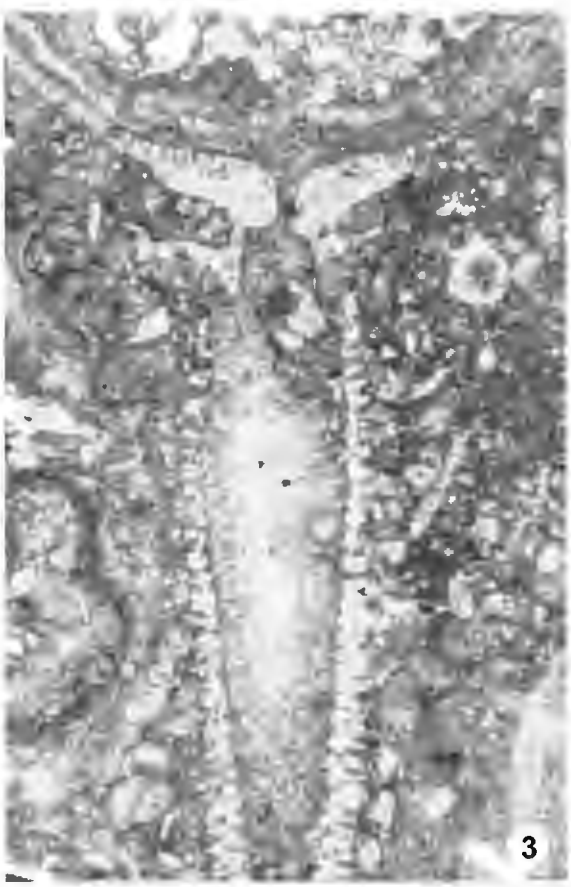
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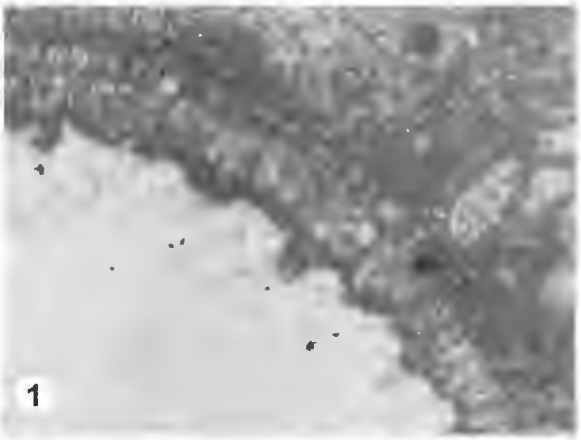
PLATE 6

Figs 1–5: *Decastroporella tergestina* n. gen. n. sp., Duino section, Danian (lower part of SBZ1 biozone). **1–4.** isotypes, **5.** holotype.
1. (A.6935.3), × 100,
2. (A.6935.2), × 100,
3. (A.6935.1), × 100,
4. (A.6937.12), × 60,
5. (A.6935.2), × 30.

Figs 1–3: Details of the skeleton at the head region of the thallus.

Figs 4–5: Longitudinal and axial section respectively showing the stalk and the head joined.
1. Notice the two spatitic circles; one (upper left) is partly enclosed in the skeleton, the other (middle part) is enclosed in the early cement.
2. The figure shows the thin pores and a faint dark line running amid the thickness of the skeleton.
3. Detail of pl. 5, fig. 2. Notice the thickening of the calcareous skeleton showing longer thin pores as well.
5. Detail of pl. 6, fig. 5 showing the junction between the stalk and the head.
4. When the head is entire it usually is filled by cement, **5.** if broken it is filled by sediment.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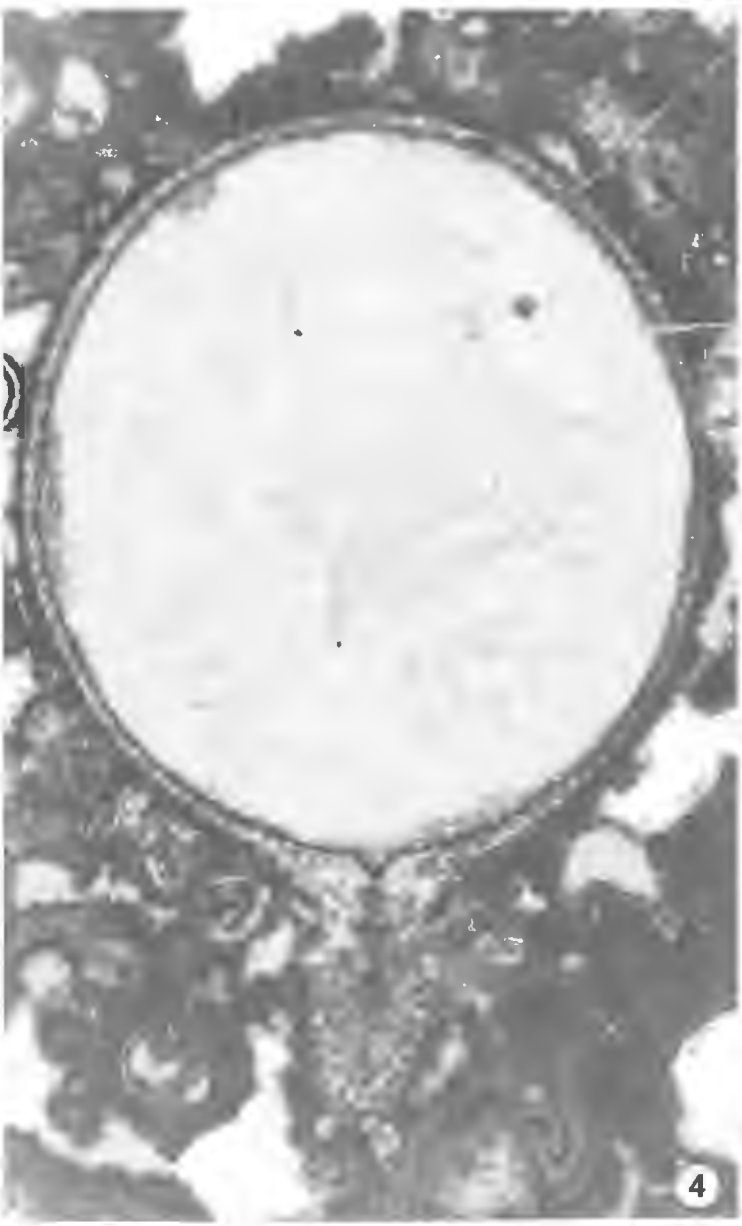
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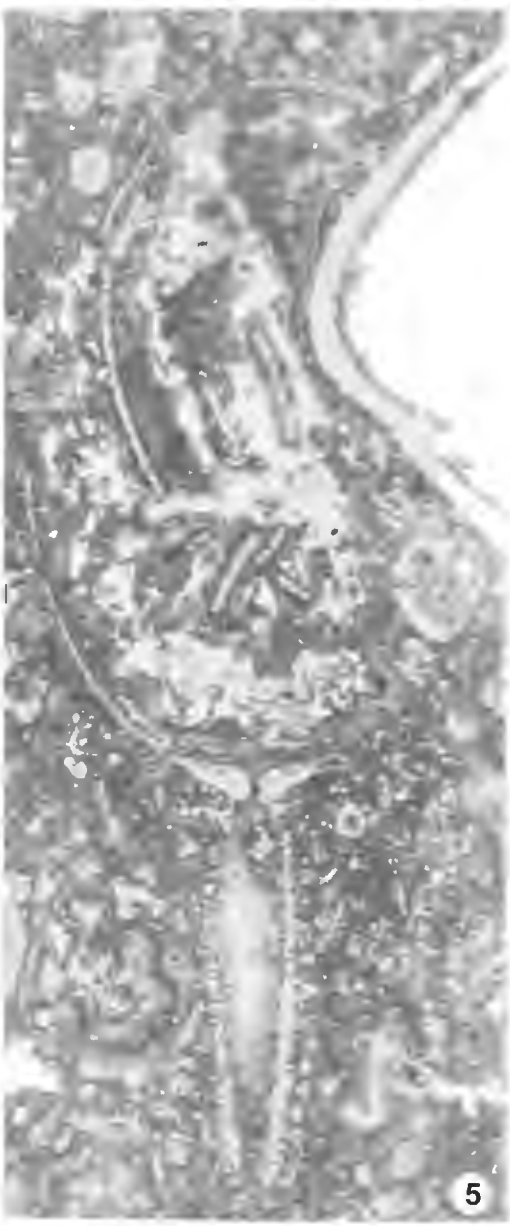
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PLATE 7

Figs 1–7: *Drobnella slovenica* n. gen. n. sp., isotypes, × 50. Sopada section, Danian (SBZ1 biozone).
1. (BA.1513.1 = Sop37.1),
2. (BA.1513.7 = Sop37.7),
3. (BA.1513.7 = Sop37.7),
4. (BA.1513.3 = Sop37.3),
5. (BA.1513.7 = Sop37.7),
6. (BA.1513.2 = Sop37.2),
7. (BA.1513.2 = Sop37.2).

Figs 1, 4: Oblique sections cutting the central stem and part of a whorl of branches.

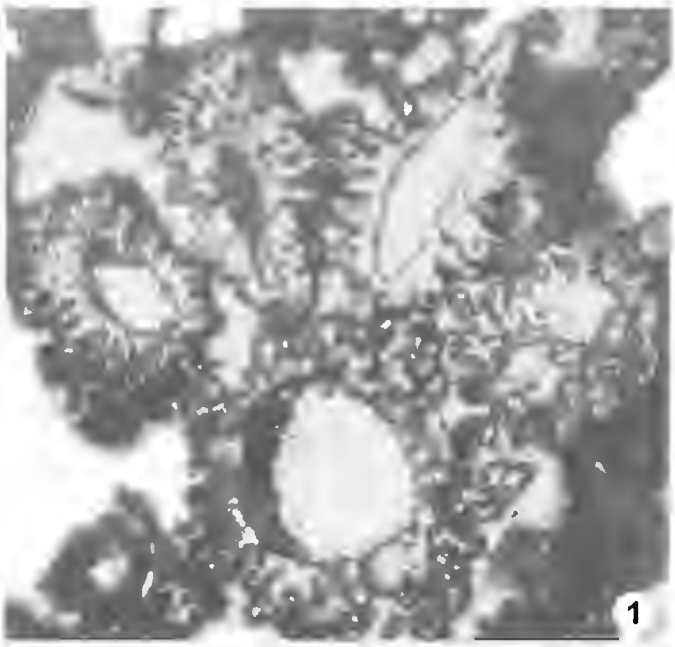
Fig. 2: Longitudinal sections of three branches probably due to a tangential section of a whorl.

Fig. 3: Oblique section showing the central stem, a branch (*right*) and the proximal pore of another (*left*).

Figs 5–6: Oblique sections referable to central stems that show smooth (**5**) to rough (**6**) inner surfaces.

Figs 7: Transversal section (*left below*) and two oblique sections referable to a central stem and to branches.

Figs 1–7: Notice the irregular calcareous skeleton pierced by blind pores. These latter usually do not open into the central cavity.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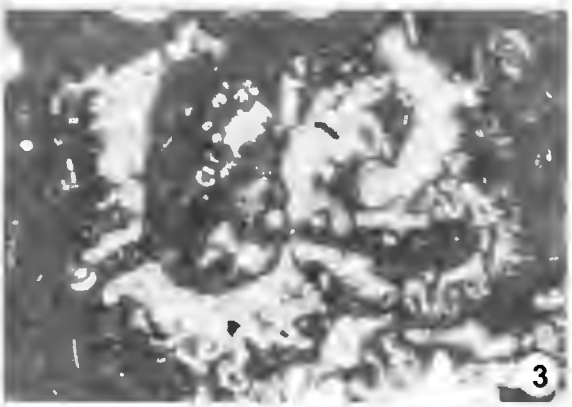
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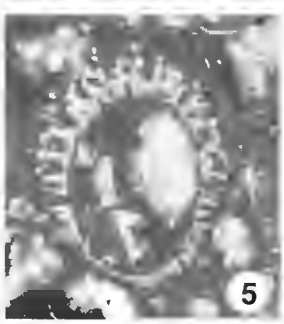
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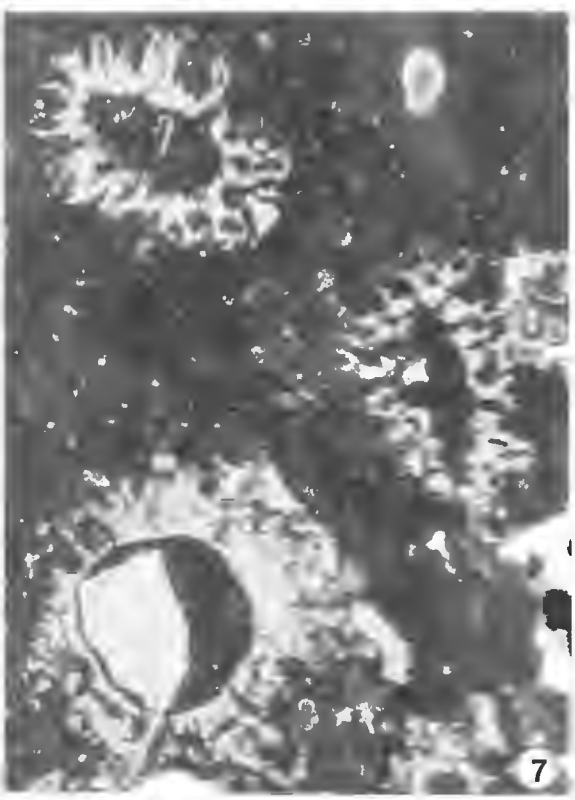
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PLATE 8

Figs 1–9: *Drobnella slovenica* n. gen. n. sp., Sopada section, Danian (SBZ1 biozone). All isotypes, × 50, except **2.** holotype, × 25.
1. (BA.1513.3 = Sop37.3),
2. (= A.1513.2 = Sop37.2),
3. (BA.1513.1 = Sop37.1),
4. (BA.1513.4 = Sop37.4),
5. (BA.1513.3 = Sop37.3),
6. (BA.1513.8 = Sop37.8),
7. (BA.1513.2 = Sop37.2),
8. (BA.1513.8 = Sop37.8),
9. (BA.1513.3 = Sop37.3).

Figs 1–2: Oblique and longitudinal sections respectively.

Figs 3, 5: Transversal sections of branches.

Figs 4, 6–8: Oblique sections of branches.

Fig. 9: Tangential section of a branch.

Fig. 2: It is visible one branch cut longitudinally (vertical section of the branch, *upper left*), two branches of a whorl cut transversally are also visible (*below*).

Figs 8–9: Notice the unpierced pointed distal end of the branches.


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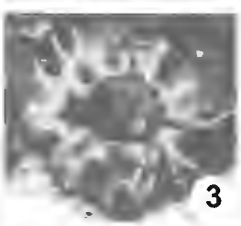
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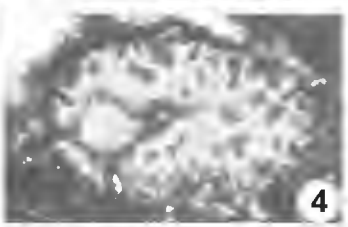
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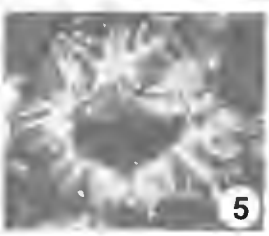
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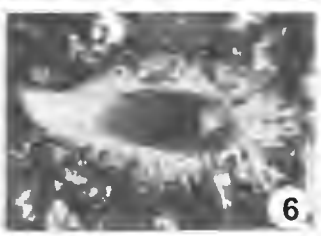
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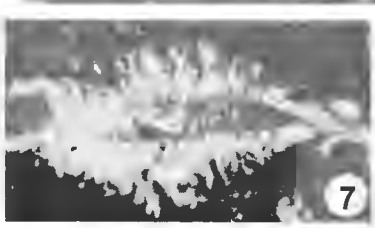
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PLATE 9

Figs 1–3: *Drobnella slovenica* n. gen. n. sp., Sopada section, Danian (SBZ1 biozone). **1, 3.** isotypes, **2.** holotype.
1. (BA.1513.1 = Sop37.1), × 50,
2. (BA.1513.2 = Sop37.2), × 50,
3. (BA.1513.8 = Sop37.8), × 25.

Fig. 1: Oblique section showing the central stem and the branches.

Fig. 2: Detail of pl. 8, fig. 2.

Fig. 3: Wackestone with fenestrae, in the assemblage *Drobnella slovenica* n. gen n. sp and *Decastroporella tergestina* n. gen n. sp.


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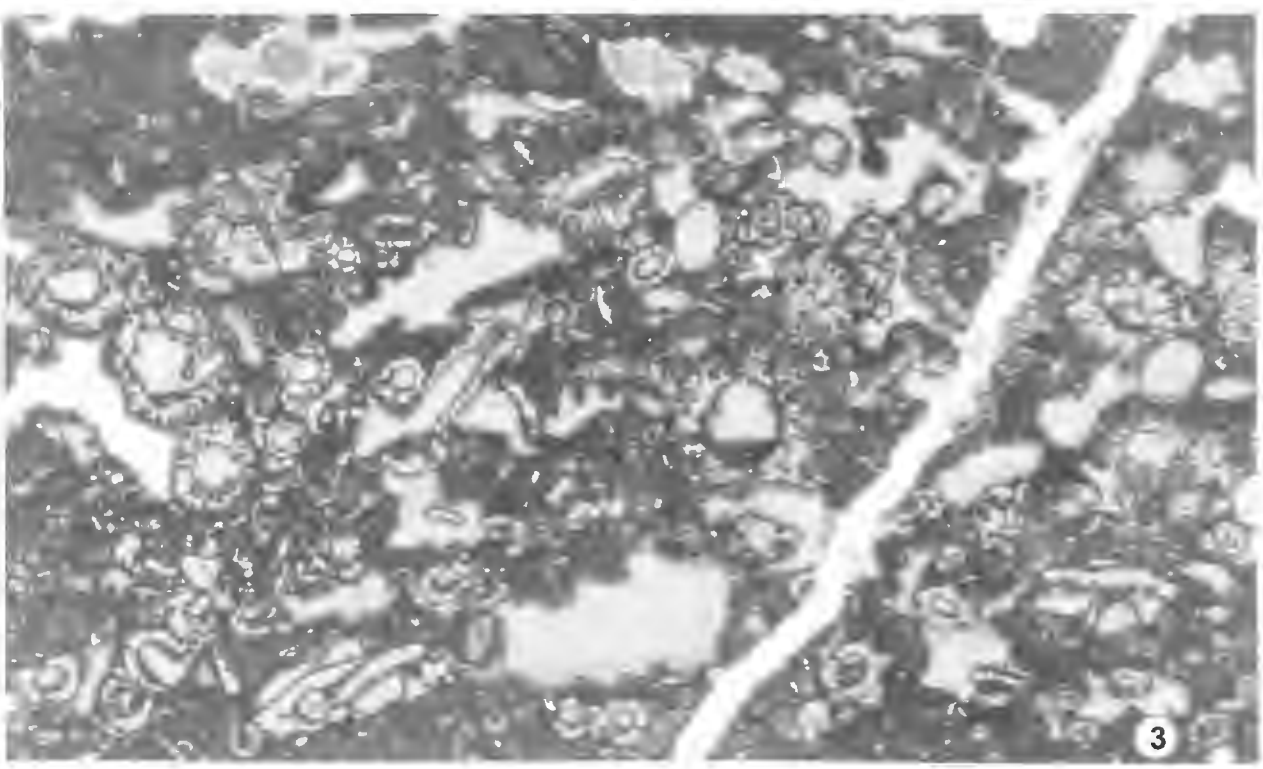
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PLATE 10

Figs 1: *Dissocladella gracilis* Radoičić, oblique section, (A.7650.1), × 120, Colle di Medea section. Danian (upper part of SBZ1 biozone).

Figs 2–6: *Hamulusella liburnica* (Buser & Radoičić), × 40, Colle di Medea section, Thanetian (SBZ3 biozone).

2. (A.6930.2),
3. (A.6930.18),
4. (A.6930.1),
5. (A.6930.3),
6. (A.6930.13).

Figs 2–3: Transversal-oblique sections.

Figs 4: Longitudinal section.

Figs 5: Tangential section.

Figs 6: Longitudinal-oblique section.

Figs 4, 6: Notice the thin encrustation of the axial stem and the lower portion of the branch below the junction to the axial stem.

Figs 6: Some pores still maintain the fragile thin calcareous encrustation that close their distal ends.

Figs 7–8: *Orioporella malaviae* Pia in Rao & Pia, Colle di Medea section, Thanetian (SBZ3 biozone).

Figs 7: Oblique section, (A.6930.2), × 31,

Figs 8: Tangential section, (A.7668.2), × 25.


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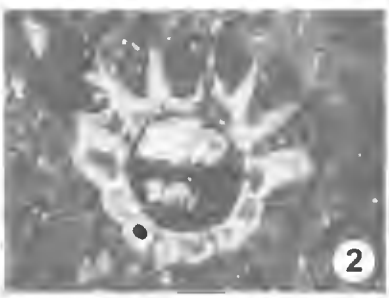
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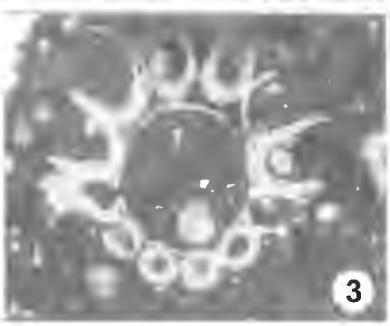
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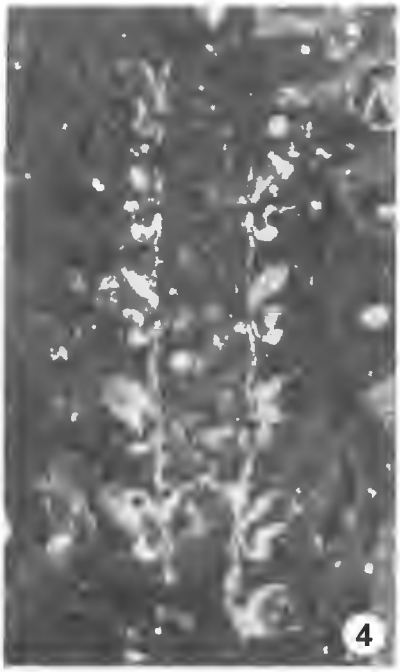
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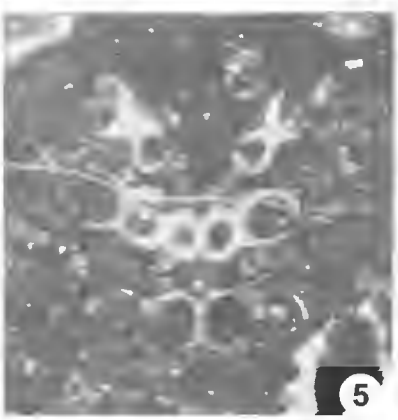
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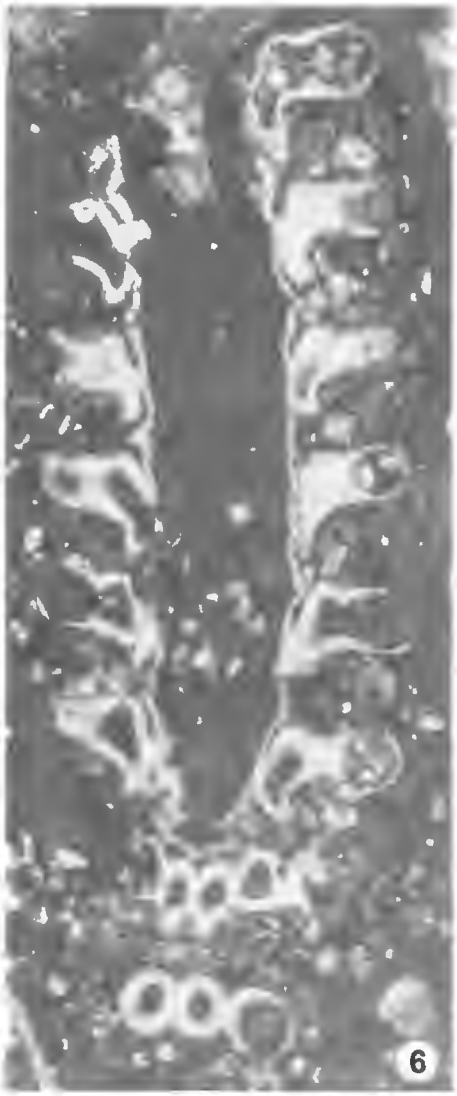
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PLATE 11

Figs 1–6: *Cymopolia mayaense* Johnson & Kaska, × 50.
1. (BA.1511.10 = Dv 11.10),
2. (BA.1511.8 = Dv 11.8),
3. (BA.1511.15 = Dv 11.15),
4. (14/43: Raineri's original material),
5. (14/43: Raineri's original material), Raineri, 1930, fig. 3, *sub C. elongata* (Defrance),
6. (BA.1511.10 = Dv 11.10).

Figs 1–3, 6: Dolenja vas W section, Danian (upper part of SBZ1 biozone).

Figs 4–5: Colle di Medea, probably Danian (upper part of SBZ1 biozone ?).

Figs 1, 3: Sterile articles in oblique sections.

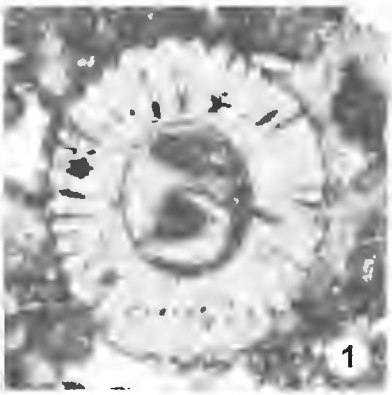
Figs 2, 4–5: Fertile articles in oblique sections

Fig. 6: Sterile article in tangential section.

Figs 7–8: *Cymopolia paronai* Raineri., × 50, Colle di Medea, probably Danian (upper part of SBZ1 biozone ?).

Fig. 7: Holotype, fertile article in oblique section, (14/42, original material, = Raineri, 1930, fig. 1),

Fig. 8: Isotype?, fertile article in transversal-oblique section, (14/48, Raineri's original material, not figured).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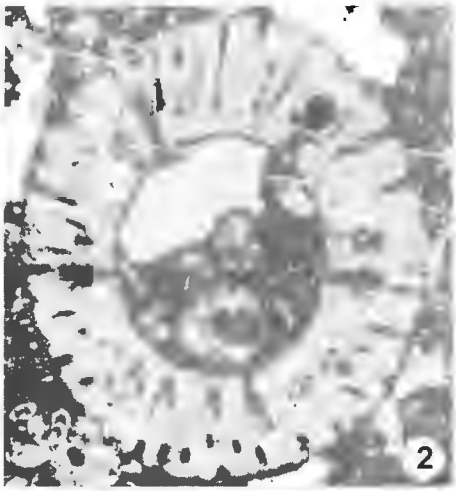
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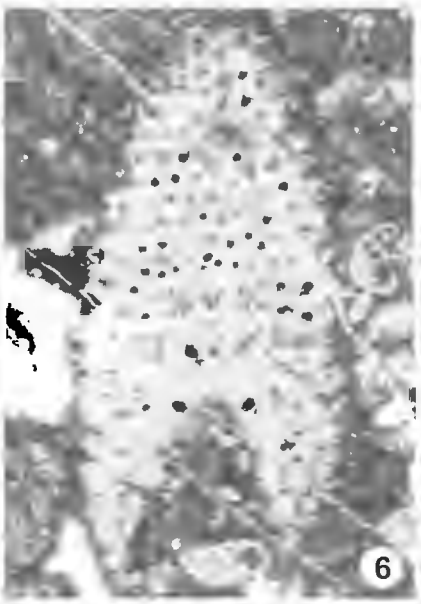
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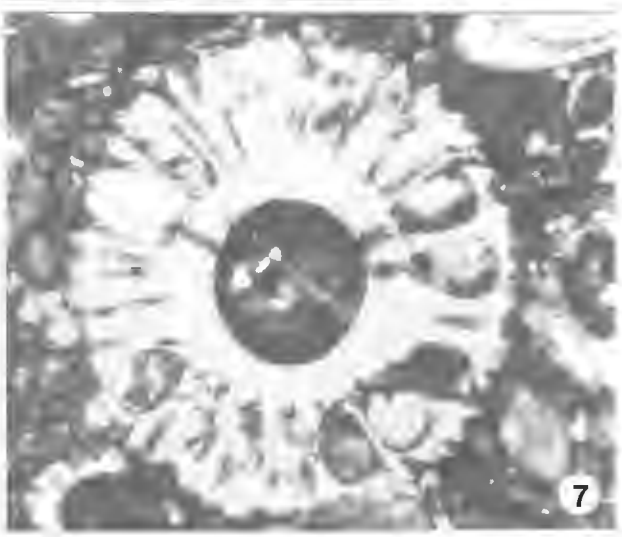
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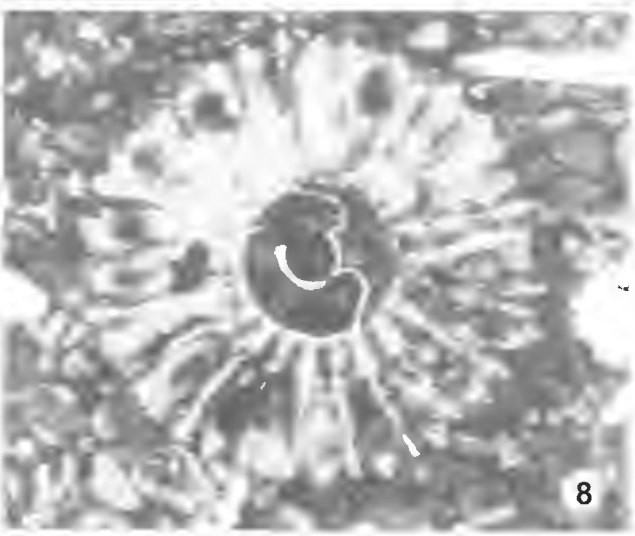
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PLATE 12

Figs 1–2: *Cymopolia mayaense* Johnson & Kaska, × 50, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

1. Fertile article in oblique section, (BA.1511.10 = Dv 11.10),

2. Fertile article in tangential-oblique section, (= BA.1511.14 = Dv 11.14).

Figs 3–4, 6: *Cymopolia* cf. *barberae* Elliott, × 50, oblique sections, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

3. (BA.1511.10 = Dv11.10),

4. (BA.1511.10 = Dv11.10).

6. (BA.1511.7 = Dv 11.7).

Figs 5, 7: *Cymopolia paronai* Raineri, × 50, Colle di Medea section. Thanetian (SBZ3 biozone).

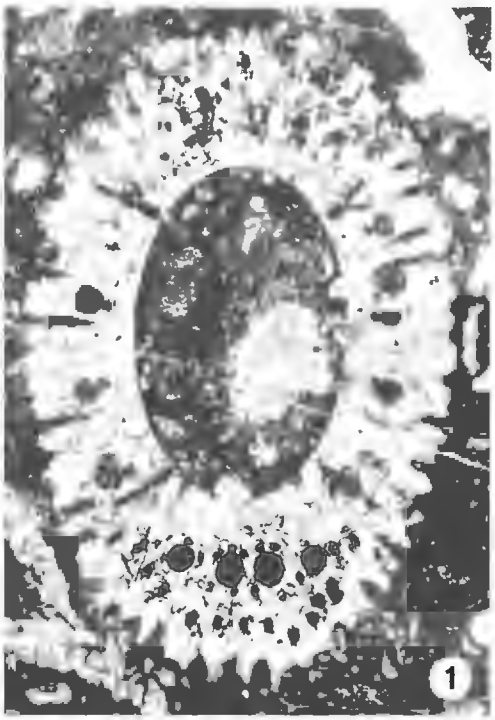
5. (A.6930.2),

7. (A.6930.3).

Figs 5, 7: Fertile articles in oblique sections. Notice the marked variability in size of articles and ampullae.

Fig. 8: *Cymopolia frugifera* Segonzac. Oblique section, (BA.1511.16 = Dv11.16), × 50, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

Fig. 9: *Broeckella belgica* Morellet & Morellet, (A.6940.2), × 60, Duino section, Danian (upper part of SBZ1 biozone).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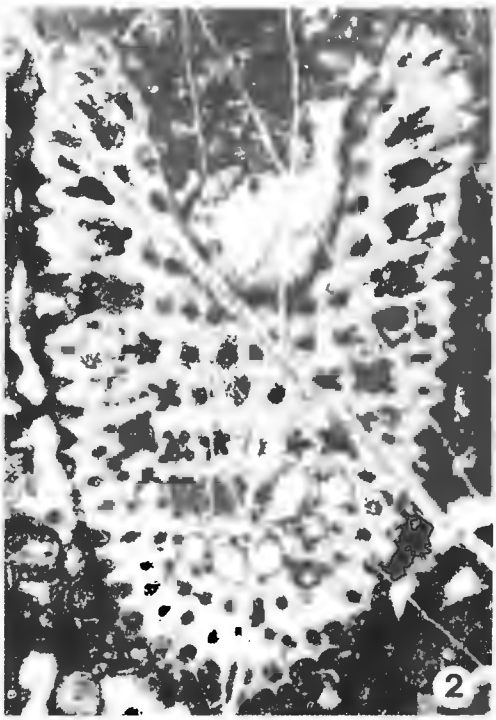
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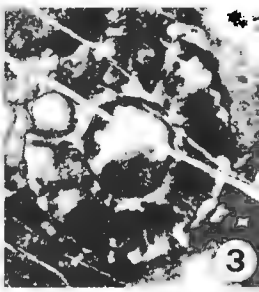
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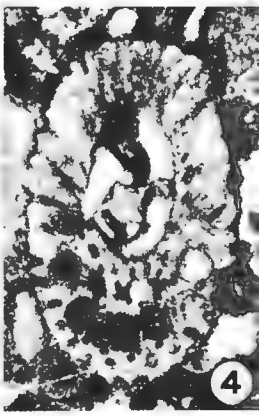
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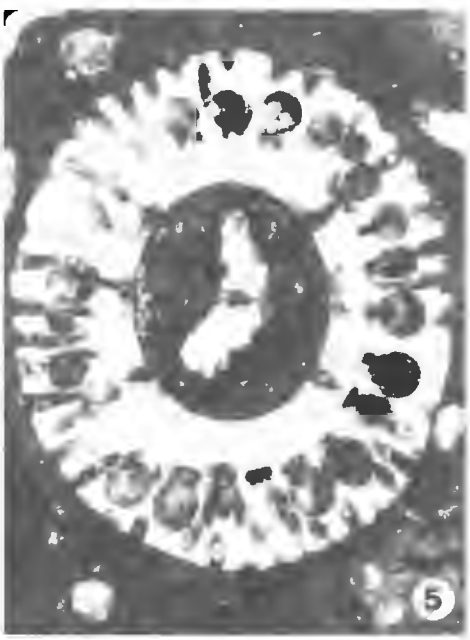
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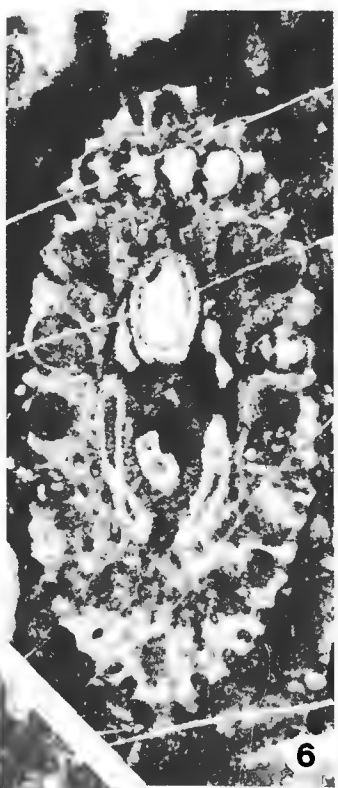
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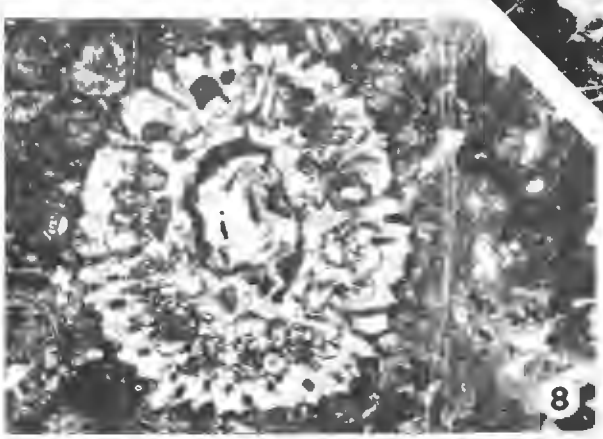
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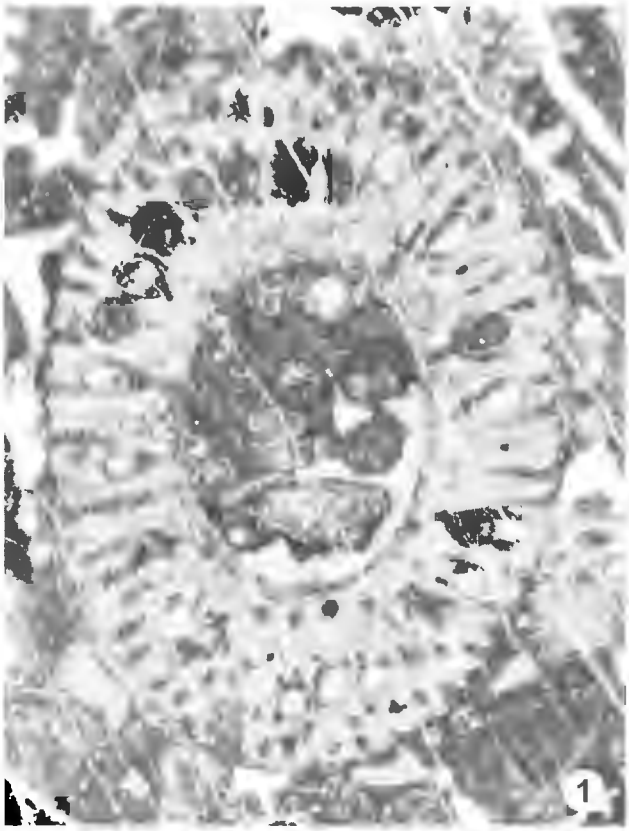
PLATE 13

Fig. 1: *Cymopolia mayaense* Johnson & Kaska. Fertile article in oblique section, (BA.1511.7 = Dv 11.7), × 50, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

Figs 2–3: *Cymopolia paronai* Raineri, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

2. Fertile article in oblique section. Notice the wide central stem. (BA.1511.11 = Dv11.11), × 50,

3. Very elongated fertile article in oblique section, the specimen shows similarities with *C. mayaense,* (BA.1511.16 = Dv11.16), × 40.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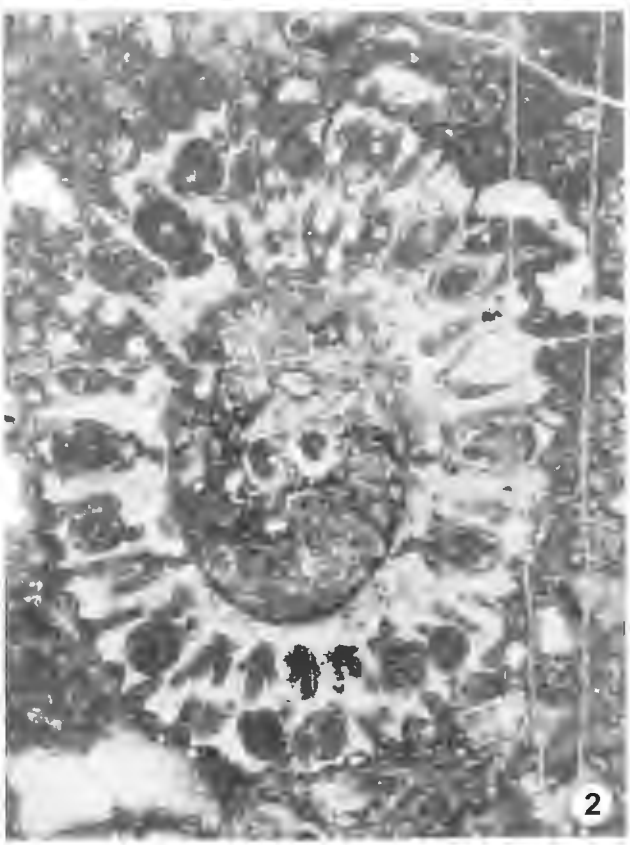
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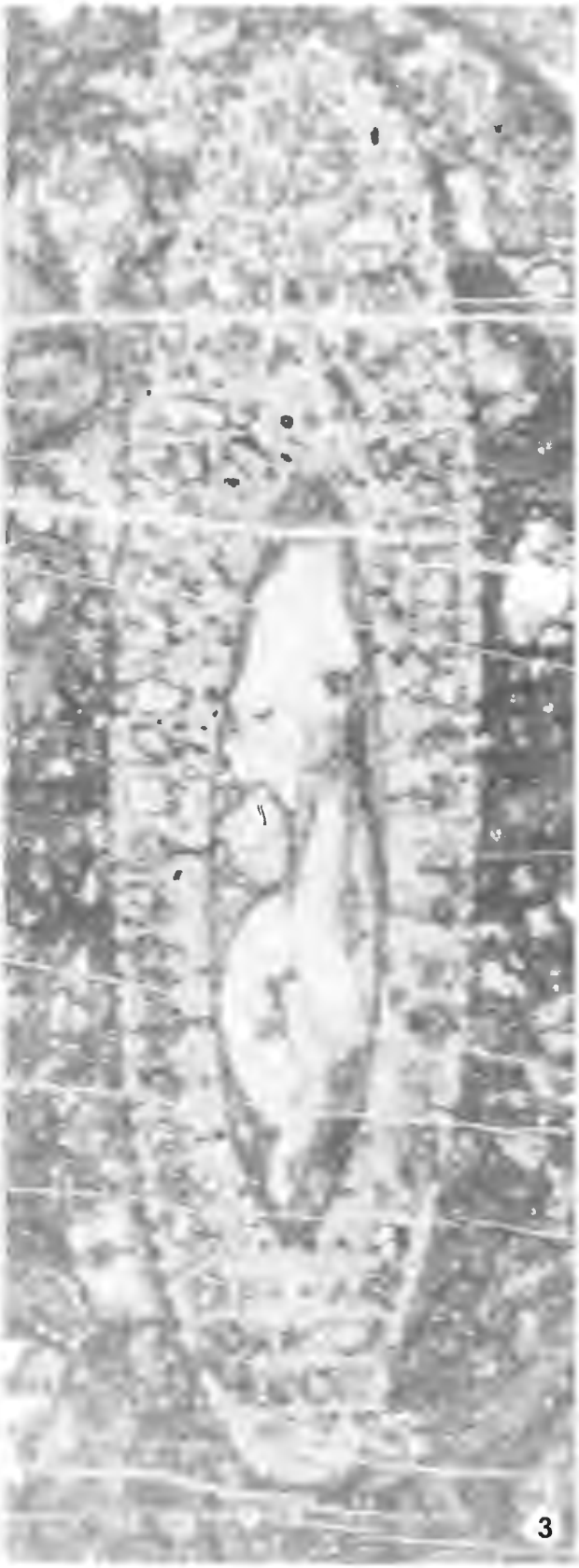
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PLATE 14

Fig. 1: *Cymopolia frugifera* Segonzac. Axial section, (A.6930.13), × 50, Colle di Medea section, Thanetian (SBZ3 biozone). Notice the swollen distal part of primary branches and the couple of ampullae per primary (e.g. 3rd whorl from the top on the left; 5th whorl from the bottom on the left).

Figs 2–3: *Neomeris* sp.

2. Transversal section, (A.6930.10), × 50, Colle di Medea section, Thanetian (SBZ3 biozone),

3. Longitudinal section showing two subsequent whorls of calcified ampullae, (A.6937.11), × 60, Duino section, Danian (SBZ1 biozone).

Figs 4–5: *Carpenterella* sp., (A.7653.2), × 120, Colle di Medea section, Danian (upper part of SBZ1 biozone).

Fig. 4: Probable longitudinal section of a corpuscule.

Fig. 5: Oblique section showing two calcified tufts of ampullae.

Figs 6–15: *Carpenterella jonesi* Morellet & Morell *et al.* × 120, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

6. (BA.1511.14 = Dv11.14),
7. (BA.1511.13 = Dv11.13),
8. (BA.1511.11 = Dv 11.11),
9. (BA.1511.13 = Dv11.13),
10. (BA.1511.6 = Dv11.6),
11. (BA.1511.7 = Dv 11.7),
12. (BA.1511.14 = Dv 11.14),
13. (BA.1511.2 = Dv 11.2),
14. (BA.1511.2 = Dv 11.2),
15. (BA.1511.13 = Dv 11.13).

Figs 6–7: Longitudinal sections.

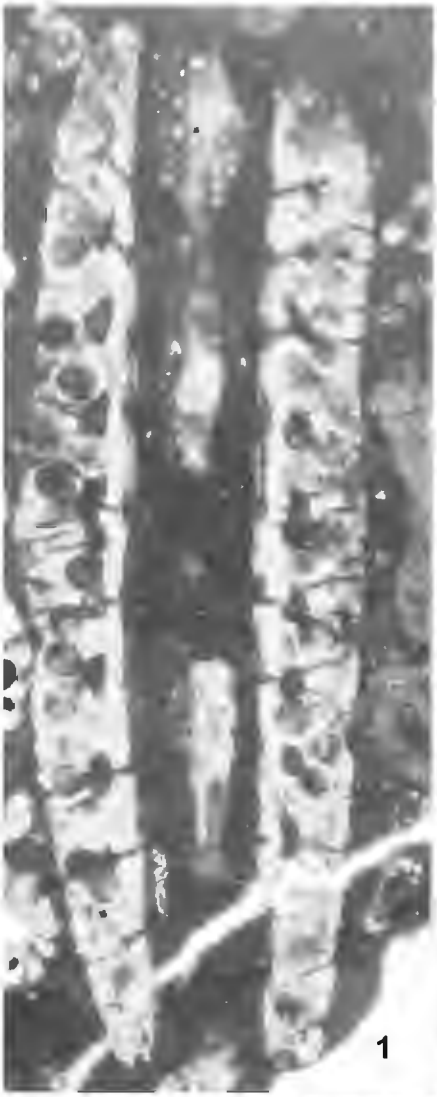
Figs 8–11, 13: Oblique sections.

Figs 12, 14: Transversal sections.

Figs 15: Tangential section.

Figs 7, 10, 13: The specimens show two opposite little bodies (tufts of ampullae), they most likely correspond to two subsequent tufts placed in the space between successive verticils.

Fig. 14: Tufts of ampullae laterally connected, they probably pertained to a same verticil.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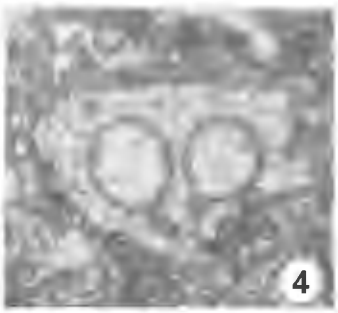
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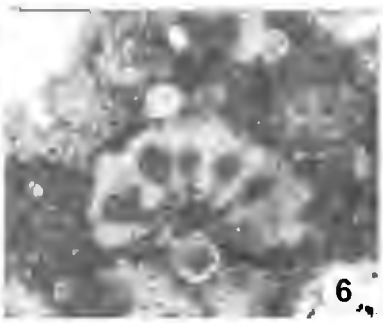
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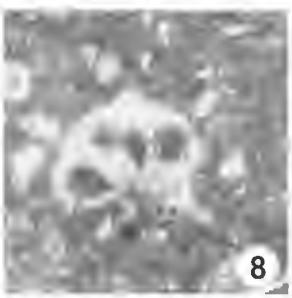
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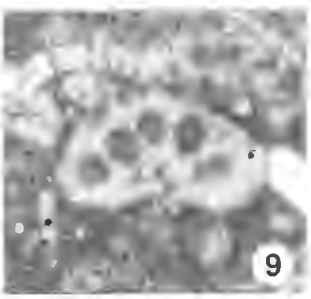
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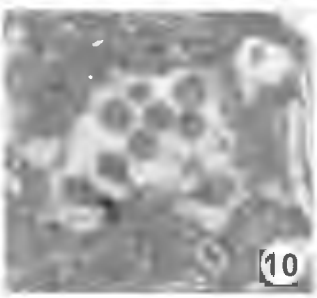
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PLATE 15

Figs 1–16: *Microsporangiella buseri* n. sp. All isotypes except **14.** holotype, × 120.
1. (BA.1511.6 = Dv11.6),
2. (BA.1511.6 = Dv11.6),
3. (BA.1511.8 = Dv 11.8),
4. (A.7650.1),
5. (BA.1511.11 = Dv11.11),
6. (BA.1511.7 = Dv 11.7),
7. (A.7653.1),
8. (BA.1511.8 = Dv 11.8),
9. (BA.1511.3 = Dv 11.3),
10. (A.7653.1),
11. (BA.1511.11 = Dv11.11),
12. (BA.1511.7 = Dv11.7),
13. (BA.1511.7 = Dv11.7),
14. (A.7650.1),
15. (BA.1511.10 = Dv11.10),
16. (BA.1511.15 = Dv 11.15).

Figs 1–3, 5–6, 8–9, 11–13, 15–16: From Dolenja vas W section, Danian (upper part of SBZ1 biozone),

Figs 4, 7, 10, 14: From Colle di Medea section, Danian (upper part of SBZ1 biozone).

Figs 1–4: Transversal to oblique sections cutting a whorl of primary branches.

Figs 5–8. Transversal-oblique sections at the ampullae level.

Figs 9–16: Oblique sections.

Figs 2, 4, 7: Notice the marked cortical swelling of the branches at their distal end.

Figs 1, 6, 8: The scallopping outer surface is to be related to the cortical swelling of primary branches.

Fig. 16: The elongated pores (*top*) probably represent swollen primary pores close to the cortical layer.

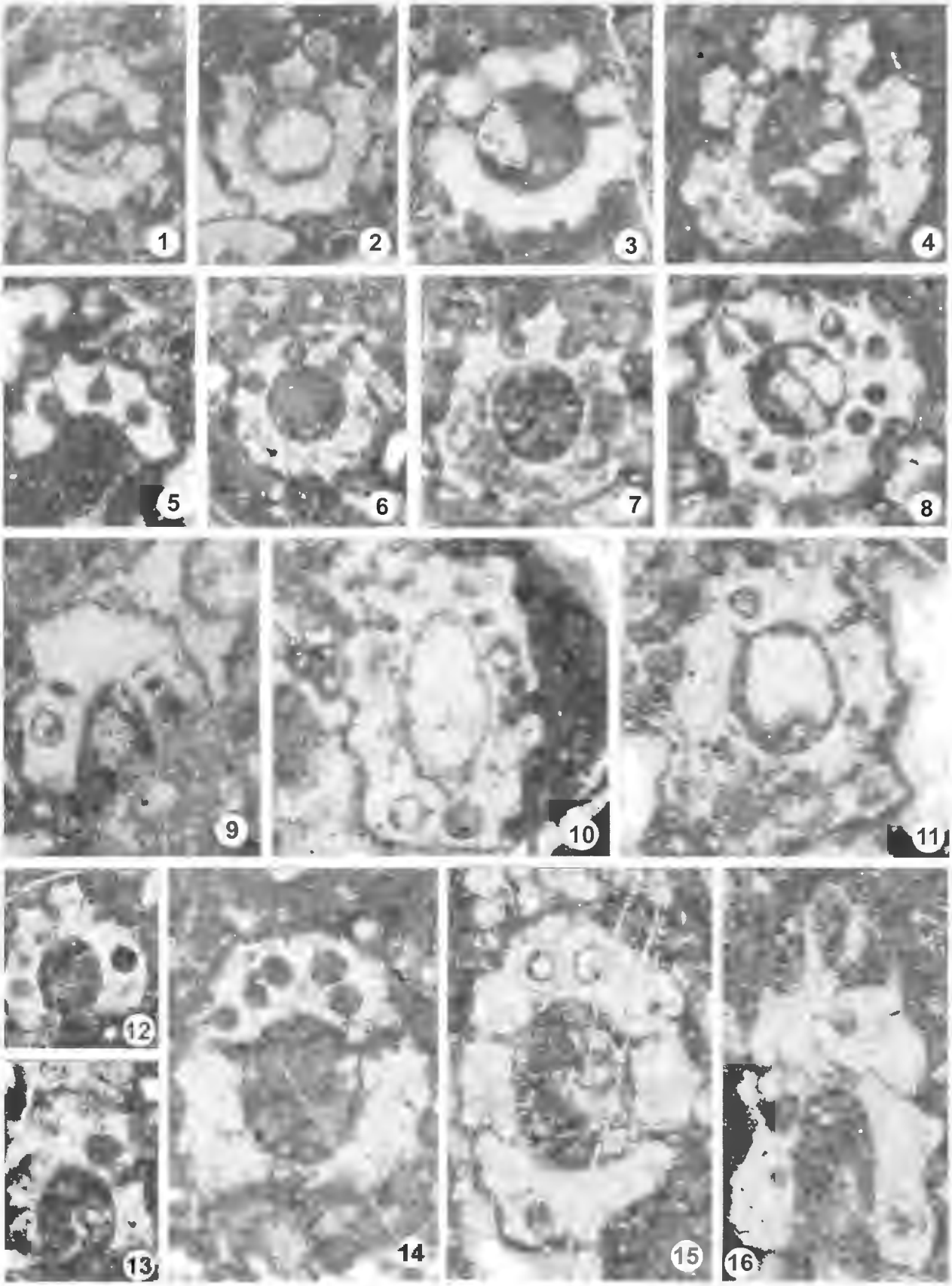
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PLATE 16

Figs 1–6: *Microsporangiella buseri* n. sp. All isotypes, × 120 except **6.** × 30., Dolenja vas W section, Danian (upper part of SBZ1 biozone).
1. (BA.1511.11 = Dv11.11),
2. (BA.1511.11 = Dv11.11),
3. (BA.1511.13 = Dv 11.13),
4. (BA.1511.2 = Dv11.2),
5. (BA.1511.11 = Dv11.11),
6. (BA.1511.14 = Dv 11.14).

Fig. 1: Tangential section showing in the middle a verticil of primary branches and two ampullae,

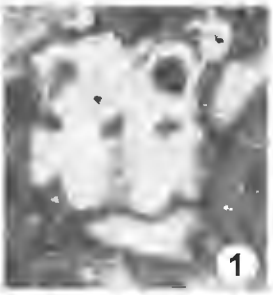
Figs 2–3, 5: Longitudinal sections, notice how the junction of ampullae happens in the vicinity of the swelling of primary pores.

Fig. 4: Oblique section, notice the fissuration between two articles.

Fig. 6: Wackestone with vugs, microfacies.

Fig. 7: Crustose corallinacean alga (gen. et sp. ind.) in longitudinal section, (BA.1511.16 = Dv11.16), × 100, Dolenja vas W section, Danian (upper part of SBZ1 biozone).

Fig. 8: *Thyrsoporella longa* Radoičić. Tangential section, (Sop8–57738), × 60, Sopada section, upper Thanetian (SBZ4 biozone).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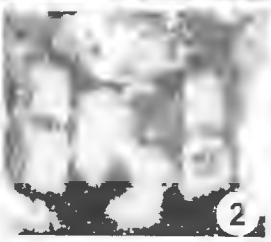
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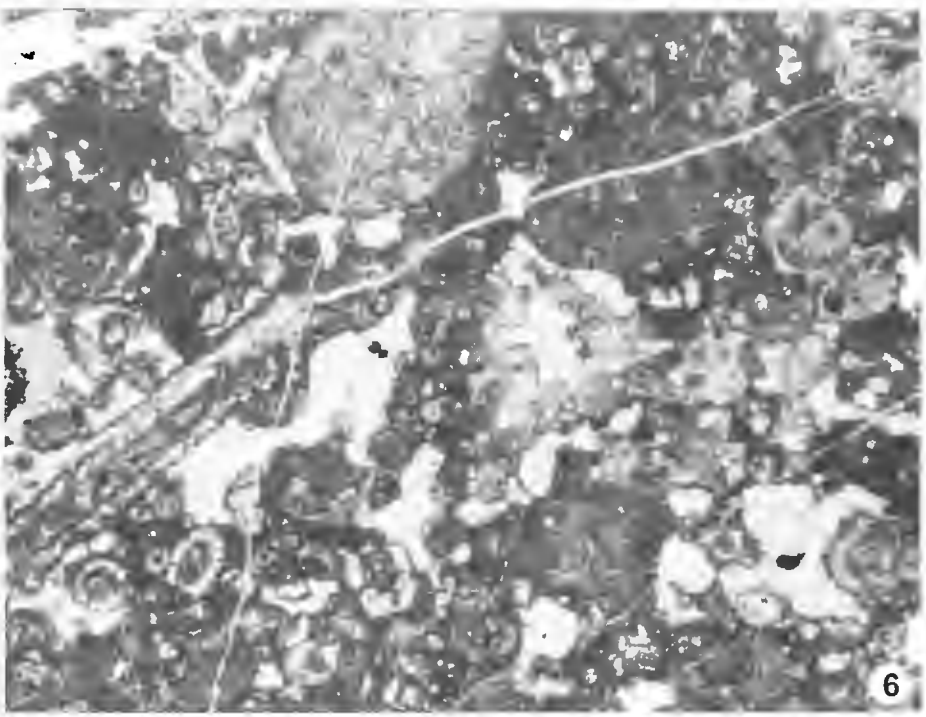
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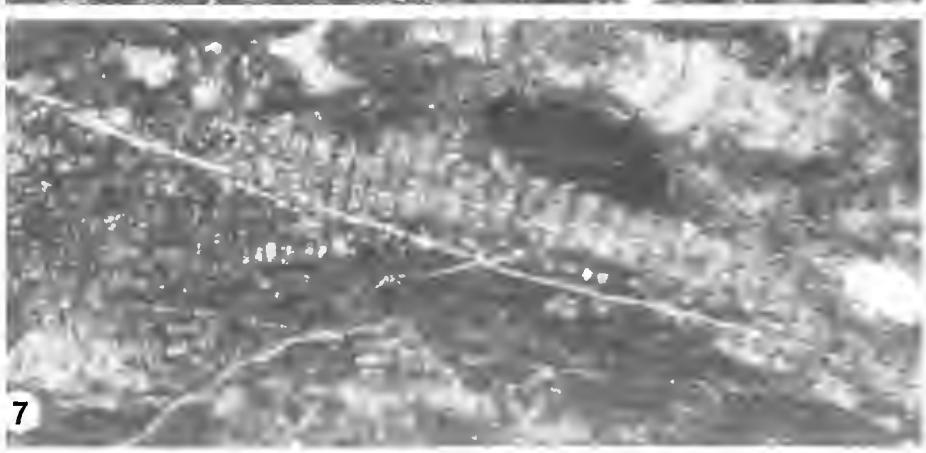
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PALEOCENE CORALS FROM THE NORTHERN ADRIATIC PLATFORM

Dragica Turnšek and Katica Drobne

Abstract

1. From the northern margin of the Adriatic platform 22 species of Paleocene corals belonging to 15 genera were systematically described. Two species (*Rhizangia padricensis* and *Goniopora hrpeljensis*) are new.

2. The most convinient circumstances for the beginning of coral growth were at the edge of the platform near to the open sea. Here in Dolenja vas as first the local dendroid-phaceloid coral association thrived. Then, toward the hinterland, perhaps in more stages, toward Sopada, Padriciano, Hrpelje–Kozina, Golež to Breg, new generations of massive and phaceloid corals settled which built smaller or larger patch reefs.

3. Corals found in Adriatic platform can be compared with similar findings of species in the wide area from Greenland to Volga and Egypt.

Izvleček

1. Iz severnega obrobja Jadranske platforme je sistematsko opisanih 22 vrst paleocenskih koral, ki pripadajo 15 rodovom. Dve vrsti (*Rhizangia padricensis* in *Goniopora hrpeljensis*) sta novi.

2. Najbolj ugodni pogoji za začetek rasti koral so bili na obrobju platforme blizu odprtega morja, kjer je v Dolenji vasi nastala samosvoja dendroidno-faceloidna koralna združba. Potem so morda v več fazah v zaledju od Sopade preko Padrič, Hrpelja–Kozine, Golča do Brega sledile naselitve z novimi generacijami masivnih in faceloidnih koral, ki so gradile večje ali manjše "patch" grebene.

3. Najdene korale z Jadranske platforme lahko primerjamo z najdbami enakih vrst od Grenlandije do Volge in Egipta.

Key words: Dendroid-faceloid corals, Paleocene, zonation, NW Adriatic platform, Karst, Slovenia, Italy.

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INTRODUCTION

The northern part of the Adriatic carbonate platform is one of the few regions in the world where shallow carbonate deposits of Early Paleocene age may be preserved as an exceptionally complete series of strata documenting the rise of carbonate producers after the Cretaceous-Tertiary boundary event. In this context, the nature and composition of the first coral communities contributing a major part of the biomineralized carbonate are of particular interest in order to understand the processes of recovery of the carbonate producing communities. Comparing the pattern of biostratigraphic first appearences, in the common framework of the Shallow Benthic (SBZ) zonation, of coral, algal and foraminiferan taxa may provide additional insight of their respective role in the recovery of environments dominated by K-strategists producing the carbonate.

So far, only 9 taxa from a single locality Dolenja vas in Slovenia (Drobne *et al.*, 1988), were identified. During subsequent field work, new coral bearing localities were discovered and sampled. They are Sopada, Hrpelje–Kozina, Breg, Golež (all Slovenia) and Padriciano (Italy). Thus, the inventary grows to 22 species belonging to 15 genera. Only 2 species recognized in Dolenja vas reappear at the new sites.

The specimens from Slovenia are kept in the Ivan Rakovec Paleontological Institute ZRC SAZU in Ljubljana, those from Italy in the Paleontological Institute of the University in Trieste.

The systematical research of corals was made by Dragica Turnšek, the detailed field work with stratigraphical position of the coral bearing samples from the Paleocene sections, and their paleoecological explanation was prepared by Katica Drobne.

LOCATION AND STRATIGRAPHIC POSITION OF THE CORAL BEARING LOCALITIES

Coral assemblages from the Adriatic carbonate platform were collected in SW Slovenia and on a part of the Trieste Karst on Italian territory. The deposits providing corals represent the extreme, northwestern part of the Outer Dinaric tectonic unit (Placer, 1996). The exposed carbonates are of Cretaceous to Paleogene age. The Paleogene limestones with their Late Cretaceous substrate crop out in four parallel belts corresponding to four tectonic subunits extending roughly from North-West to South-East. Sections were selected for study in each belt in order to register the stratigraphic distribution and the composition of subsequent assemblages of corals, algae and foraminifera in their respective facies (Drobne *et al.*, 1991; Ogorelec *et al.*, 1995; Pugliese *et al.*, 1995; Jurkovšek *et al.*, 1996; Barattolo in print).

Corals in particular (Fig. 1, 2) occur in all four Paleogene belts. They are always firmly cemented in the limestones and therefore had to be studied exclusively in thin-sections. The coral bearing limestones were collected in the selected and measured sections (Fig. 3).

1. Padriciano, located at the southernmost margin of the Trieste–Komen Plateau. The series of limestones crop out along the high-way leading to the settlement of Padriciano (Brazatti *et al.*, 1996).

2. Hrpelje in the Hrpelje–Kozina belt, where the corresponding beds are crossed by the forest road to the Slavnik mountain, at the foot of the hill behind the village. The samples were collected in the ditch for supply between the forest road and the railway Divača–Koper and Pula. The thickness of the Paleocene beds amounts here to cca 90 m, and of the Ilerdian beds to an additional 20 m (Figs 1, 2). This section corresponds to the section described on the hill Golež some km forward to Slavnik (Drobne *et al.*, 1991).

3. The Golež section is situated along the road leading from Kozina to the summit of Slavnik. After 5 km a path branches off towards the east. The Paleocene beds outcrop along this way, about 400 m. On the contact between Cretaceous and Paleocene limestone the bauxite occurs. The lowest part of the Paleocene is developed in the lagoonal, shallow and restricted environment. During the Thanetian marine influences prevailed, bearing the frequent foraminifers and partly also corals (Drobne & Pavlovec, 1991).

4. Sopada hill (580 m SE of Štorje) where outcrops along the road document the sedimentation of carbonates from the Cretaceous-Tertiary boundary to the limit of the Paleocene-Eocene (Pugliese *et al.*, 1995).

5, 6. Dolenja vas East and West (DvE, DvW), at km 6 of the road from Senožeče to Vrabče, on the slopes towards the Vipava valley (Drobne *et al.*, 1988, 1996).

7. An isolated outcrop at Breg IV and V provided additonal coral specimens. There outcrops are located in the eastern part of Brkini range, at km 3.5 on the road from Ilirska Bistrica to Knežak. Here, Paleogene beds are isolated from their stratigraphic context by thrust folds. Thickness of the Paleocene beds attains about 45 m, laying in the inverse position (Kahn, 1976; Kahn *et al.*, 1975).

The stratigraphic range of corals is indicated here according to the distribution of the foraminifera observed in the sections studied and their zonation recently revised (Shallow Benhtic SBZ zonation) (Serra-Kiel *et al.*, in print). Tentatively, the SBZ1 zone corresponds to the Danian stage, the SBZ2 zone may be to the Selandian stage, SBZ3 and SBZ4 to the Thanetian and SBZ5-9 to the Ilerdian stage (Fig. 3).

The zonation of foraminifera and corals mainly corresponds to the distribution of dasycladacean algae, studied partly from the same sections on the Karst area by Filippo Barattolo (this volume).

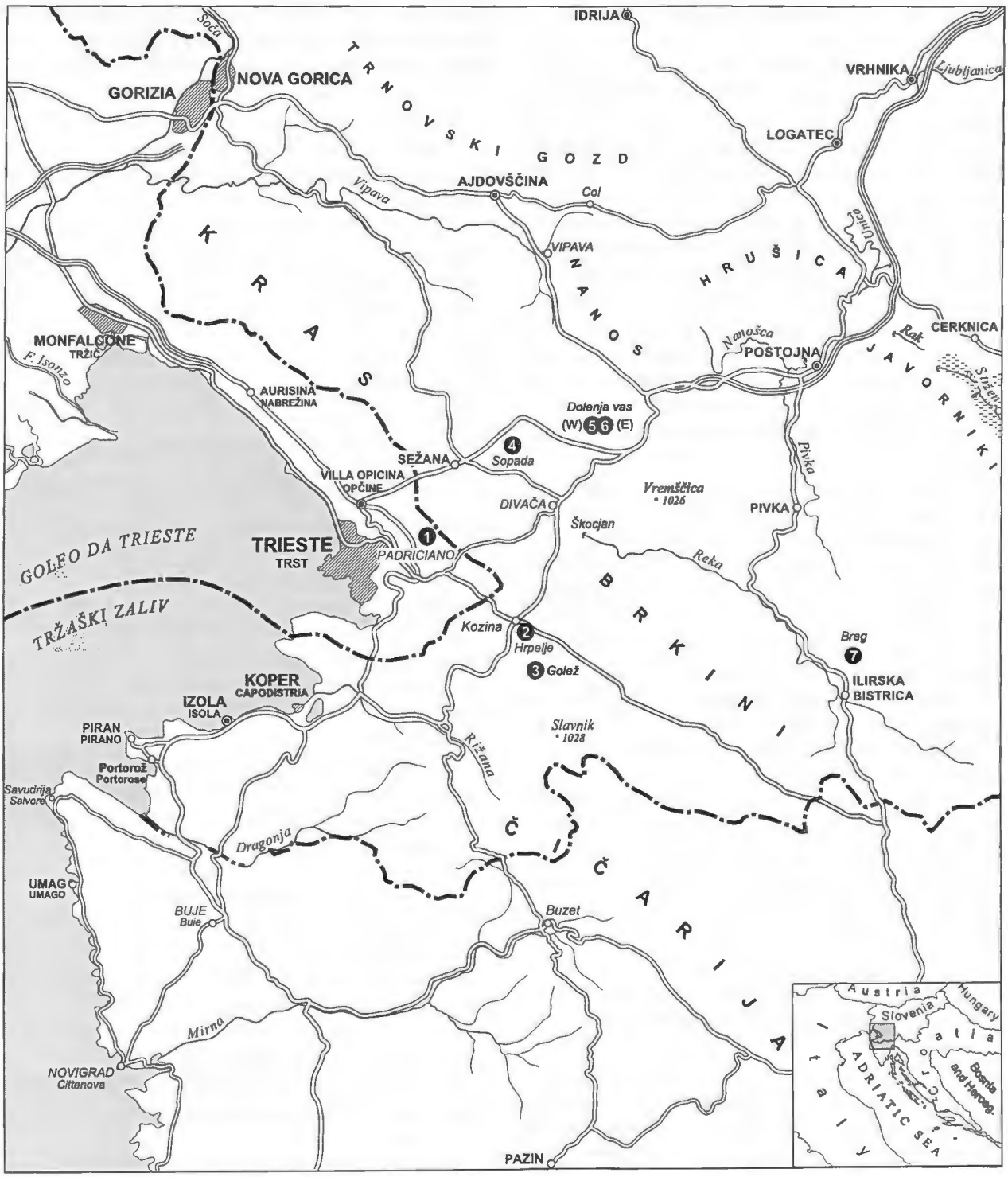

Fig. 1: Geographical position of the Paleocene sections and localities:

1 Padriciano

2 Hrpelje

3 Golež

4 Sopada

5 Dolenja vas West

6 Dolenja vas East

7 Breg

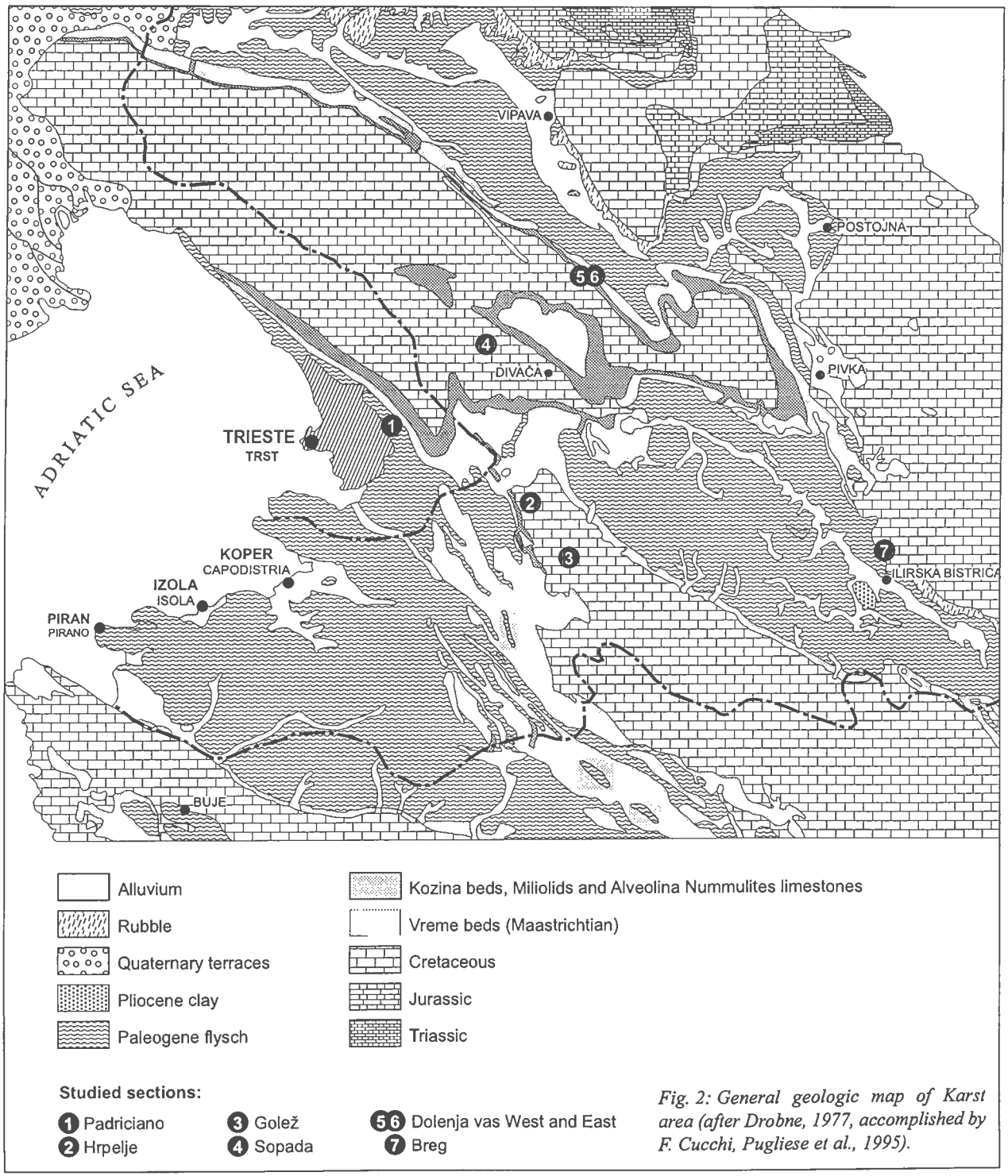

Fig. 2: General geologic map of Karst area (after Drobne, 1977, accomplished by F. Cucchi, Pugliese et al., 1995).

SYSTEMATIC DESCRIPTION OF CORALS

Dragica Turnšek

The systematics in this paper are based mainly on a combination of the revisions published by Alloiteau, 1952, 1957; Wells, 1956; Floris, 1972; Barta Calmus, 1973; Frost & Langenheim, 1974; Kuzmicheva, 1975; Russo, 1979; Beauvais, 1982; Turnšek in Drobne *et al.*, 1988, where detailed explanations were given. A difference arises as to the systematic position of the genus *Rhizangia*, attributed here to the Meandriina as explained in the text, and as to *Litharaea* previously attributed to *Litharaeopsis*. For those species already described from Dolenja vas (Drobne *et al.*, 1988) the synonymy and eventual complements to the description are given here. The microstructure is very poorly preserved; the centers

of calcification and growth of the fibres are wiped out. I was not able to recognize their pattern according to the microstructural groups proposed by Roniewicz & Morycowa (1993) and Morycowa & Roniewicz (1994).

With the description on the species level, the following measures are given: d = inner diameter of corallite, D = diameter of corallite including wall, cc = distance between the centres of the neighbouring corallites, s = number of septa or density of septa (= number of septa or skeletal elements in definite distance), s1+s2+s3 = septal cycles, () = very rare.

Subordo: Archaeocoeniina Alloiteau, 1952
Fam.: Stylocoeniidae Alloiteau, 1952

Genus: *Astrocoenia* Milne Edwards & Haime, 1848

***Astrocoenia bistellata* (Catullo, 1856)**
Pl. 1, figs 1–6

1856 *Astraea bistellata* n. sp. Catullo: n. v.
1973 *Astrocoenia bistellata* (Catullo). Barta Calmus: 215–217, Pl. 8, figs 7–8.

A modern description was given by Barta Calmus (1973). The subcerioid colony has polygonal to round corallites. Septa are compact, developed in a hexameral system, laterally sharply granulated, in their axial part thickened or having auriculae. The columella is styliform, it is sometimes joined with the septa because of recrystalization and therefore appearing very large. Wall is septothecal, wide, because the septa are touching each other over a wide region. Endotheca consists of the vesicular dissepiments. Microstructure is very poorly preserved.

Dimensions of our specimens: d = (0.8)1–1.3 mm, D = 0.9–1.5 mm, s = 12 (6+6).

Comparison: All features of our specimens fit with the Barta's description of the species, but our specimens are smaller in size (Barta-Calmus, 1973): d = 1.2–1.5 mm, D = 1.2–1.8 mm, s = 12 (6+6).

Systematic position: *Astrocoenia* was put into the suborder Meandriina by Alloiteau (1952). Barta-Calmus (1973) ascribed it to the Archaeocoeniina what is accepted here.

Previously indicated occurrences: Brendola in Venetia, Eocene.

New occurrences on the Adriatic carbonate platform: Padriciano: Pad-11 (11002, 11003), Pad-28 (11005, 11006); Breg: Br-IV/4. Zone SBZ4.

Genus: *Stylocoenia* Milne Edwards & Haime, 1848

Stylocoenia was compared to *Astrocoenia* by Alloiteau (1957), and Barta-Calmus (1973). They emphasize the presence of "colonnettes murales" as a typical characteristic to distinguish this genus from *Astrocoenia*. Our specimens of these two genera differ also in their endotheca, *Stylocoenia* having tabulate and *Astrocoenia* vesicular dissepiments.

***Stylocoenia montium* (Oppenheim, 1912)**
Pl. 2, fig. 1

1912 *Stylophora montium* n. sp. Oppenheim: 132, Taf. 14, figs 14–14a.
1975 *Stylocoenia montium* (Oppenheim). Kuzmicheva: 18, Tab. 1, fig. 1.
1988 *Stylocoenia montium* (Oppenheim). Drobne *et al.* 184, Pl. 29, figs 1–3.

A description, comparison and distribution of this species were given by Turnšek in Drobne *et al.* (1988).

Previously indicated occurrences: Paleocene of Rosići in Majevica in northern Bosnia, Montian-Thanetian of Luzanovka in Ukraine.

Occurrence on the Adriatic platform: Dolenja vas: DvW-22 (4683). Zone SBZ2.

***Stylocoenia neutra* Barta-Calmus, 1973**
Pl. 2, figs 2–5

1973 *Stylocoenia neutra* sp. n. Barta-Calmus: 200–202, Pl. 10, figs 10–13.

A description was given by Barta-Calmus (1973). Our specimens form bulbous subcerioid colonies with polygonal corallites, and produce new buds extracalicinally. Septa are compact, developed in a hexameral system, the first cycle joining with the styliform columella. Their lateral granulations are small. Wall is septothecate, endotheca is consisting of tabulate dissepiments. Microstructure is very poorly preserved.

Dimensions of our specimens: d = 1–1.2 mm, s = 12 (6+6).

Comparison: Our specimens are almost identical to those of Barta as to their structural features and their dimensions d = 1–1.5 mm, s = 12 (6+6). They differ a little as to their columella, which in our specimens is more irregularly joined with the septa and endotheca better preserved.

Previously indicated occurrences: Sud de Blieux in Basses Alpes, France, Eocene.

Occurrences on the Adriatic carbonate platform: Dolenja vas: DvW-29. Zone SBZ3; Sopada Sop-6/0 (10463, 10456, 10457, 10459, 10461, 10462). Zone SBZ4.

Subordo: Dendrophylliina Vaughan & Wells, 1943
Fam.: Acroporidae Verrill, 1902

Genus: *Haimesastraea* Vaughan, 1900

***Haimesastraea peruviana* Vaughan, 1922**
Pl. 3, fig. 1

1922 *Haimesastraea peruviana* n. sp. Vaughan: n. v.
1974 *Haimesastraea peruviana* Vaughan. Frost & Langenheim: 193–194, Pl. 29, figs 1–5.
1988 *Haimesastraea peruviana* Vaughan. Drobne *et al.*: 186, Pl. 30, fig. 3.

Description and distribution were given by Turnšek in Drobne *et al.* (1988).

Previously indicated occurrences: Paleocene-Lower Eocene of Mexico and NW Peru.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-9 (979). Zone SBZ1.

Genus: Astraeopora de Blainville, 1830

***Astraeopora pseudopanicea* Oppenheim, 1912**
Pl. 3, figs 2–6

1912 *Astraeopora pseudopanicea* n. sp. Oppenheim: 101–102, Pl. 10, figs 1–1a.

Description: The coral colony is massive, bulbous, plocoid, composed of round corallites and large peritheca. In cross section corallites have rounded outline. Septa are compact corresponding to an hexameral system. First cycle septa are thickened in their axial part, sometimes joined with each other. Second cycle is much shorter. Lateral ornamentations are consisting of rare granulae. An important part of the colony consists of a peritheca, named coenenchyme by Eliašova (1974). In the centre of the peritheca there are big round spaces which could be very large centres of calcification. Some of them could also be explained as new buds of young corallites. In our specimens the corallites appear as if they were surrounded by a paratheca. Endotheca is composed of very abundant tabulate and vesicular dissepiments. In the relevant literature it is emphasized that there is no columella. In our specimens the septa reach the centre and often join each other forming some kind of axial structure. The microstructure can be compared with the one described in *Astraeopora decaphyllia* by Eliašova (1974, 141, text-fig. 17) i. e. some kind of large trabeculae in the wall, and mini trabeculae with median line in the septa. In our specimens it is much more recrystalized.

Dimensions of our specimens: d = (1.2)1.5–1.8 (2) mm, cc = 1.5–2 mm, s = 12–14 (6+6+s3).

Comparison: Oppenheim (1912) mentioned somewhat larger corallites (d = ca 2 mm), but if we measure diameter of corallites on his figures it also shows 1.5 mm. The exact value of the diameter of corallite depends on the degree of wall recrystalzation. There is no real columella, but recrystalized and thickened axial endings of septa form some kind of axial structure.

The similar genus *Parastraeopora* Eliašova (1974) differs in being cerioid, and *Pseudastraeopora* (Russo, 1979) in having "septocostae and reticulated coenenchim".

Previously indicated occurrences: Probable Paleocene in Rosići (northern Bosnia).

New occurrences on the Adriatic carbonate platform: Sopada: Sop-7 (11133, 11134, 11136, 11137, 57734, 57735, 57736). Zone SBZ4.

Fam.: Dendrophylliidae Gray, 1847

Genus: *Dendrophyllia* de Blainville, 1830

***Dendrophyllia candelabrum* Hennig ,1899**
Pl. 4, figs 1–2

1899 *Dendrophyllia candelabrum* n. sp. Hennig: n. v.
1972 *Dendrophyllia candelabrum* Hennig. Floris: 92–93, Pl. 6, figs 35–37, Pl. 7, figs 2, 5, 6, (synonymy).
1988 *Dendrophyllia candelabrum* Hennig. Drobne *et al.*: 185, Pl. 29, figs 4–6.
1990 *Dendrophyllia candelabrum* Hennig. Bernecker & Weidklich: 113, Pl. 26, figs 1–2, Pl. 29, figs 1–4, Pl. 30, figs 1–2.

Description and distribution were given by Floris (1972) and also by Turnšek in Drobne *et al.* (1988, 185).

Previously indicated occurrences: Danian of Denmark, Lower Danian of Greenland, Lower and Middle Danian of Sweden, Paleocene of Medvednica.

Occurrences on the Adriatic carbonate platform: Dolenja vas: DvW-1, -7, -8, -15, -16, -18, -21, -22, -23, -28, -K/5986, DvE-31, -32, -37, -38. Zones SBZ1, SBZ2, SBZ3, SBZ4.

***Dendrophyllia dendrophylloides* Milne Edwards & Haime, 1850**
Pl. 4, fig. 5

1850 *Dendrophyllia dendrophylloides* M. Edwards & Haime: 36–37, Tab. 6, figs 2, 2a–c.
1975 *Dendrophyllia dendrophylloides* M. Edw. & Haime. Kuzmicheva: 28, Tab. 4, figs 2–3.
1988 *Dendrophyllia dendrophylloides* M. Edw. & Haime. Drobne *et al.*: 185–186, Pl. 30, figs 1–2.

Description and distribution were given by Kuzmicheva (1972) and also by Turnšek in Drobne *et al.* 1988.

Previously indicated occurrences: Lower Eocene of England, Montian-Thanetian of Luzanovka in Ukraine, Paleocene of Middle Volga region.

Occurrences on the Adriatic carbonate platform: Dolenja vas: DvW-7, -8, DvE-32, -37. (Not DvW-28 as mentioned in Drobne *et al.*, 1988. 186, text-fig. 16). Zone SBZ1.

***Dendrophyllia* sp.**
Pl. 4, fig. 4

In almost all investigated localities individual corallites were found which, in their structure, resemble the genus *Dendrophyllia*. The whole colonies are not known, so they are designated as *Dendrophyllia* sp.

Occurrences on the Adriatic carbonate platform: Dolenja vas: DvW-28; Sopada: Sop-5 (11141), Sop-8/2 (10367), Sop-12 (11120, 11121), Sop-13 (11112, 11113), Sop-14 (11105), Sop-16 (11068), Sop-18 (11062), Sop-28 (10881); Hrpelje–Kozina: Hrp-23 (11343), Hrp-25 (11333), Hrp-40 (11288, 11890); Breg: Br-IV/10, -IV/16, -V/30; Golež: Go-6, Go-10); ?Padriciano: Pad-G12. Zones SBZ2, SBZ3, SBZ4.

Fam.: Oculinidae Gray, 1847

Genus: *Oculina* Lamarck, 1816

***Oculina conferta* Milne Edwards & Haime, 1850**
Pl. 5, figs 1–4

1850 *Oculina conferta*. Milne Edwards & Haime: 27–28, Tab. 2, figs 2, 2a–b.

Description: Dendroid-phaceloid colony has cylindrical corallites, wich bud under an almost right angle. Corallites are in some places set very closely but in some become free and long after budding. Septa are compact, they are developed in irregular septal cycles, with strong lateral granulae. Wall is some kind of septotheca, but it has no costae outwards. Axial ends of septa thicken or join with pali to produce a papillose columella. Endotheca is consisting of thin rare dissepiments. Microstructure is very poorly preserved.

Dimensions of Adriatic specimens: d = 1.5–2 mm, s = ca 24.

Comparison: Our specimens show the characteristics of the species as originally described by all their structures, all patterns and even in their dimensions. Only adult corallites can be something longer. In dimensions they are also similar to *O. oziris* Wanner (1902, 100, Pl. 14, figs 8–9) from the Paleocene of Libya, but differ by having irregular septal cycles.

Previously indicated occurrences: London Clay at Bracklesham Bay, England, Lower Eocene.

New occurrences on the Adriatic carbonate platform: Sopada: Sop-8 (10334–10343), Sop-8/H (11239–11256), ?Sop-6/0 (10460, 10464); Hrpelje–Kozina: Hrp-23. Zone SBZ4.

Subordo: Meandriina Alloiteau, 1952
Fam.: Phyllocoeniidae Alloiteau, 1952

Genus: *Plocophyllia* Reuss, 1868

***Plocophyllia carstica* Turnšek, 1988**
Pl. 6, fig. 1

1988 *Plocophyllia carstica* n. sp. Drobne *et al.*: 187, Pl. 31, figs 1–3, Pl. 32, figs 1–3.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-23B (981a, b, c, d). Zone SBZ2.

Fam.: Dendrogyridae Alloiteau, 1952

Genus: *Orbignygyra* Alloiteau, 1952

***Orbignygyra* sp.**
Pl. 6, figs 2–3

Description: A fragment of the meandroid colony shows corallites in a single meandroide serie. Septa are compact, costate, differentiated in 3–4 cycles. They are axially thickened, and laterally granulated. The type of wall is paraseptotheca. Endotheca consists of thin tabular and vesicular dissepiments placed in thecal region only. The columella is thin, lamellar, continuous, sometimes joining with the axial prolongations of septa. Microstructure in septa and wall is recrystalized.

Dimensions: d of series = 4 mm, s = 6–7/2 mm (at wall).

Comparison: In the Eocene of Mexico the very similar coral *Placosmilia copoyensis* was found (Frost & Langenheim, 1974: 240–242, Pl. 83, figs 1–7). Our specimen could be compared with one of the meandroid parts of it, where they would fit in structure and dimensions. Nevertheless, the Mexican coral is more angular. Because of the presence of several meanders, the latter could perhaps be ascribed to *Orbignygyra*. Very similar is also the Upper Cretaceous *Orbignygyra daedalea* (Reuss) found also in Slovenia (Turnšek, 1994, 12, Pl. 6, figs 1–3) which differs from Paleocene form by loosely spaced skeletal elements (4/2 mm) and much shorter septa of the third cycle.

Occurrence on the Adriatic carbonate platform: Padriciano: (Pad-G/11). Zone SBZ4.

Fam.: Rhizangiidae d'Orbigny, 1851

Genus: *Rhizangia* Milne Edwards & Haime, 1848

According to Beauvais (1982) *Rhizangia* was attributed to the Fungiina (Turnšek & Drobne *et al.*, 1988). Nevertheless, its compact septa and synapticulotheca as well as its lateral granulations without pennulae indicate a closer relationship to the Meandriina.

***Rhizangia* sp.**
Pl. 7, fig. 1

Description was given by Turnšek in Drobne *et al.* (1988, 188, Pl. 33, fig. 5).

We can compare our specimen with *Rhizangia* sp. described by Frost & Langenheim (1974: 285–287, Pl. 109, figs 1–7) from the Eocene beds of Mexico. Our specimen differs from the latter by its somewhat larger corallites (our specimen: d = 3–4 mm, s = 6+6+s; Mexican material: d = 2–3 mm, s = 12–24). *Rhizangia brevissima* Deshayes, 1834, described in Oppenheim, 1901 (224–225, Taf. 19, fig. 8) and 1912 (116–117, Taf. 13, figs 8–8a (not Taf. 14, fig. 1) is even larger in size and exhibits regularly spaced corallites.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-9 (979a, 4654). Zone SBZ1.

***Rhizangia padricensis* n. sp. /Turnšek/**
Pl. 7, figs 2–4

Name: after its type locality Padriciano (Northern Italy).

Holotypus: Pad-28 (11008).

Age: Upper Thanetian

Diagnosis: *Rhizangia* with cylindrical corallites of irregular hexameral septa, diameter of inner calice = 1.5– 2 mm, diameter including wall = 1.5–2.5 mm, s = 24 (6+6+12).

Description: Colony is reptoid with the phaceloid corallites connected by the stolonal offsets. Septa are compact, arranged in an irregular hexameral system. First cycle is thick, second and third cycles thinner and shorter. Lateral ornamentations are consisting of sharp granulae. Columella is very variable: different, parietal if built by prolongations of septa, lamellar if two oposite septa touch, lacking in some sections, taking a papillose appearance when axial structure is built of pali. the pali may appear in front of every septum or fuse with the septa to thickened axial endings. The wall is represented by a septotheca or synapticulotheca, in some places by an epitheca. Endotheca is consisting of rare tabulate dissepiments. The stolonal offsets exhibit a vermiculate costate and tabulate structure. Budding is extracalicinal lateral or circumoral with larger mother corallite and some smaller daughter corallites around. Microstructure is very poorly preserved: in transverse sections of the wall, only some kind of irregularly placed, middle trabeculae, can be observed; in transverse section of the septa short median lines occur sometimes.

Comparison: The Upper Cretaceous species of *Rhizangia* were revised by Beauvais (1982 II, 213–218). All are larger than ours (d = ca 10 mm, s = 48–100). Also the Eocene *Rhizangia brevissima* Deshayes, 1834 (see Oppenheim, 1901, 1912) is larger (d = 4–5 mm, s = 48).

New occurrences on the Adriatic carbonate platform: Padriciano: Pad-28 (11006, 11007, 11008), Hrpelje–Kozina: Hrp-16 (11366). Zone SBZ4; Dolenja vas: DvW-29, -5676, Golež: Go-9. Zone upper part of SBZ3.

Subordo: Fungiina Verrill, 1865
Fam.: Siderastraeidae Vaughan & Wells, 1943

Genus: *Siderastraea* Blainville, 1843

***Siderastraea* sp.**

The only thamnasteriid fragment of an encrusting colony (with d = 2–3 mm, s = 3–4 cycles) was described by Turnšek in Drobne *et al.* (1988, 187).

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvE-32/1). Zone SBZ1.

Genus: *Pironastraea* d'Achiardi, 1875

***Pironastraea discoides* d'Achiardi, 1875**
Pl. 8, figs 1–2

1875 *Pironastraea discoides* n. sp. d'Achiardi: 197–198, Pl. 18, figs 2–3.
1956 *Pironastraea discoidea* d'Ach. Wells: F385, fig. 276, 3.
1957 *Pironastraea discoidea* d'Ach. Alloiteau: 324.

Description: Circumoral thamnasteriid colony has porous, confluent, laterally granulated septa. Synapticulae are common, columella is not distinct, appearing as composed of a single separate pillae. Microstructure is very poorly preserved.

Dimensions: d in series ca 2 mm, d between series ca 2.5 mm, s = 10–11/2 mm (d'Achiardi: 30/5)

Comparison: In dimensions (d = 1–3 mm) *Cyathoseris parvistella* Oppenheim, 1912 (110–111, Taf. 13, fig. 3) is similar, however it differs from our species by its irregular, not circumoral series.

Previously indicated occurrences: Eocene (Lutetian) of Frioul, Italia.

New occurrence on the Adriatic carbonate platform: Padriciano: Pad-11/K-1 (11001). Zone SBZ4.

Fam.: Actinacididae Vaughan & Wells, 1943

Genus: *Actinacis* d'Orbigny, 1849

***Actinacis cognata* Oppenheim, 1901**
Pl. 8, figs 3–4

1901 *Actinacis cognata* n. sp. Oppenheim: 182, Taf. 12, fig. 7, Taf. 14, fig. 5.
1988 *Actinacis cognata* Oppenheim. Drobne *et al.*, 188, Pl. 33, figs 2–4.
1995 *Actinacis cognata* Oppenheim. Boselinni & Russo: 218–220, Pl. 1, figs 1–4, text-figs 1–2 (with complete synonymy).
1996 *Actinacis cognata* Oppenheim. Schuster, 73, Pl. 14, figs 8–9.

A modern description and revision were made by Bosellini & Russo (1995).

The dimensions of our specimens (d = 1.2–1.3 mm, cc = 1.3–2.5 mm, s = 20–24) fit with their descriptions.

Previously indicated occurrences: Paleocene of Medvednica in Croatia, Luzanovka in Ukraina, Majevica in Bosnia, Egypt, Eocene in Italy, Czech. R., Hungary etc. (see also: Bosellini & Russo, 1995).

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-23). Zone SBZ2.

Fam.: Poritidae Gray, 1842

Genus: *Goniopora* Blainville, 1830

***Goniopora elegans* (Leymerie, 1846)**
Pl. 8, fig. 5

1846 *Porites elegans*. Leymerie: n. v.
1875 *Stephanocoenia elegans* Leymerie. d'Achiardi: 184.
1912 *Goniaraea elegans* Leymerie. Oppenheim: 98–100, Taf. 12, figs 2–3, text-fig. 2.
1975 *Goniopora elegans* (Leymerie). Kuzmicheva: 26–27, Tab. 3, fig. 6.
1988 *Goniopora elegans* (Leymerie). Drobne *et al.*: 188–189, Pl. 34, figs 1–3.
1988 *Goniopora* sp. Drobne *et al.*: 189, Pl. 34, fig. 4.
1996 *Goniopora elegans* (Leymerie). Schuster, 73–74, Pl. 15, fig. 4.

Description, revision and distribution were given by Kuzmicheva (1975) and Turnšek in Drobne *et al.*, 1988.

Dimensions of our specimens: d = 2 mm, cc = 2–2.5 mm, s = ca 20 (11–13/2 mm).

Previously indicated occurrences: Paleocene of Rosići on Majevica in northern Bosnia, Montian-Thanetian of Luzanovka in Ukraine, Early Eocene of Egypt, Lower and Middle Eocene of Corbières in southern France.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-18, -20, -22. Zone SBZ2.

***Goniopora* sp.**
Pl. 8, figs 6,7

One specimen is very similar to *G. elegans*, but has a scarser skeleton.

Dimensions: d = (1.5) 2 mm, s = ca 16 (7–8/2 mm).

Because of its poor preservation it is not specifically determined.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-29). Upper part of the zone SBZ3.

***Goniopora hrpeljensis* n. sp. /Turnšek/**
Pl. 9, figs 1–4

Name: after the locality Hrpelje

Holotypus: Hr. 15 (thin sections: 11373, 11374, 11375)

Locus typicus: At the road Hrpelje–Kozina

Age: Upper Thanetian

Diagnosis: *Goniopora* with very small corallites of diameter 1–1.3 mm, cc = ca 2 mm, s = 20–24, density of vertical elements 15–18/2 mm.

Description: large bulbous or irregularly encrusting colonies have plocoid corallites. Porous septa are developed in 2–3 irregular cycles. They bear lateral pennulae. Columella is trabecular. Endotheca is consisting of synapticulae and rare thin dissepiments. The wall is incomplete synapticulotheca. Between corallites there is wide porous spongy peritheca. Microstructure is very poorly preserved. Transverse sections of septa reveal irregularly dispersed middle or large trabeculae (ca 50–100 mm).

Comparison: The new species has the smallest corallites within this genus. Their diameter is similar to the one observed in *G. copoyensis* (Frost & Langenheim, 1974, 238, Pl. 81, figs 5–6), but our specimens have much denser vertical skeletal elements. In *G. copoyensis* the density of the vertical elements is according to the picture ca 10/2 mm. In its description it is even mentioned, that the "vertical rods" were spaced 0.3–0.5 mm apart.

New occurrences on the Adriatic carbonate platform: Hrpelje–Kozina: Hrp-15 (11373, 11374, 11375) = holotype, Hrp-16 (11368, 11369), Hrp-23 (11345); Sopada: Sop-5/3 (10307), Sop-6/12 (10411, 10412, 10413), Sop-6 (57732), Sop-7/5 (57737); Breg: Br-IV/9, Br-IV/11, Br-IV/12, Br-IV/17); Padriciano: Pad-G-11, Pad-11/K (11000). All in zone SBZ4.

Genus: *Litharaea* Milne Edwards & Haime, 1851

***Litharaea subepithecata* Oppenheim, 1912**
Pl. 10. figs 1–2

1912 *Litharaea subepithecata* n. sp. Oppenheim: 103–104, Taf. 11, figs 7–8, Taf. 12, figs 12–12a.
1988 *Litharaeopsis subepithecata* (Oppenheim). Drobne *et al.*: 189–190, Pl. 35, figs 1–4.

Description was given by Turnšek & Drobne *et al.*, 1988. Then it was put by mistake into the genus *Litharaeopsis* Beauvais, 1982. Additional studies of more material show that there is no reason to exclude this species from the genus *Litharaea*, as the differences in width of the peritheca and the number of dissepiments may vary to a considerable extent.

Previous indicated occurrences: Paleocene of Rosići on Majevica in northern Bosnia.

Occurrence on the Adriatic carbonate platform: Dolenja vas: DvW-24. Uppermost part of the zone SBZ2.

***Litharaea websteri* (Bowerbank, 1840)**
Pl. 10, figs 3–4

1840 *Astraea websteri*. Bowerbank: n. v.
1850 *Litharaea Websteri*. Milne Edwards & Haime: 38–39, Tab. 7, figs 1–1c.
1975 *Goniopora websteri* (Bowerbank). Kuzmicheva: 26, Tab. 3, fig. 5.

A modern description was worked out by Kuzmicheva (1975). Our specimens are massive nodules with subplocoid corallites. Septa are very porous and irregularly developed in 2–3 cycles, laterally pennulated. Peritheca and wall are synapticulothecate. Columella is spongy. Microstructure is poorly preserved, but apparently characterized by large trabeculae. Often also a median line can be observed.

Dimensions: d = ca 4–5, s = ca 24+s (= 6–7/2 mm).

Remarks: *L. websteri* differs from *L. subepithecata* Oppenheim by its somewhat denser skeletal elements. Because of loosely spaced skeletal elements I attribute this species into *Litharaea* instead of *Goniopora*.

Previously indicated occurrences: Lower Eocene of England, Paleocene of the Middle Volga region.

New occurrence on the Adriatic carbonate platform: Hrpelje–Kozina: Hrp-23 (11344); Padriciano: Pad-GK, Pad-11/K (11004). Both in zone SBZ4.

Fam.: ?Thamnasteriidae Vaughan & Wells, 1943

Genus: *Mesomorpha* Pratz, 1883

***Mesomorpha* sp.**
Pl. 10. figs 5–6

Description: One single specimen is represented by a fragment having the characteristics of the genus. It looks like a piece of an encrusting, massive colony with subthamnasterid corallites, and compact, confluent septa. The synapticulae are very common, especially in the peripheral part of corallites. Peritheca is recrystalized. Columella looks styliform. Microstructure is not preserved.

Dimensions: d = 0.8–1 mm, s = 8–10, (in centrum= 7), density of costae in peripheral part = 5/1 mm.

Comparison and remarks: Our specimen is very similar to *Mesomorpha andrusovi* (Kuzmicheva, 1975, 24, Tab. 2, fig. 10, Tab. 3, fig. 1), nevertheless it is too poorly preserved for species determination. The revision and comparison of the genus *Mesomorpha* was worked out by Alloiteau (1957) and others but its systematic position is questionable and should be discused.

New occurrence on the Adriatic carbonate platform: Breg: Br-V/30. Zone SBZ4.

THE SUCCESSION OF CORALS WITHIN THE INVESTIGATED AREA

The stratigraphic zonation of the localities where coral specimens have been collected on the northern Adriatic platform is based on other fossils, mainly foraminifers and other stratigraphic arguments summarized in the following table:

		Paleocene			
		SBZ1	SBZ2	SBZ3	SBZ4
Dolenja vas W	(DvW)	1–16	18–24	25–30	
Dolenja vas E	(DvE)	38–31			
Sopada	(Sop)	–	28–23	22–9	8–3
Hrpelje–Kozina	(Hrp)	–	–	–	15–23
Breg	(Br)	–	–	–	IV/4–17
Golež	(Go)	–	–	6–10	–
Padriciano	(Pad)	–	–	–	11,12,28
		Dan/Selandian		Thanetian	

Remarks: Stages "Danian/Selandian and Thanetian" can be compared with shallow benthic zones SBZ1, SBZ2, SBZ3, SBZ4 after Serra-Kiel *et al.*, in print.

The earliest Paleocene corals on the northern Adriatic platform were found in the Dolenja vas section, beds 1–16 and 38–31 (Drobne & al., 1988) interpreted as of the SBZ1 zone. In this layers branching phaceloid and dendroid forms of the species *Dendrophyllia candelabrum* and *D. dendrophylloides* prevail. Small specimens or fragments of *Haimesastraea peruviana*, *Rhizangia* sp. and *Siderastraea* sp. are associated to the *Dendrophyllia*. Both *Dendrophyllia* species and many broken branches of unidentified *Dendrophyllia* sp. were found also in younger horizons.

The development of massive plocoid and thamnasterid corals in Dolenja vas started in levels 18–24 attributed to the SBZ2 zone. These were identified as *Actinacis cognata*, *Goniopora elegans*, *Litharaea subepithecata*. In the horizon 23b we found also the phaceloid form *Plocophyllia carstica*.

In the beds 25–30 in the Dolenja vas section the species *Stylocoenia neutra*, *Rhizangia padricensis* and *Goniopora* sp. were found. Theese beds are assigned to the SBZ3 zone.

In the other investigated localities (Sopada, Breg, Golež, Hrpelje and Padriciano) the corals emerged later than in Dolenja vas. In Sopada we found individual fragments of *Dendrophyllia* sp. in SBZ2 zone, forms of the species *Stylocoenia neutra* are known from the SBZ3 zone. To the same SBZ3 zone belongs the locality Golež with *Rhizangia padricensis* and *Dendrophyllia* sp. The majority of massive corals in all these localities appear in the SBZ4 zone: *Pironastraea discoides, Astraeopora pseudopanicea, Astrocoenia bistellata, Litharaea websteri, Orbignygyra* sp., *Oculina conferta*, particularly abundant is *Goniopora hrpeljensis*.

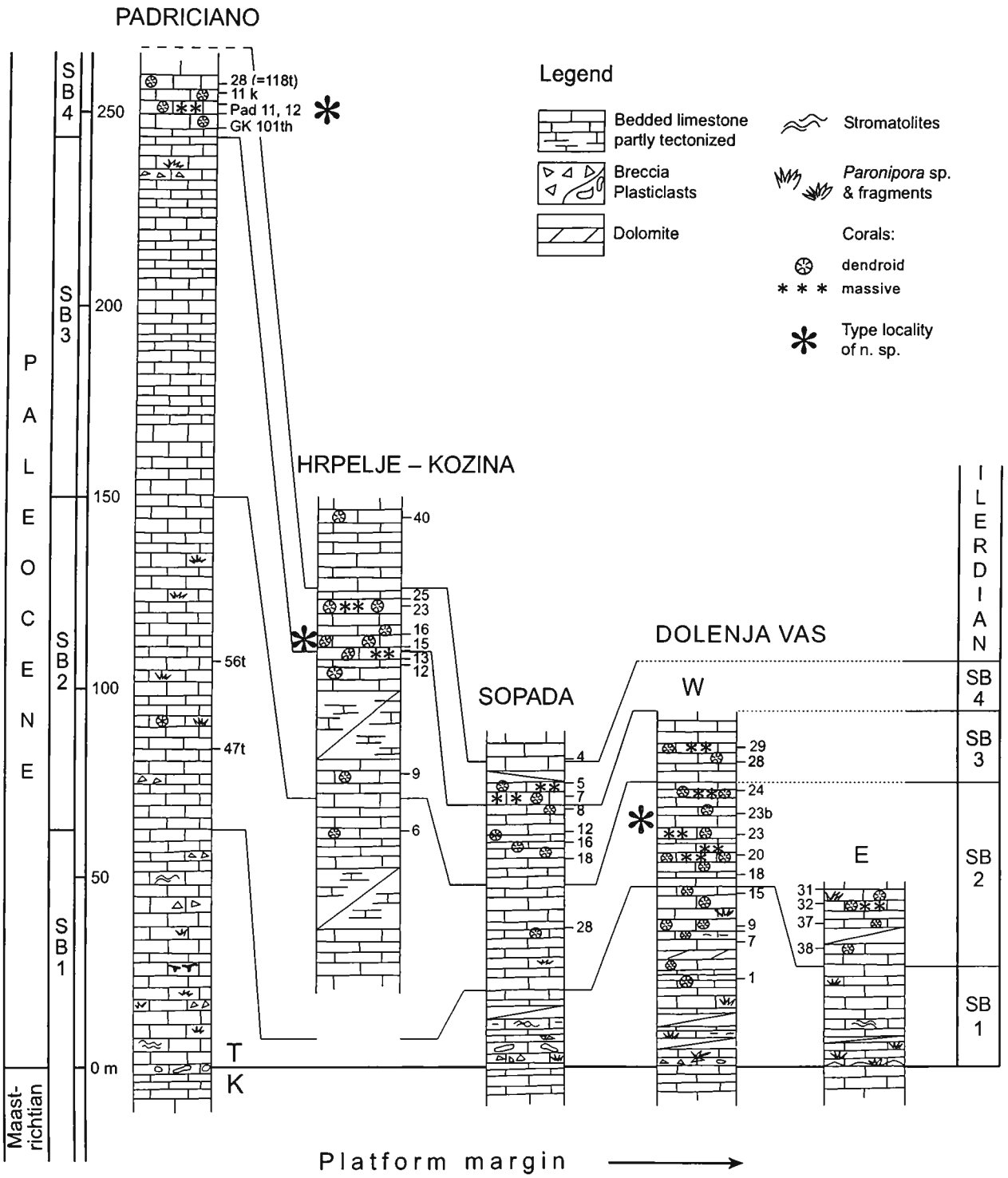

Fig. 3: Geologic columns with display of beds containing corals. Asterisk (*) marks the type horizon of the new species Goniopora hrpeljensis *n. sp.*, Rhizangia padricensis *n. sp. and* Placophyllia carstica *Turnšek, 1988. The thickness of the beds in the sections on the platform margin is considerably lower as in its interior part. There, the thickness of the sediments is particularly high during the Danian, owing to lagoonal-lacustrine depositional conditions. (Drobne* et al., *1996, Pugliese* et al., *1995, Brazzati* et al., *1996).*

From the paleoecological point of view it can be indicated that the oldest Paleocene corals in the Dolenja vas, located in the northernmost margin of the Adriatic platform are the first small coral specimens which appeared after the K/T crysis. They are mainly dendroid-phaceloid forms and cannot be considered as reef builders. They can be compared with group II of non-reefal az-like (azooxantellate) corals (see Rosen & Turnšek, 1989; Macleod *et al.*, 1997). Some of polyp individuals found their satisfactory place for surviving. The first patch reef building colonial corals settled the northern Adriatic platform in the Uppermost Danian (?Selandian) and in Thanetian. The phaceloid corals are accompanied by prevailing massive forms (*Actinacis* and others), and can be compared with group I of z-like (zooxantellate) corals (MacLeod, 1997). It seems that reef growth mooved from the north toward the south, i.e. from Dolenja vas toward Sopada, and further to Padriciano, Hrpelje–Kozina, Golež to Breg, and most probably can be explained by the following up the sea transgression wich as well widened from the north to the south. In the most convinient phases of the sea water oscilations connected with other favourable environments (sea level, temperature, nutrient supply, sunshine energy, water energy etc.) the corals for short periods found their living places and settled the local ecological nishes. By the same way the short term growth of patch reefs during Paleocene in middle Italy was explained by Moussavian & Vecsei (1995), as "controlled primarily by fluctuations of relative sea-level" within the eustatic cycles.

Very interesting is the variety of coral species in investigated localities. There are 15 of total 22 taxa limited to the one locality only, 4 taxa were found in two localities, one species in three, and two species in four localities. The most widespread are corals of the genera *Dendrophyllia*, *Rhizangia* and *Goniopora*. These types can be found in all so far known localities in Adriatic platform, but also in the wide area of Paleogene Tethys. The other species in Paleocene are rare and restricted to single localities. Such kind of local restriction can also be explained by the short term convinient environments which enabled the expansion of several individual colonies or species but lasted too short time to enable them to grow and multiply. Very soon corals were superseeded by less sensitive organisms.

Paleocene corals on the northern Adriatic platform appear as follows:

SBZ1 (Danian)
Haimesastraea peruviana Vaughan, 1900
Dendrophyllia dendrophylloides Milne Edwards & Haime, 1850 *Rhizangia* sp.
Siderastraea sp.
Dendrophyllia candelabrum Hennig, 1899

SBZ2 (Selandian/upper part of Danian)
Dendrophyllia candelabrum Hennig, 1899
Stylocoenia montium (Oppenheim, 1912)
Actinacis cognata Oppenheim, 1901
Goniopora elegans (Leymerie, 1846)
Litharaea subepithecata Oppenheim, 1912
Placophyllia carstica Turnšek, 1988
Dendrophyllia sp.

SBZ3 (lower part of Thanetian)
Dendrophyllia sp.
Goniopora sp.
Stylocoenia neutra Barta-Calmus, 1973
Rhizangia padricensis n. sp.
Mesomorpha sp.

SBZ4 (upper part of Thanetian)
Dendrophyllia sp.
Stylocoenia neutra Barta-Calmus, 1973
Rhizangia padricensis n. sp.
Pironastraea discoides d'Achiardi, 1875
Astraeopora pseudopanicea Oppenheim, 1912
Astrocoenia bistellata (Cattulo, 1856)
Oculina conferta Milne Edwards & Haime, 1850
Orbignygyra sp.
Goniopora hrpeljensis n. sp.
Litharaea websteri (Bowerbank, 1840)

WORLDWIDE DISTRIBUTION OF THE CORALS DESCRIBED

The corals from the investigated localities on the Adriatic carbonate platform have a world-wide distribution. The same and similar species are known from the Paleocene in Scandinavia (including Denmark, Sweden and Greenland) (Floris, 1972; Bernecker & Weidlich, 1990), from Pyrenees (Alloiteau & Tissier, 1958), Central Italy (Vecsei & Moussavian, 1997), Croatia (Polšak, 1985; Babić & Zupanič, 1981), North Africa (Wanner, 1902; Schuster, 1996), from Ukraina and Volga region (Kuzmicheva, 1975), and even Alabama (Bryan, 1991). Most probably, Oppenheim's (1912) so-called Eocene locality in Majevica in northern Bosnia is also of Paleocene age (Bulić *et al.*, 1978; Radoičić, 1991). Similar are genera *Oculina* and *?Cladocora* from Antarctica (Filkorn, 1994). Many other localities of Paleocene reefs are known from Europe, northern Africa, the Middle East, America (see compilations of Bryan, 1991; Schuster, 1996) where the corals have not been identified yet.

Some of the species found in the Paleocene strata of the Adriatic platform are also known from the Eocene of northern Italy, France, England, Czech R., Carpathians, Spain, Mexico and elsewhere (see: Barta Calmus, 1973; Frost & Langenheim, 1974; Eliašova, 1974; Drobne *et al.*, 1988, Bosellini & Russo, 1995; Schuster, 1996).

List of the described coral species with their Karst area and world stratigraphic zonation:

Species	Locality	Stratigraphic distribution						
		Adriatic platform Paleocene (Dan/Seland Thanet)				world		
		SBZ1	SBZ2	SBZ3	SBZ4	D	T	E
Dendrophyllia dendrophylloides	DvE-W	SBZ1				D	T	E
Rhizangia sp.	DvW	SBZ1				–		
Siderastraea sp,	DvE	SBZ1				–		
Haimesastraea peruviana	DvW	SBZ1				D	T	E
Dendrophyllia candelabrum	DvE-W	SBZ1	– SBZ2			D		
Stylocoenia montium	DvW		SBZ2			D	T	
Actinacis cognata	DvW		SBZ2			D	T	E
Goniopora elegans	DvW		SBZ2			D	T	E
Litharaea subepithecata	DvW		SBZ2			D	T	
Plocophyllia carstica	DvW		SBZ2			D		
Dendrophyllia sp.	Pad, Sop, Hrp, Br, Go		SBZ2	– SBZ3	– SBZ4	–		
Goniopora sp.	DvW			SBZ3		–		
Stylocoenia neutra	DvW, Sop			SBZ3	– SBZ4			E
Rhizangia padricensis	DvW, Pad, Hrp, Go			SBZ3	– SBZ4		T	
Pironastraea discoides	Pad				SBZ4			E
Astraeopora pseudopanicea	Sop				SBZ4		T	
Astrocoenia bistellata	Pad				SBZ4			E
Oculina conferta	Sop, Hrp				SBZ4			E
Orbignygyra sp.	Pad				SBZ4	–		
Goniopora hrpeljensis	Hrp, Sop, Br, Pad				SBZ4		T	
Litharaea websteri	Hrp, Pad				SBZ4	D	T	E
Mesomorpha sp.	Br				SBZ4	–		

LEGEND:

Stratigraphy: Paleocene zonation (SBZ1, SBZ2, SBZ3, SBZ4) after the Shallow Benthic zones (Serra-Kiel et al., 1998).

D = Danian, T = Thanetian, E = Eocene

Localities: DvW-E = Dolenja vas West and East, Sop = Sopada, Br = Breg, Hrp = Hrpelje–Kozina, Pad = Padriciano, Go = Golež.

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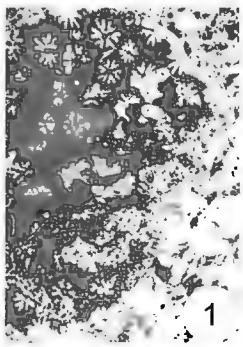
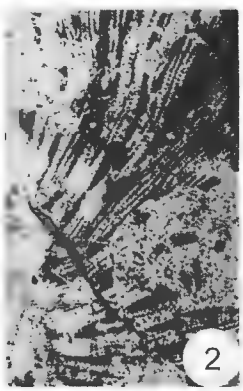
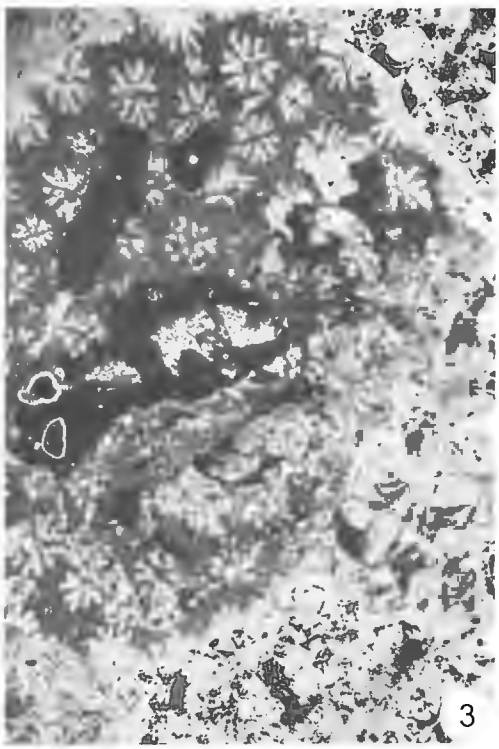
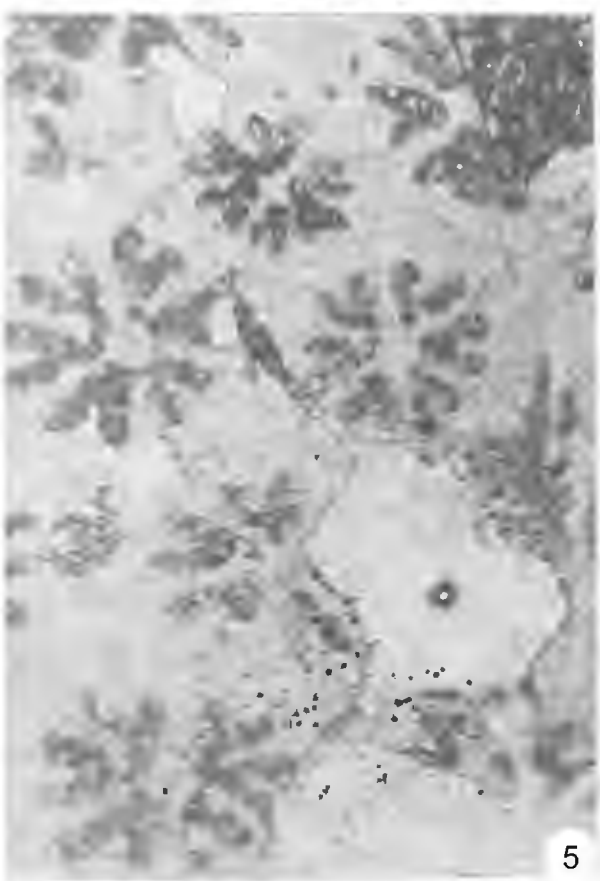
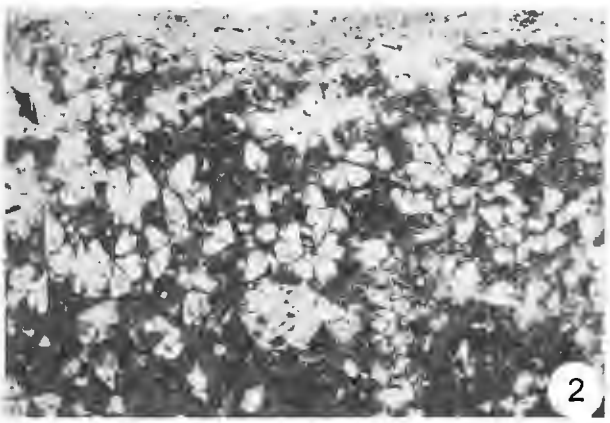


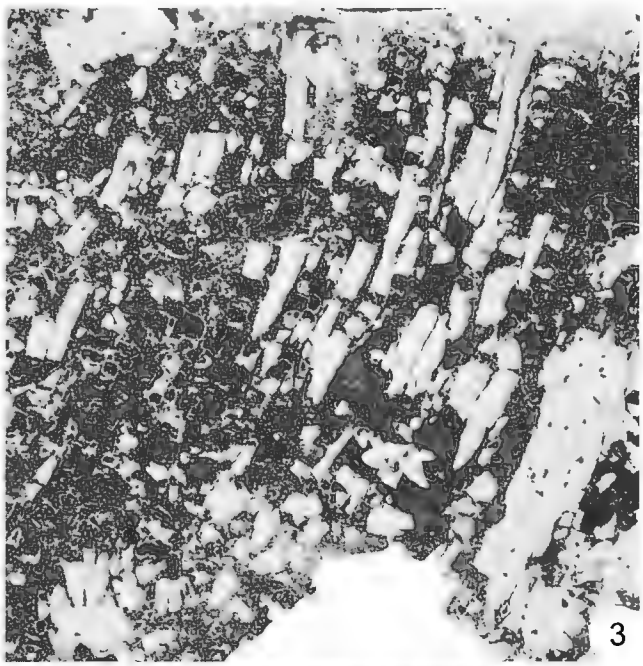


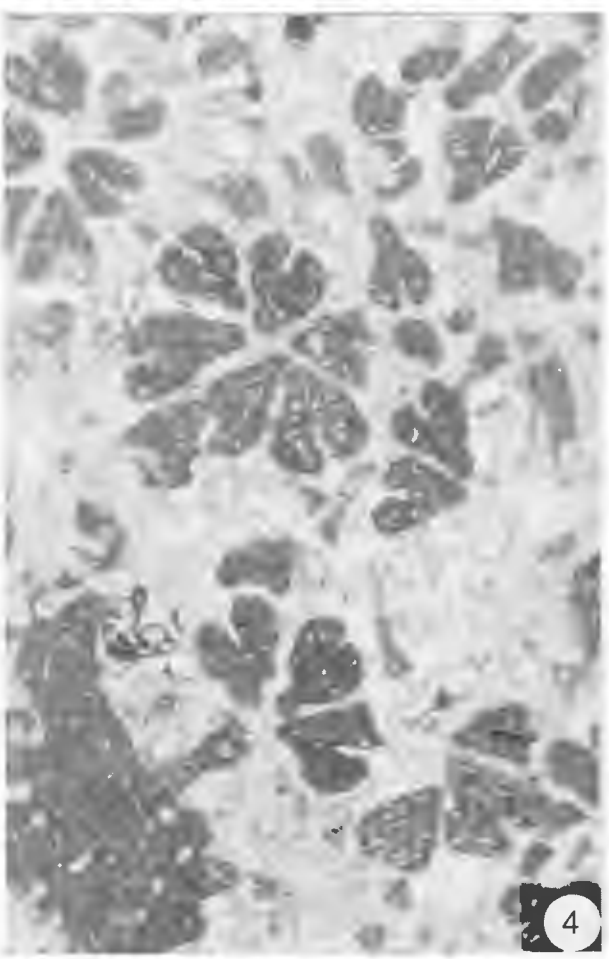




Figs **1–6:** *Aastrocoenia bistellata* (Catullo, 1856)
1, 3, 5: Pa-11 (11003); 2, 4, 6: Pa-28 (11005),
1–2 =× 4, 3–4 = × 8, 5–6 = × 30, U. SBZ3–SBZ4.







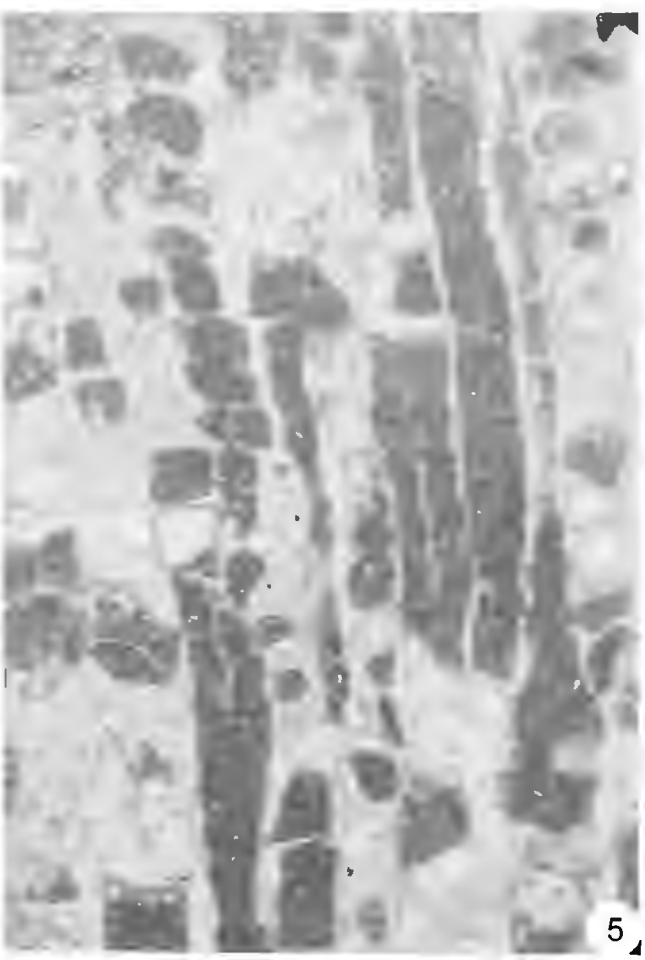
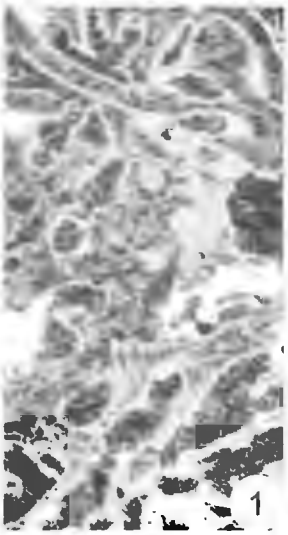
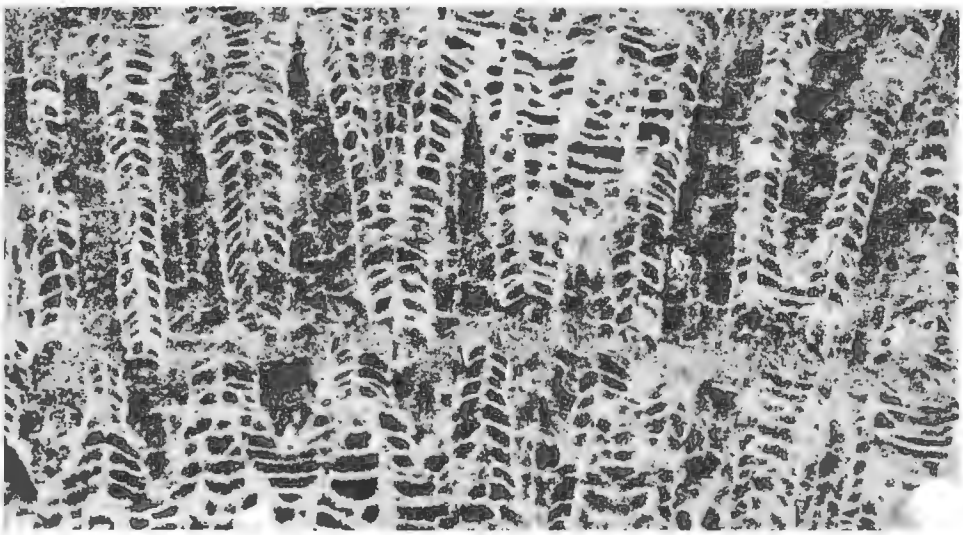
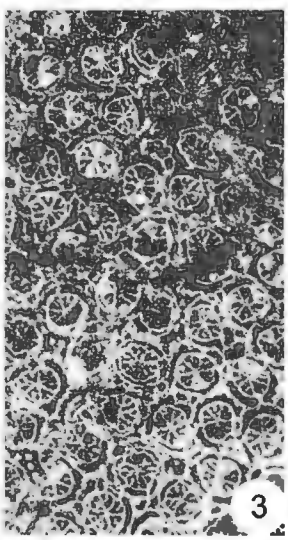


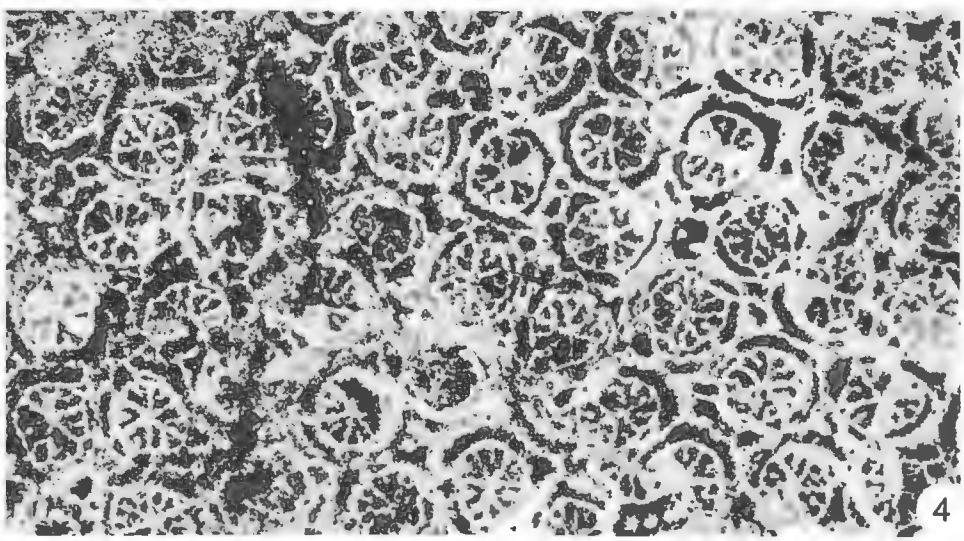
Fig. 1: *Stylocoenia montium* (Oppenheim, 1912)
DvW-22, × 6, SBZ2.

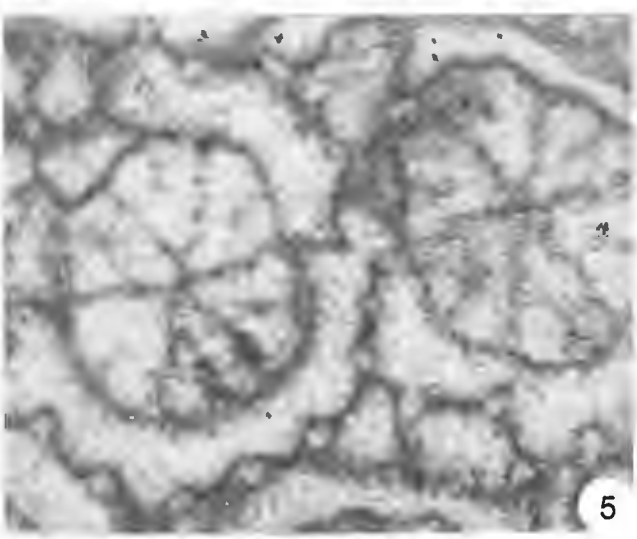
Figs 2–5: *Stylocoenia neutra* Barta Calmus, 1973
So-6 (10456); 2–3 = × 8, 4–5 = × 30, SBZ4.











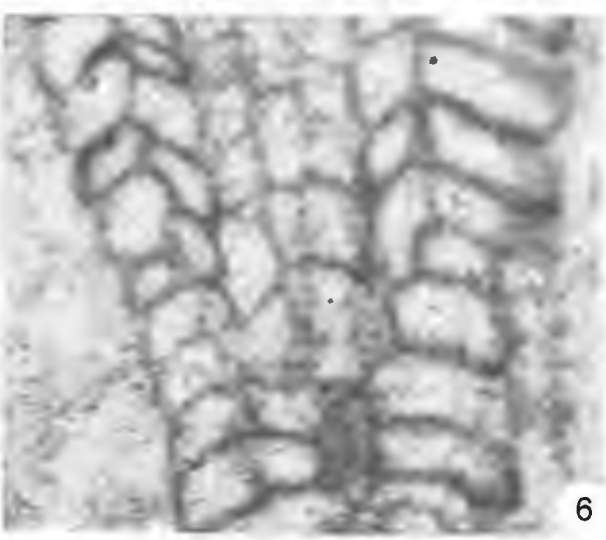
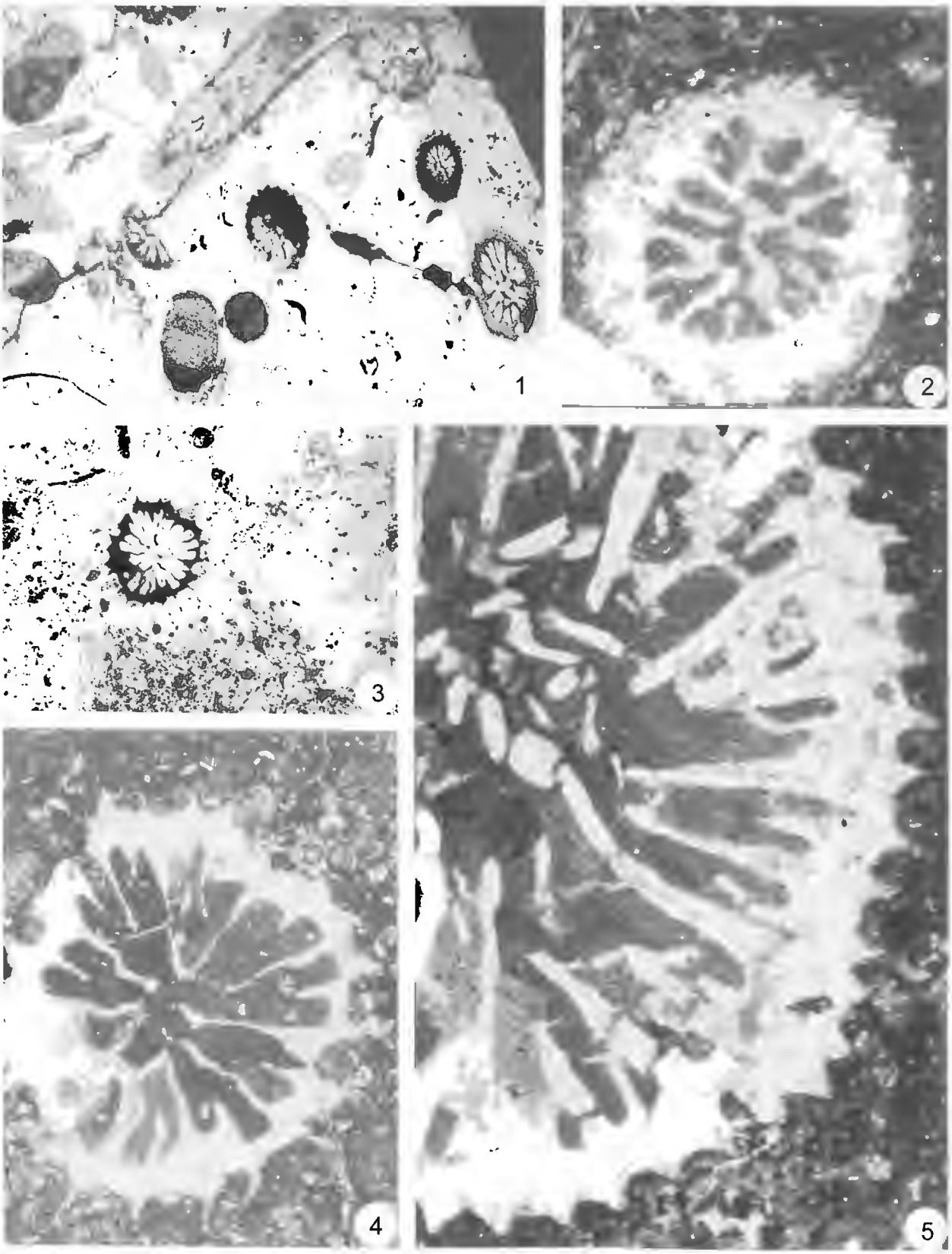


Fig. 1: *Haimesastraea peruviana* Vaughan, 1922
DvW-9, × 20, SBZ1.

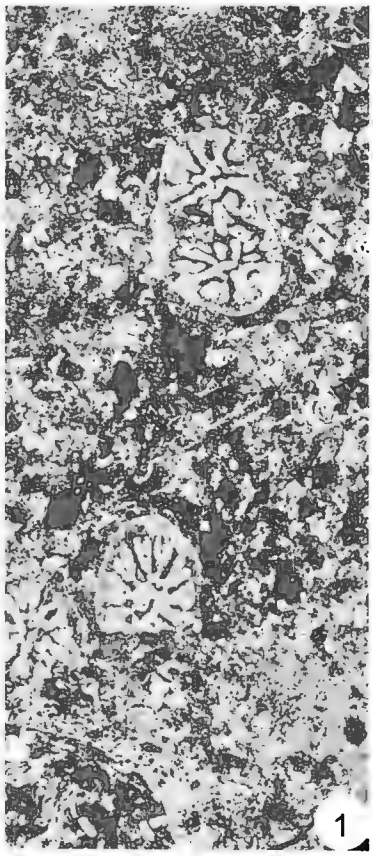
Figs 5–6: *Astraeopora pseudopanicea* Oppenheim, 1912
2, 6: So-7 (11137), 3, 4, 5: So-/ (11136);
2, 4 = × 8, 3 = × 4, 5–6 = × 30, SBZ4.

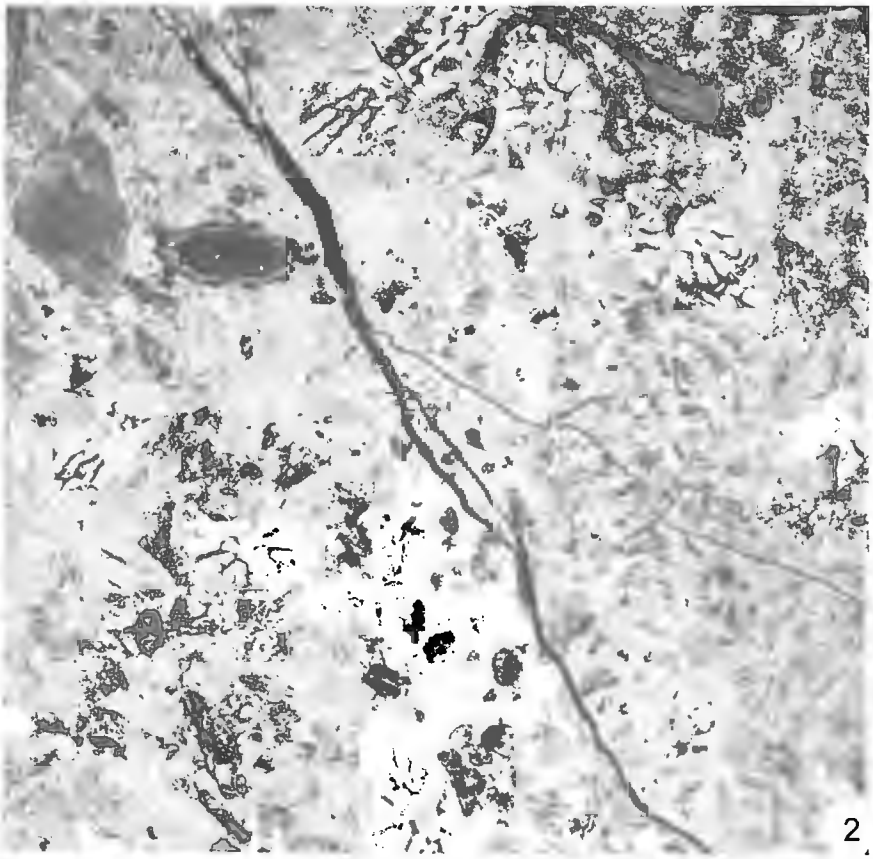


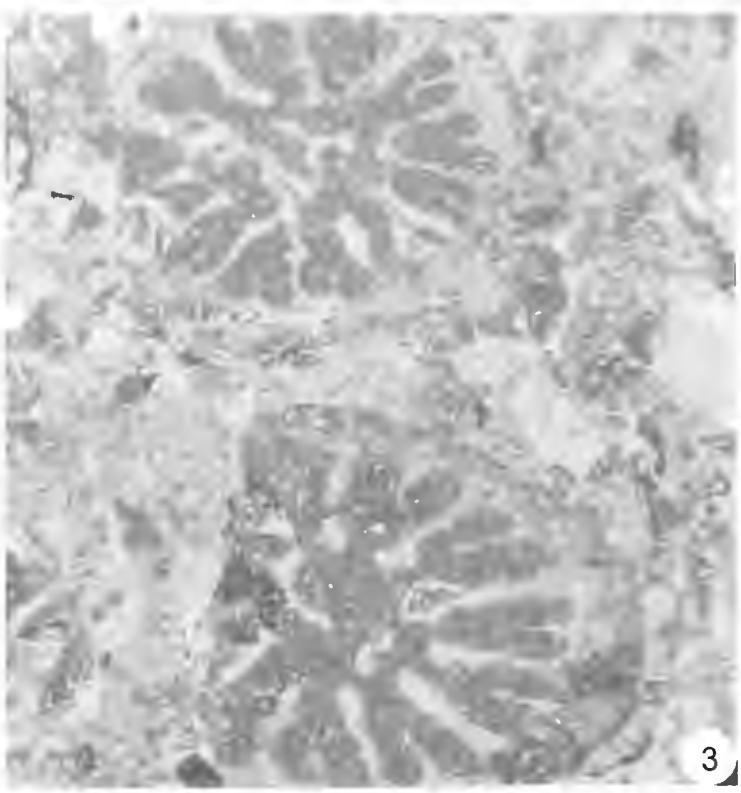
Figs 1–2: *Dendrophyllia candelabrum* Hennig, 1899
1: DvW-21 (4679), 2: DvW-7 (978a);
1 = × 6, 2 = × 30, SBZ1–SBZ2.

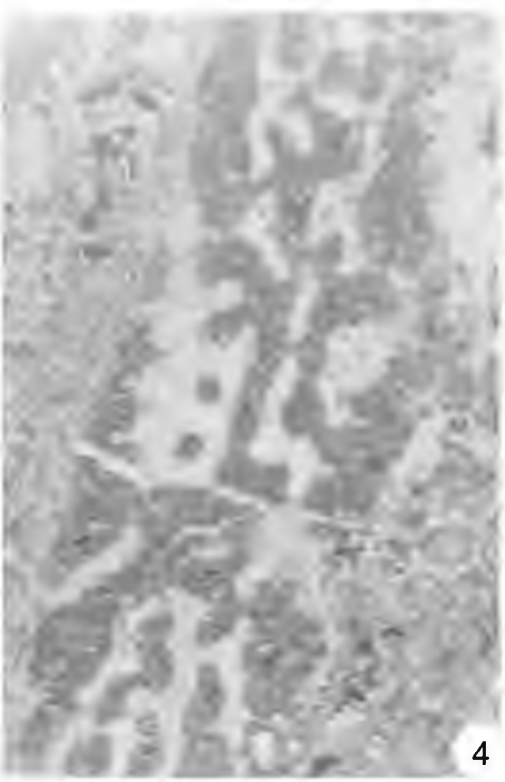
Figs 3–4: *Dendrophyllia* sp.
So-28 (10881); 3 = × 8, 4 = × 30, SBZ2.

Fig. 5: *Dendrophyllia dendrophylloides* M. Edw. & H., 1850
DvW-7 (978b); × 30, SBZ1.

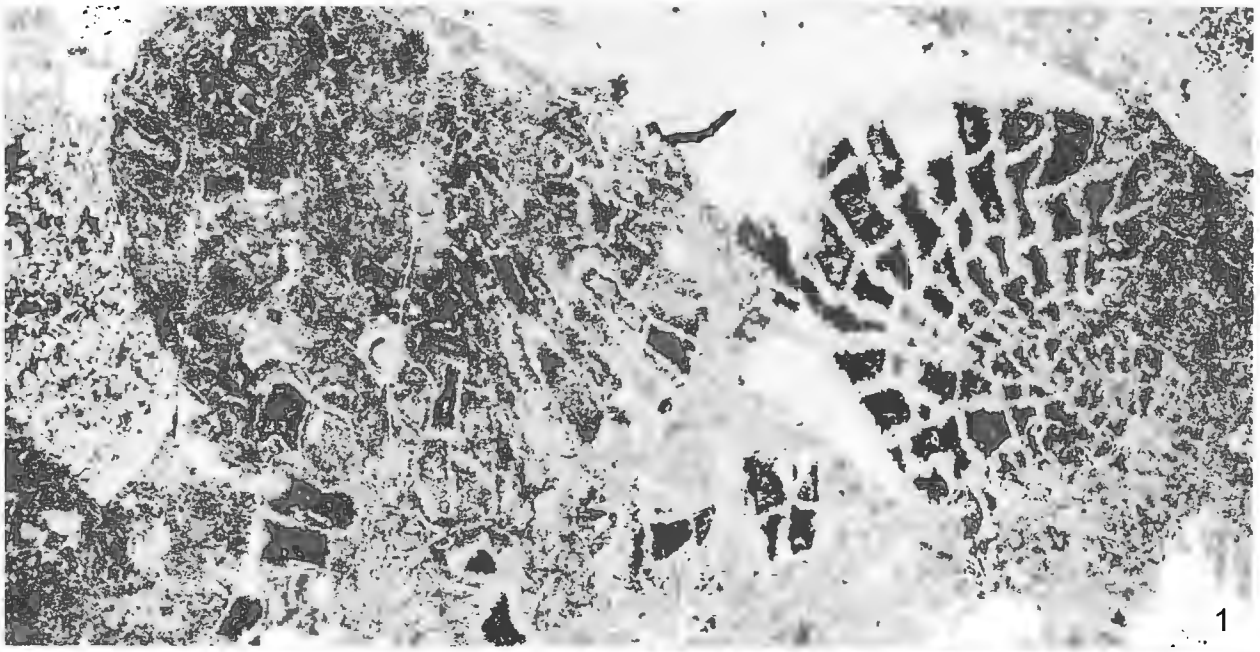








Figs 1–4: *Oculina conferta* M. Edw. & H., 1850
1, 3: So-8 (11245), 2, 4: So-8 (11239);
1–2 = × 8, 3–4 = × 30, SBZ4.



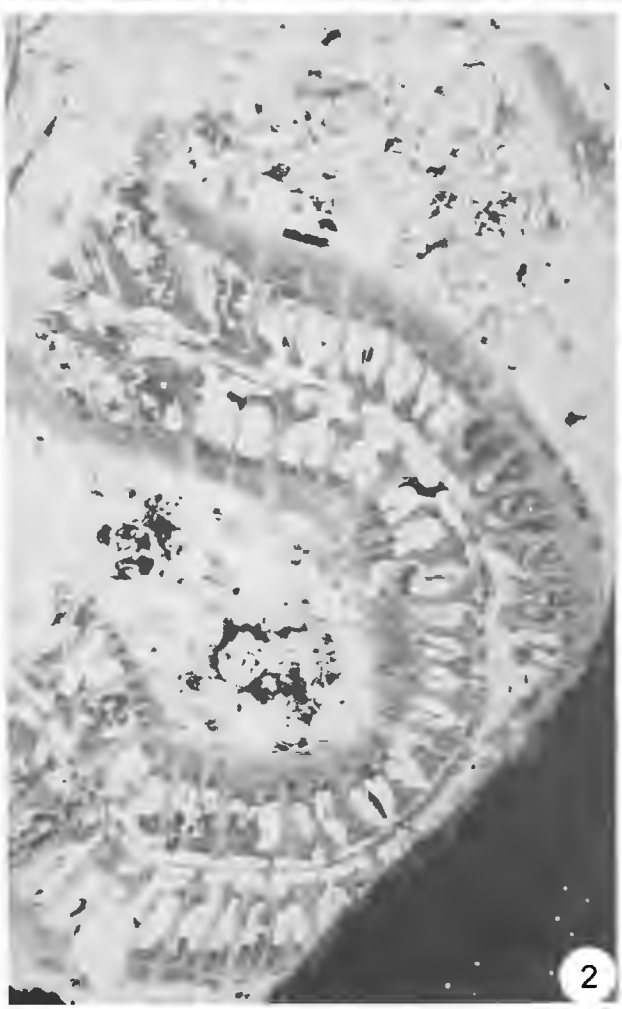
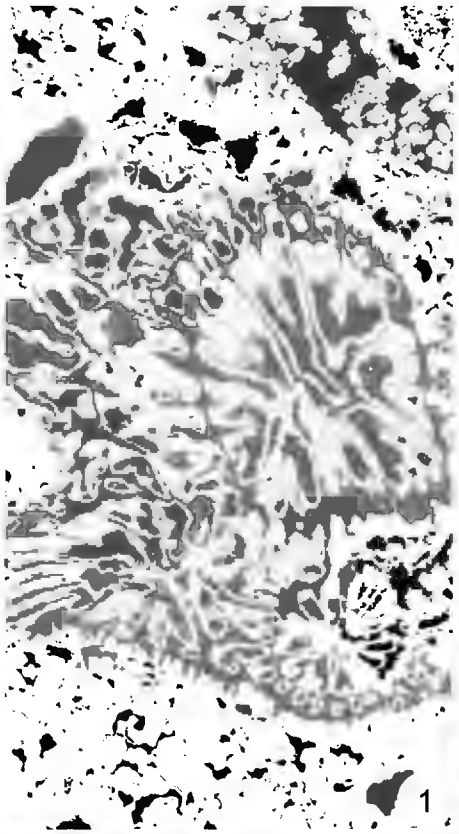
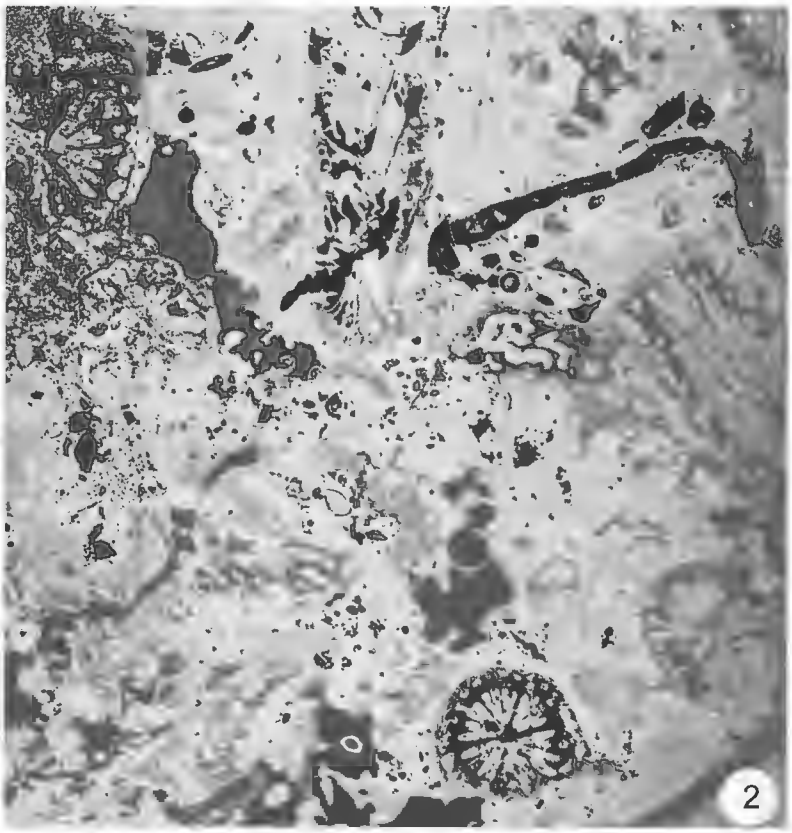


Fig. 1: *Plocophyllia carstica* Turnšek, 1988
DvW-23B (981a), × 8, SBZ2.

Figs 2–3: *Orbignygyra* sp.
Pa-11, 2 = × 8, 3 = × 30, SBZ4.





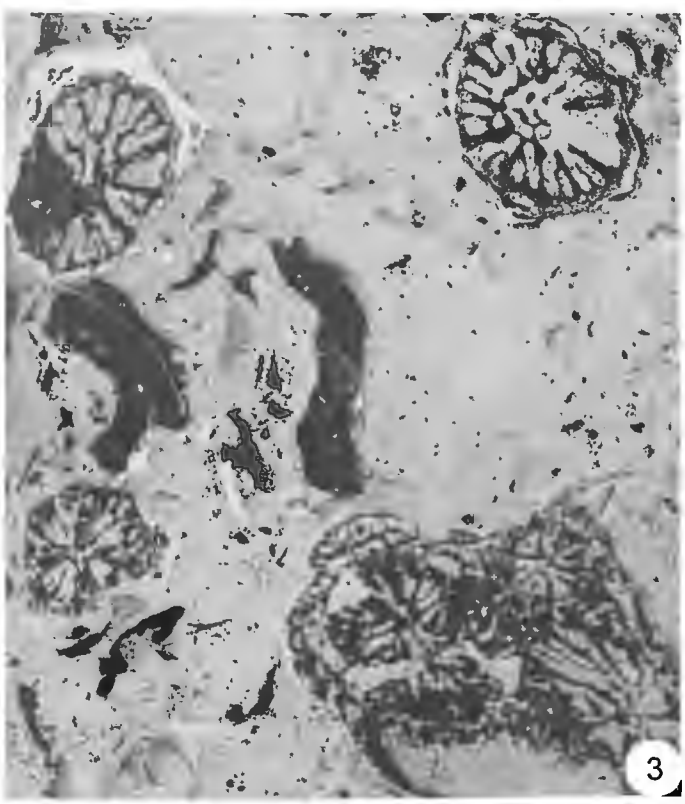
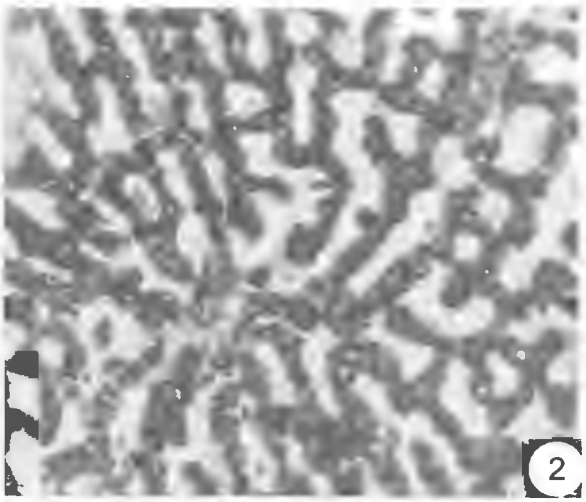
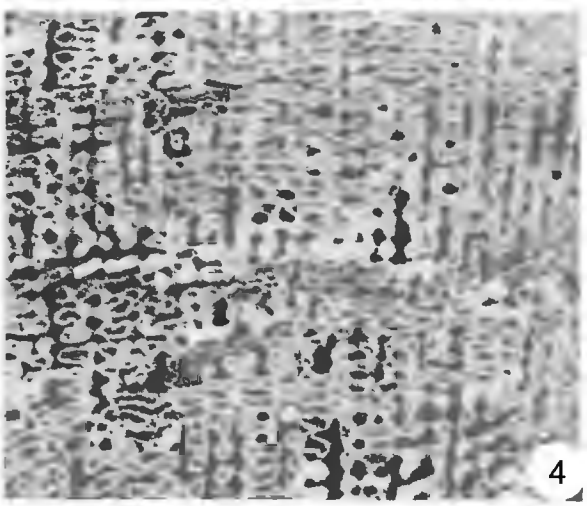
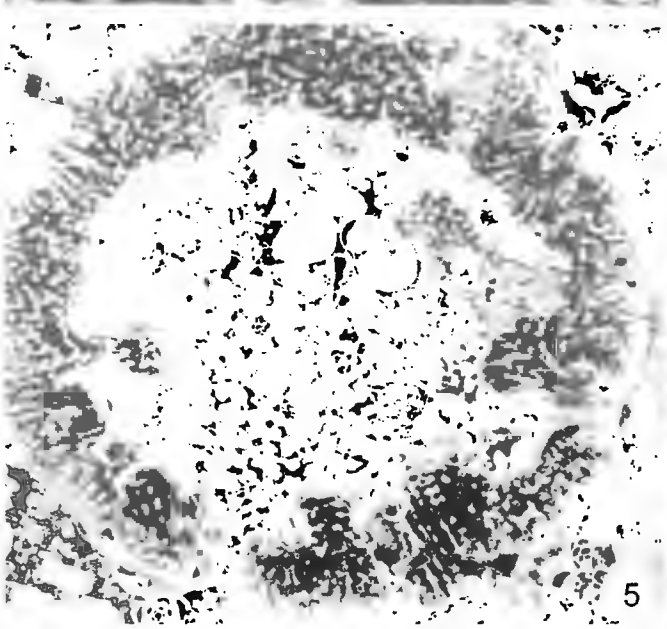


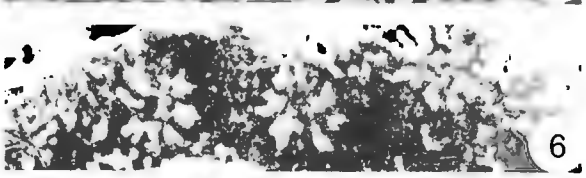
Fig. 1: *Rhizangia* sp.
DvW-9 (4654), × 8, SBZ1.

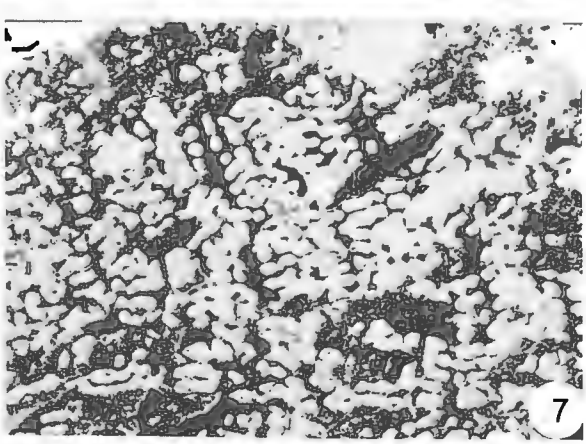
Figs 2–4: *Rhizangia padricensis* n. sp.
2, 4: Pa-28 (11008) (holotype), 2 = × 8, 4 = × 30, SBZ4,
3: DvW-29 (5676), × 10, SBZ3.









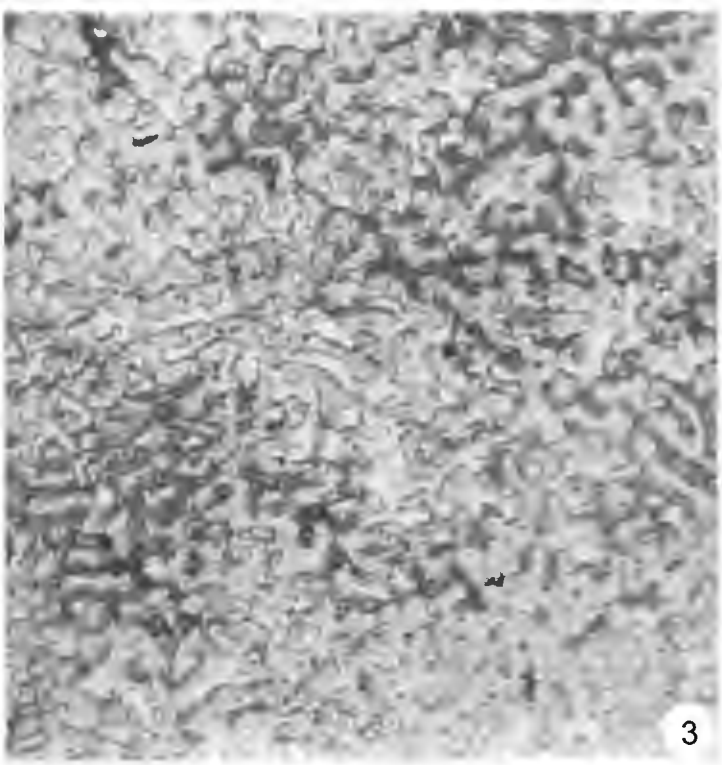


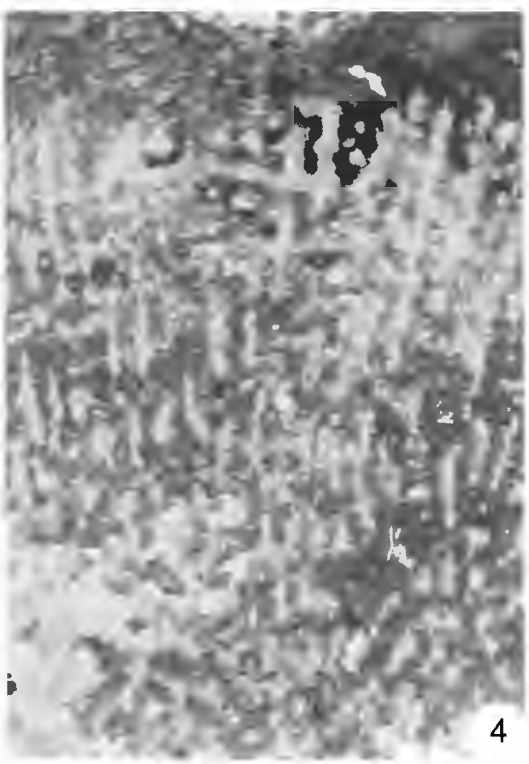
Figs 1–2: *Pironastraea discoides* d'Achiardi, 1875
Pa-11 (11001b), 1 = × 8, 2 = × 30, SBZ4.

Figs 3–4: *Actinacis cognata* Oppenheim, 1901
3: DvW-23 (4684), 4: DvW-23 (4685), 3–4 =× 20, SBZ2.

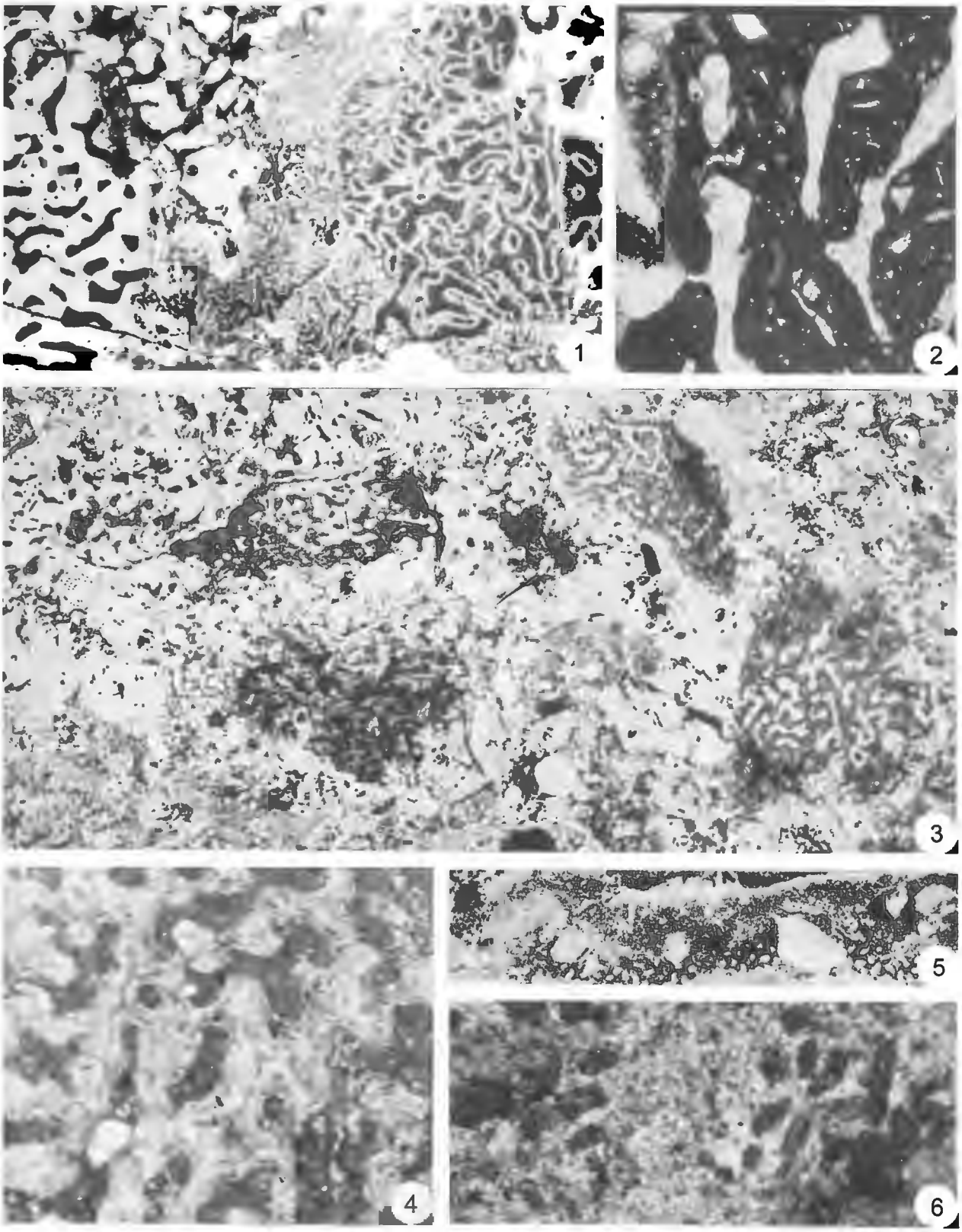
Fig. 5: *Goniopora elegans* (Leymerie, 1846)
DvW-18 (4673), × 8, SBZ2.

Figs 6–7: *Goniopora* sp.
6: DvW-29 (983c), 7: DvW-29 (4695), 6–7 = × 8, SBZ3.





Figs 1–4: *Goniopora hrpeljensis* n. sp.
1, 3, 4: Hr-16 (11368) holotype, 2: Hr-16 (11369),
1–2 = × 8, 3–4 = × 30, SBZ4.



Figs 1–2: *Litharaea subepithecata* Oppenheim, 1912 DvW-24 (982a), 1 = × 8, 2 = × 30, SBZ2.

Figs 3–4: *Litharaea websteri* (Bowerbank, 1840) Pa-11 (11004), 3 = × 8, 4 = × 30, SBZ4.

Figs 5–6: *Mesomorpha andrusovi* Kuzmicheva, 1975 Br-V/30, 5 = × 8, 6 = × 30, SBZ4.

Dela – Opera SAZU 4. razr.	34/2	155–163		3 Plates		Ljubljana 1998

EMENDATION OF *ALVEOLINA VREDENBURGI* DAVIES AND PINFOLD, 1937 FROM THE SURGHAR RANGE, PAKISTAN

Lukas Hottinger[1], Shahid J. Sameeni[2], and Ahmed Aftab Butt[2]

Abstract

Alveolina cucumiformis Hottinger, 1960 is considered a junior synonym of *A. vredenburgi* Davies and Pinfold, 1937 as emended on the grounds of a topotype taphocoenosis recovered from the uppermost Patala shales at Makerval, Surghar Range. The synonymy permits to combine the biostratigraphic ranges of the specimens attributed so-far to different taxa and to use them for trans-Tethyan correlation. Thus, the presence of *A. vredenburgi* indicates the shallow benthic biozones SBZ 5 and 6 which correspond to the planktic foraminiferal zone P 5 (*Morozovella velascoensis*) as deduced from direct association in the type locality and from indirect, complex, Tethys-wide correlation.

Résumé

Alveolina cucumiformis Hottinger, 1960 est considérée comme synonyme de *A. vredenburgi* Davies et Pinfold, 1937, taxon prioritaire. Ceci fut établi par une étude de topotypes d'*A. vredenburgi* découverts au sommet des marnes de Patala à Markerval, chaîne des Surghar, Pakistan. La synonymie permet de combiner l'extension stratigraphique définie par les specimens des deux taxa, ce qui conduit à les utiliser pour une corrélation biostratigraphique à travers toute la Téthys. Leur présence dans un sédiment indique donc un age SBZ 5–6 dans la nouvelle zonation benthique en milieu marneux peu profond, ce qui correspond à la zone de foraminifères planctiques P 5 (*Morozovella velascoensis*), correspondence établie par association directe à Makerval et par correlation indirecte complexe à travers la Téthys.

Key words: *Alveolina cucumiformis*, *Alveolina vredenburgi*, taxon emendation, biostratigraphic range, trans-tethyan correlation.

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INTRODUCTION

In the alveolinid zonation of the Paleogene (Hottinger and Drobne, 1988), *Alveolina cucumiformis* Hottinger, 1960 is a key species characterizing the earliest zone based on *Alveolina* sstr., i.e. on Eocene alveolinids with dimorphic adult growth stages. The species is most abundant in marly facies of the Pyrenean basin but occurs also on the Adriatic platform (Drobne, 1977, p. 40). Similar specimens identified as *A. cucumiformis* by L. Hottinger (1971) were discovered at the other end of the Tethys in material collected by P. Parks and W.O. Gigon at two localities in the area of Hyderabad, Pakistan from the Ranikot formation. The question arose, if *A. vreden-*

burgi, described earlier from the Salt Range, Pakistan, by Davies and Pinfold (1937) would be identical with *A. cucumiformis*, as suggested by a schematic drawing of an axial section by Davies (1927) or with another, elongate-oval species from the Nammal shales of the Salt Range collected by W.D. Gill and figured by Hottinger (1971, pl. 1 E) under the name *A.* sp. 1. Davies and Pinfold's (1937) only picture shows slightly pointed poles in the external view of the shell similar to the Nammal shale species. Topotypes had to be found in order to solve the problem by characterizing the specific identity of *A vredenburgi* in axial sections.

As a sequel of the GEOSAS I Congress in Islamabad 1992, the senior author of this paper was offered an occasion to repeatedly visit and sample a certain number of sections in the Salt Range under the guidance of the colleagues from Punjab University headed by A. Butt and accompanied by a crew from Barcelona University headed by J. Serra-Kiel. During this fieldwork, Davies and Pinfold's type locality for *A. vredenburgi* at the top of the Patala shales in the Markerval section has been rediscovered and sampled. The litho- and biostratigraphy of the Salt Range section will be published elsewhere as soon as the abundant and diverse faunas will be analysed to a satisfying degree of completeness. This preliminary paper is necessary to emend and redefine a key index species in order to support the new biozonation for the Paleogene, based mainly on larger formainifera (shallow benthic standard zonation SBZ, see Serra-Kiel *et al.* in press). The identity of *A. cucumiformis* with *A. vredenburgi* dissussed below provides a cornerstone for trans-tethyan correlation at the time level SBZ 5 (Earliest Ilerdian). One of the reasons why the index fossil names have been replaced by numbers in this SBZ zonation precisely is the frequent necessity to revise the names of the index fossils when topotypes from remote type localities after many years eventually become available as in the present case.

TYPES AND TYPE LOCALITY OF *ALVEOLINA VREDENBURGI* DAVIES AND PINFOLD, 1937

The type description of this species by Davies and Pinfold (1937) does not mention a type locality. However, their type figure on Pl. V, fig. 25 presenting a specimen designated as holotype is labeled in the legend as provenient from the Patala shales at Makerval, a well known section in the trans-indus Surghar-Range (Davies and Pinfold, 1937, pl. 1, see also Weiss, 1993, fig. 1). The type specimen is figured by its external aspect documenting a peculiar preservation where outer shell whorls are peeled off from the core exposing the open chamberlets as well as pre- and postseptal passages all over the shell surface.

Visiting the Patala shale outcrops at Makerval, we found a series of dark-gray marly beds deepening upward until their top below the Nammal shales marked by an abrupt colour change from dark-gray to white. This indicates a discontinuity in the sedimentation process. The upper part of the Patala shales is rather rich in planktonic foraminifera indicating a depth of deposition much superior to the habitat of alveolinids. About 8 m below the top of the Patala shales, there is a single bed, 20–50 cm thick, representing a conglomerate of various bioclasts and some lithic components up to 1 cm in size which are irregularly cemented. Part of the bed having a marly ground mass, the bioclasts can be separated and washed out in priviledged places. The conglomeratic bed is not graded, indicating a debris flow from shallower parts nearby into its present position in the basin. The single conglomeratic bed can be followed in the field for several hundred meters.

The bioclasts found in this conglomeratic bed mainly consist of shells of larger foraminifera, nummulites, assilinas and alveolinids transported from shallower environments to deeper places of final deposition. The alveolinids can be peeled off from the hard rock and show the same peculiar preservation as on Davies and Pinfold's type figure. In Makerval, and in all other comparable sections of the Salt Range up to Dhak Pass studied so far, the Patala shales have not yielded any alveolinids except in this unique conglomeratic bed at Makerval. Therefore, we consider this bed as type locality and type horizon of the species *A. vredenburgi* and the alveolina specimens recovered from this bed as topotypes of *A. vredenburgi*.

EMENDATION OF THE SPECIES *ALVEOLINA VREDENBURGI* DAVIES AND PINFOLD, 1937

Diagnosis: A moderately elongate species of the genus *Alveolina* sstr. in its lowest size-range. The topotypes from Makerval show a considerable variation in the thickening of the basal layer, both in polar direction and in the equatorial plane. The latter, equatorial thickening may reach a stage of faint flosculinisation in median to outer shell whorls. The polar thickening of the basal layer, responsible for the elongation of the shell, reaches a maximum between the 6th and the 12th whorl. Thus, the ontogeny of the shell can be divided into three parts, a nepionic, and adult, and a gerontic one.

The nepionic stage is composed by 3–6 whorls reaching an index of elongation of 1.4–2. The adult stage ends with about the 12th volution reaching an elongation between 1.8 and 2.6 The gerontic stage, rarely preserved, usually peeled off in free specimens, may comprise 3–5 whorls distinctly less elongated than the previous whorls, and lowering the final elongation of the shell to 1.9–2.2. At the adult stage, at equatorial diameters of about 0.8 mm, there are 6–7 chambers per whorl.

In the equatorial zone, the basal layer is thin in the tightly coiled nepionic stage and reaches the height of the chamberlets in adult and gerontic stages. Sometimes, it gets slightly thicker than the height of the chamberlets,

rarely so for more than one or two whorls (= faint flosculinisation).

In axial section, the poles of the shell appear rounded to slightly pointed. Their shape depends on the varying combination of equatorial and polar thickening of the basal layer in different growth stages. Seen from outside, the shape of the shell depends much on the growth stage, to which the peeling of the outer whorls has progressed: the holotype obviously is peeled to the end of the adult stage when elongation reaches its maximum during ontogeny.

There are 14–18 chamberlets per 1 mm chamber breadth, as counted in axial section, in polar direction. From equator to pole, the number of chamberlets in a chamber per 1 mm axial distance does not change significantly. Their cross-section has a more or less circular outline, slightly depressed in the distal part of the chamber, near the preseptal passage, slightly higher than broad in the proximal part of the chamber, near the postseptal passage.

The spherical proloculus varies from 110–150 µm in diameter. Its size ranges therefore just above the threshold value of nepionic dimorphism (Hottinger, 1963) suppressing the streptospiral early growth stage in the megalospheric generation. No microspheric specimens were found among the topotypes.

Remarks: The presently emended diagnosis is based on specimens from the taphocoenosis in the type locality at Makerval obviously reuniting the specimens of a certain depth range, i. e. from different habitats on the shelf. Therefore, the variability of the shell is considered to be comparatively large. This is in agreement with the depth-dependent variability of recent *Borelis schlumbergeri*, an extant alveolinid of similar shell size and shape range (Hottinger *et al.*, 1993, pl. 75). Taphocoenoses reflecting a more restricted, localized habitat are expected to be less variable.

The specimens mentioned from Haiderabad area by Hottinger, 1971 (Jamshoro Medical College and Karachi-Haiderabad road) under the name of *A. cucumiformis* (pl. 2, pl. 3, fig. 5) are more uniform as to their elongation and polar shapes than the topotypes of *A. vredenburgi*. However, their size, dimensions and the character of their basal layer approximating in thickness the height of the chamberlets are in our view sufficiently close to integrate the Haiderabad specimens into the species *A. vredenburgi*. Their diameter of the megalosphere varies from 110–145 µm, the number of chamberlets per 1 mm axial breadth of an adult chamber is 14 to 17. The peculiar, iron-stained preservation in one of these faunas (Pl. 2) produces an impression of a coarser architectural fabric as compared to the topotypes from Makerval which is not confirmed by the comparative measurements.

The Pyrenean specimens of *A. cucumiformis* Hottinger, 1960 from the type area also show a cosiderable variation: the index of elongation may range from 1.35 to 2.8 (mean 1.8–2.4). 15–17 chamberlets per 1 mm axial breadth of adult chambers. The megalosphere diameter is slightly larger than in the topotypes of *A. vredenburgi*, i.e. 140 to 195 µm, but there is no possibility to separate the two species statistically by this, in our view insignificant, discrepancy.

In higher stratigraphic levels of the Pyrenees, there occurs a somewhat larger-sized elongated alveolinid with much the same basic characters and proportions are observed in *A. vredenburgi*. This has been described under the name *A. cucumiformis tumida* by Hottinger (1960). The megalosphere diameter in this subspecies ranges from 175–215 µm and the index of elongation reaches 2.05–2.25 at the end of the adult stage. 10–15 chamberlets are counted per 1 mm axial breadth of adult chambers.

A. cucumiformis tumida is given here the rank of a species, i.e. *A. tumida* Hottinger, 1960, in spite of its relative rareness: the outer whorls of the megalospheric forms and the microspheric forms are missing and can therefore not be characterized. In view of its potential value as index fossil for higher stratigraphic levels we carry on this specific name until further notice.

The Nammal shales in the Salt Range frequently yield an oval-elongate species with pointed poles called *Alveolina* sp. 1 by Hottinger (1971, pl. I, fig. E) and tentatively put in relation to *A. vredenburgi*. We figure here the inner whorls of a megalospheric specimen on pl. 3, fig. 11 for comparison. Adult specimens from the Nammal shales reach about 50 % larger sizes than observed in *A. vredenburgi*, have a basal layer constantly thinner as compared to the height of the chamberlets in the equatorial zone, higher than large cross-sections of the chamberlets in the polar region, distinctly and permanently pointed poles and a regular gradual elongation increase in nepionic and adult stages. The spherical megalosphere is significantly larger, about 250 µm in diameter. Its microspheric forms are oval in outline, much less elongate than microspheric forms of *A. vredenburgi* from the Pyrenees. The Nammal shale species might be an endemic sideline of *A. ellipsoidalis* group, with pointed poles. It merits a name of its own to be published elswhere.

SYNONYMY OF *ALVEOLINA VREDENBURGI*

1927 *Alveolina oblonga* d'Orbigny. Davies, p. 282, text-fig. 4.

1937 *Alveolina vredenburgi* Davies and Pinfold. Davies and Pinfold, 57, pl. V, fig. 25.

1960 *Alveolina cucumiformis* Hottinger. Hottinger, p. 135, text-figs 26, 29/1, and 2, 71 c and d, 72, 73.

1971 *Alveolina cucumiformis* Hottinger. Hottinger, p. 148, pl. I, figs. F, G. non 1971 *Alveolina* sp. 1 (= ? *A. vredenburgi*). Hottinger, p. 148, pl. I, fig. E.

1977 *Alveolina cucumiformis* Hottinger. Drobne, p. 40.

1994 *Alveolina cucumiformis* Hottinger. Tambareau *et al.*, pl. 1, fig. 12.

1996 *Alveolina vredenburgi* Davies, 1937 = *Alveolina cucumiformis* Hottinger, 1960. Sameeni et Butt, Pl. 1, fig. 1.

BIOSTRATIGRAPHIC RANGE OF *ALVEOLINA VREDENBURGI*

The synonymy of *A. vredenburgi* with *A. cucumiformis* permits to compare and combine the ranges of the two species in order to use them for long-range, transtethyan correlation of shallow marly sediments deposited in the upper photic zone. *A. vredenburgi* characterizes the first zone of the Ilerdian stage as observed in particular in the Petites Pyrénées (Southern France), (Hottinger, 1960;Tambareau, 1994), in the Corbières, Southern France (Hottinger, 1960), in the Tremp area, Northern Spain (Hottinger, 1960; Luterbacher, 1973; Schaub, 1981; Barnolas *et al.*, 1990). In the Pyrenean realm, *A. vredenburgi* is associated to *A. avellana* Hottinger and *A. dolioliformis* Schwager. The three species, together with a possibly endemic Pyrenean species *A. varians* Hottinger, characterize the marly facies from this time interval.

Problems arize to correlate in detail this marly facies with pure limestones dominated by wide-spread spherical flosculinids such as *A. aramaea* Hottinger, *A. globula* Hottinger or *A. pasticillata* Schwager. The latter, associated in particular with *A. ellisoidalis* Schwager, characterizes the second zone of the Ilerdian stage, i.e. zone SBZ 6 in the new shallow benthic zonation (Serra-Kiel *et al.* in print). It is difficult to recognize the time-stratigraphic range of a species when facies changes tend to obscure evolutionary change in sedimentary sequence. Therefore, the top of the biostratigraphic range of *A. vredenburgi* might be located either prior to the first appearance of *A. ellipsoidalis* or overlap with the later's range and penetrate the SBZ 6 zone. *A. dolioliformis* has a rather extended range into SBZ 6 in Egypt and can therefore not be used to control the range of *A. vredenburgi*.

The biostratigraphic range of *A. vredenburgi* within SBZ 5 and maybe SBZ 6 is confirmed by its association with *Nummulites fraasi* (see Schaub, 1981) and other nummulitic species in the type locality at Makerval.

Both SBZ 5 and SBZ 6 zones correspond according to the correlation tables worked out so far (Barnolas *et al.*, 1990;Serra-Kiel *et al.*, in print) to the planktonic foraminiferal zone P 5 (*Morozovella velascoensis*) and to nannoplankton zone NP 9. *Morozovella velascoensis* occurs in the upper part of the Patala shales in Makerval into which the type level of *A. vredenburgi* is imbedded.

Thus, the presence of *A. vredenburgi* in a sediment indicates Tethys-wide an age corresponding to P 5 for all practical purposes of time-correlation.

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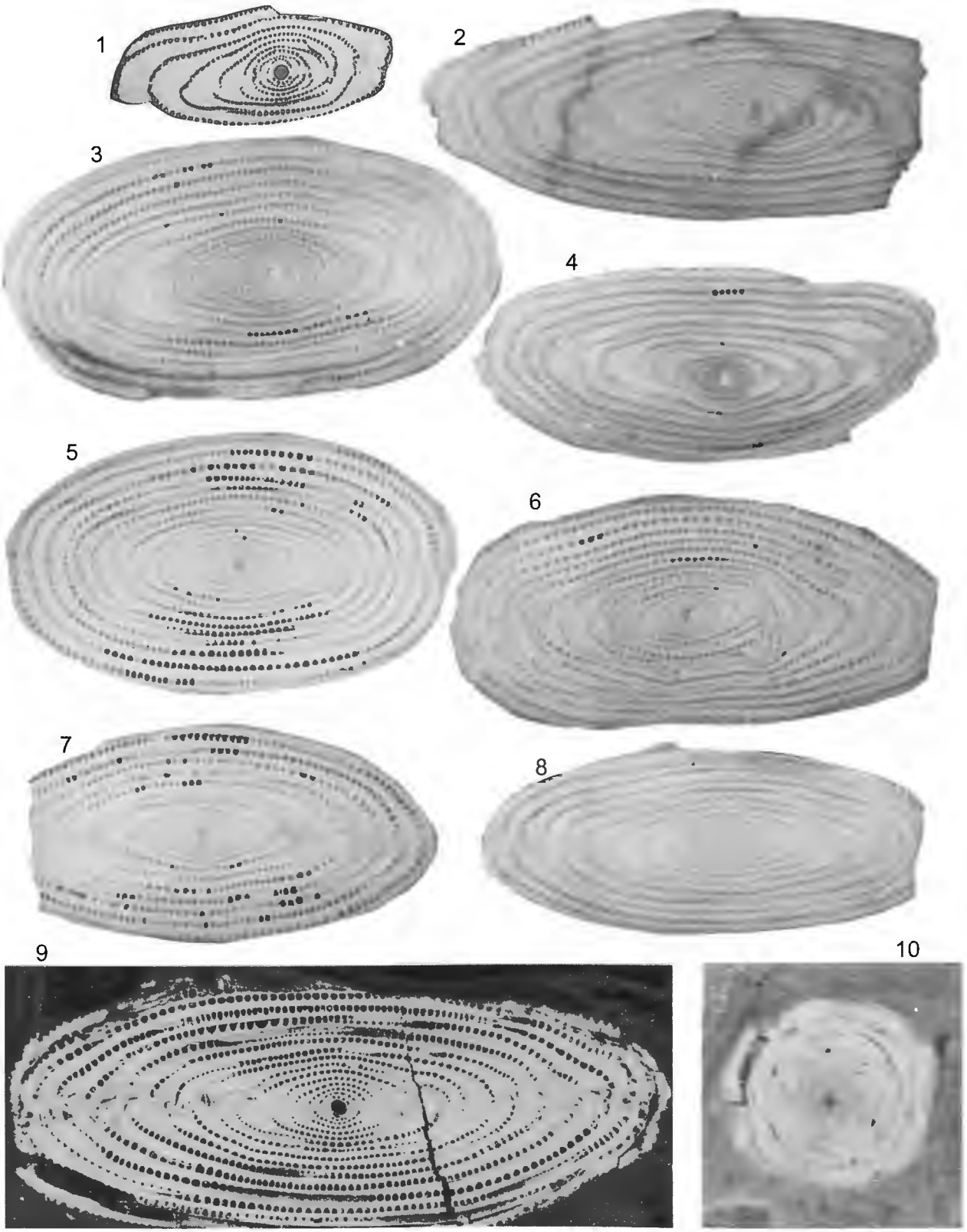

Alveolina vredenburgi Davies and Pinfold, 1937. Megalospheric topotypes from conglomeratic bed at the top of the Patala shales, Makerval, Surghar Range, Pakistan. SBZ 5–6.

Figs 1–9: Axial sections, fig. 10: equatorial section. Note specimens 3, 5 and 9 to be comparatively complete, all others lack larger or smaller parts of the gerontic and adult growth stages. Specimen 1 shows best the limit between nepionic and adult stages (arrow). Specimen 6 is regenerated.

PLATE 2

Alveolina vredenburgi Davies and Pinfold, 1937

Figs 1–10: Megalospheric specimens from an *in situ* taphocoenosis collected by W.O. Gigon in 1959 from a location 90.5 miles from Karachi on the road to Haiderabad, 40 m below the top of the Ranikot formation, and associated to *Assilina jiwani* (Davies and Pinfold). SBZ 5–6. Axial section. Shell cavities infiltrated by iron oxyde, porcellaneous shells recrystallized during diagenesis. Note the modest intraspecific variation.

Light microscope, transmited light, × 20.

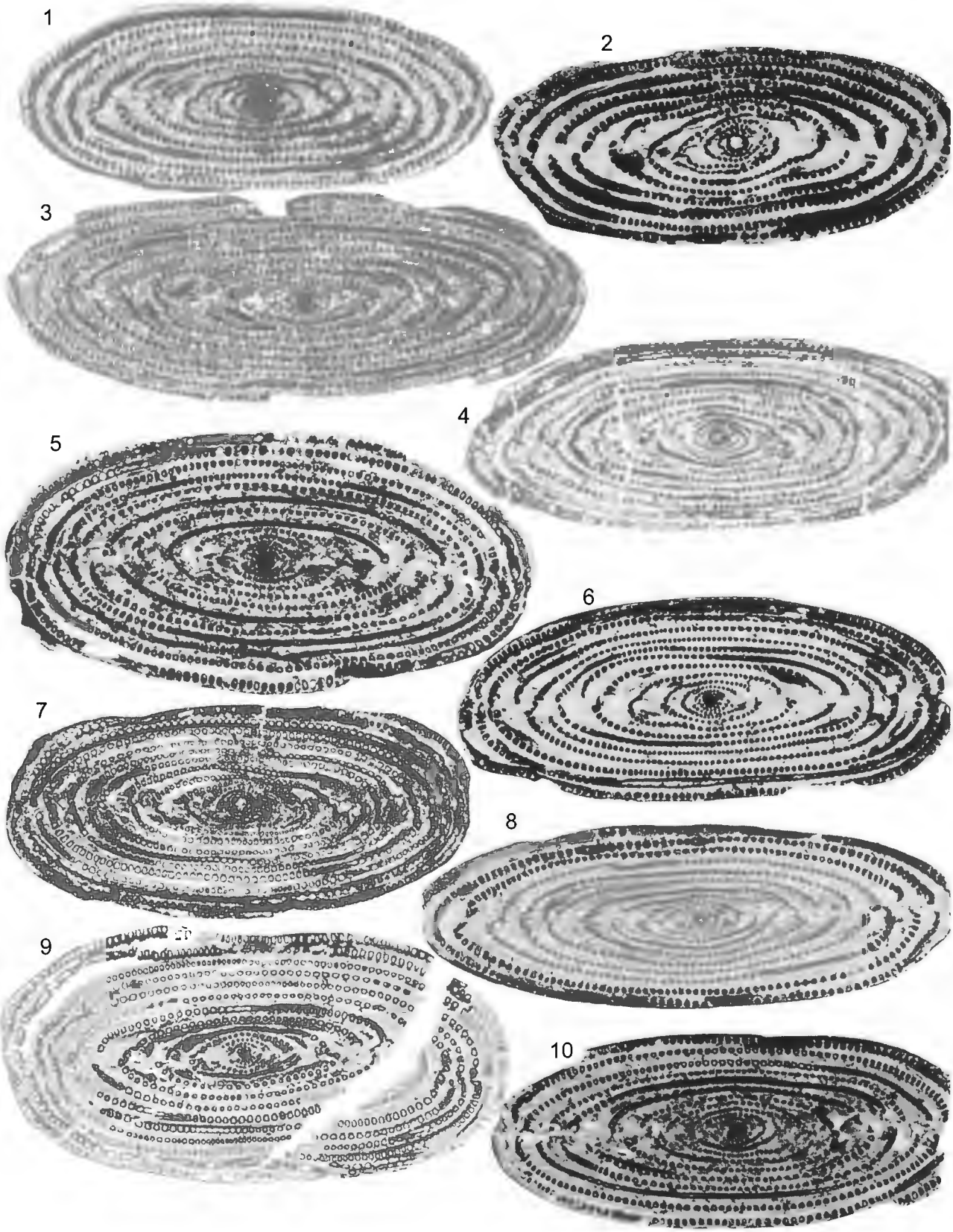
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PLATE 3

Alveolina vredenburgi Davies and Pinfold, 1973 and related forms for comparison. Axial sections of megalospheric specimens.

Figs 1, 2: *Alveolina tumida* Hottinger, 1960. Topotype (1) and holotype (2) from Assignan, Montagne Noire, Southern France (Hottinger, 1960, p. 197, fig. 103). SBZ 7 (*moussoulensis* zone).

Fig. 3: *Alveolina vredenburgi* Davies and Pinfold, 1937. Tightly coiled, oval specimen from Orignac, Southern France (Schaub, 1981, p. 45, fig. 44). SBZ 5 and 6 (associated with *Assilina tectosaga* (Hottinger, 1977) see ibid., legend pl. 24).

Fig. 4: *Alveolina vredenburgi* Davies and Pinfold, 1937. Specimen from the type locality of *Alveolina cucumiformis* Hottinger, 1960, i.e. from Tourtouse, Petites Pyrénées, Southern France. SBZ 5. See Hottinger 1960, p. 201. Note teh lack of early whorls broken away during preparation.

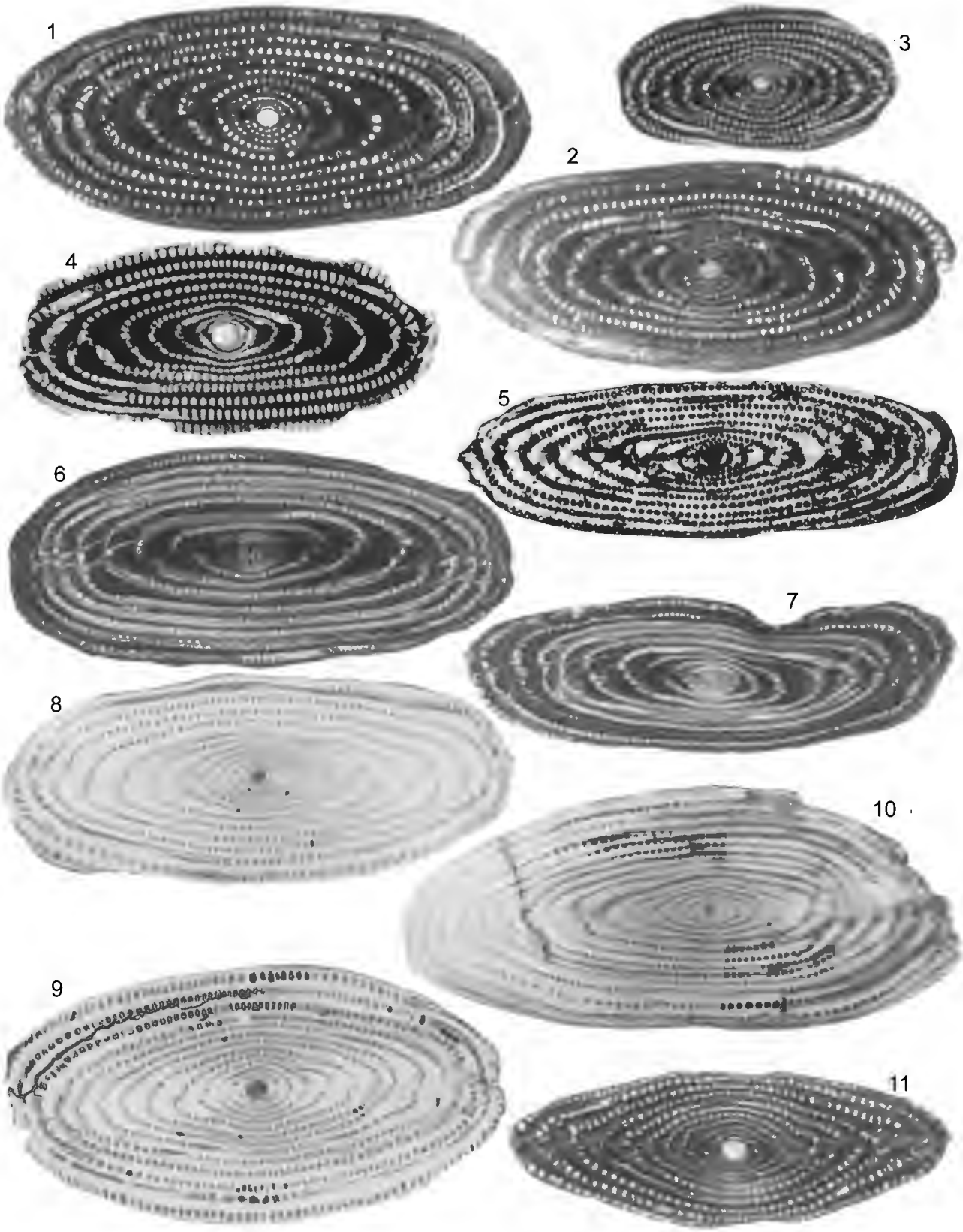
Fig. 5: *Alveolina vredenburgi* Davies and Pinfold, 1937. Specimen from an outcrop 90.5 miles from Karachi on the road to Hayderabad, 40 m below top of Ranikot fm. collected by W.O. Gigon, associated to *Assilina jiwani* (Davies and Pinfold). Shell infiltrated by iron oxyde and recrystallized.

Figs 6–7: *Alveolina vredenburgi* Davies and Pinfold, 1937. Specimens from Jamshoro Medical College, Hyderabad, collected by P. Marks, associated to *Assilina jiwani* (Davies and Pinfold) and *Ranikothalia nuttalli* (Davies) (see Hottinger, 1977, p. 57). The specimen 7 is crushed by a neighboring lamellar-perforate foraminifer resisting the compaction of teh sediment much better than a porcelaneous shell.

Figs 8–9: *Alveolina vredenburgi* Davies and Pinfold, 1937. Specimen from Tourtouse, Petites Pyrénées, type locality of *Alveolina cucumiformis*. SBZ 5. See legend Pl. 3, Fig. 4.

Fig. 10: *Alveolina vredenburgi* Davies and Pinfold, 1937. topotype from Makerval, see legend Pl. 1.

Fig. 11: *Alveolina* n. sp. 1, inner whorls, from sample 93546, Nilawahan section of Salt Range, upper part of Nammal shales, Middle Ilerdian (SBZ 7–8, confirmation of age pending until the rich associated fauna is fully analyzed).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NUMMULITES CATARI: A NEW SPECIES FROM THE LATE PALAEOCENE OF THE PYRENEAN BASIN

Josep Tosquella and Josep Serra-Kiel

Abstract

A new species of *Nummulites (N. catari)* from the late Palaeocene of the Pyrenean basin is described and illustrated. *N. catari* n. sp. shows a chronostratigraphic range restricted to the late Thanetian, and occurs associated to *Glomalveolina levis, Assilina yvettae. N. catari* is the first *Nummulites* found in the *Glomalveolina levis* Biozone or SB 4 Biozone.

Key words: *Nmmulites*, Palaeocene, Thanetian, Pyrenean basin.

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SYSTEMATIC DESCRIPTION

Superfamily Nummulitacea De Blainville, 1827.
Family Nummulitidae De Blainville, 1827.

Genus *Nummulites* Lamarck, 1801.

Type species: *Nummulites laevigatus* (Bruguière) [= *Camerina laevigata*, Bruguière 1792].

***Nummulites catari* n. sp.**
(text-fig. 1a–e; pl. 1, figs. 1–2; pl. 2, figs. 1–4).

1972 *Operculina* sp. aff. *Douvillei* Doncieux; TAMBAREAU: 218, pl. XIII, figs. 17–23; pl. XVIII, figs. 1–2, 4.
1995 *Nummulites catari* nov. sp.; TOSQUELLA: 298, làm. III, figs 1–2.
1995 *Assilina azilensis* TAMBAREAU; TOSQUELLA: 351, partim; làm. LVII, figs. 2, 4; non làm. LVII, figs. 1, 3, 5 (*Assilina azilensis*).

Diagnosis: *Nummulites* with flattened test and slightly swollen polar region, fairly loose spire, narrowly spaced thin septa, straight or slightly undulose in the lower part and strongly recurved in the upper part of the chamber, and thin septal filaments partially covering the previous whorls.

Derivation of name: From the "Pays Catar", region located in Southeastern France.

Holotype: Specimen NT95001 (Pl. 1, fig. 1) housed in the Departament de Geologia Dinàmica, Geofísica i Paleontologia, Facultat de Geologia, Universitat de Barcelona (Spain).

Material: Specimens from the Cérisols and Le Quillet localities (Pétites Pyrénées, Ariège, France).

Locality type: *N. catari* occurs in the Pétites Pyrenées

(Ariège, France) in the locality of Cérisols: "... la coupe de Cérisols effectuée au Nord du village, sur la route de Plagne ..." according to Tambareau (1972; vol. 1, p. 53).

Horizon type: "Marno-calcaire gréseux au dessus du calcaire à Nummulitidés dans le Complexe calcaire du Thanétien supérieur" according to Tambareau (1972; vol. 1, p. 78–79).

Description:

B-Form (microspheric generation).

The test is flattened with a slightly swollen polar region and rounded periphery (text-fig. 1b). In adults it varies from 5.0 mm to 9.0 mm in diameter and ranges from 1.0 mm to 1.5 mm in thickness. The spire is operculiniform with an irregular assilinoid tendency (text-fig. 1a; pl. 1, figs. 1–2). Chambers are narrow, slitly falciform, 5–10 × higher than long. The densly distributed septa are thin, irregular, straight or slightly undulose in the lower part of the chamber and strongly recurved in the upper part. The marginal cord is very thin, with a constant thickness ranging from 1/5 to 1/10 of the chamber height. The equatorial section shows radii of 1.1–1.3 mm in the 5th whorl, 2.3–2.4 mm in the 6th, and 3.8–4.0 mm in the 7th whorl. The number of chambers is about 22–24 in the 5th whorl, 25–30 in the 6th, 34–40 in the 7th and about 50 in the 8th whorl. The test is slightly involute, especially in the early stages of the spire, but the peripheral whorls also partially embrace the previous whorls (pl. 2, fig. 1). In fig. 1 (pl. 2) the trabeculae are easily visible specially in the early whorls of the test surface.

A-Form (megalospheric generation)

The test is flattened with a rounded periphery (text-fig. 1e). In adults the test varies from 2.5 mm to 5.5 mm in diameter and from 0.8 mm to 1.0 mm in thickness. The spire is regular and loose (text-fig. 1c–d; pl. 2, fig. 3). Chambers are rectangular and they are 3–4 × higher than long in the outer whorls. Septa are thin, straight or slightly undulose in the lower and strongly recurved in the upper part of the chamber; they are compactly distributed (text-fig. 1c–d; pl. 2, fig. 3). The marginal cord is very thin, with a constant thickness ranging from 1/3 to 1/5 of the chamber height. The equatorial section shows radii of 0.5–0.75 mm in the whorl, 0.9–1.4 mm in the 2nd, and 1.8–2.7 mm in the 3rd whorl. The number of chambers is about 10–11 in the 1st whorl, 20–26 in the 2nd, 27–35 in the 3rd, and 38–40 in the 4th whorl.

Remarks: *N. catari* presents some resemblance to *Assilina azilensis* (text-figs. 1f–k) which frequently occurs in the same outcrops. In both species the test exhibits an operculiniform growth. Externally, *N. catari* presents a test with a very distinct ornament constituted by thin septal filaments partially covering its previous ontogenetic stages (pl. 2, fig. 1). In contrast, *A. azilensis* shows an ornament markedly evolute, "rectangulaire" according to Hottinger's (1977) terminology for *Operculina*, with traces of thesepta and marginal cord in relief (text-fig. 1h, k). In the axial section, *N. catari* presents a more flattened test (text-fig. 1b, e), whereas *A. azilensis* shows a swollen polar region and a thick marginal cord in relief with respect to the neighbouring areas. In the equatorial section, *N. catari* shows long straight septa with an undulous character in the half of the chamber and a strongly arcuate character in the outer third of the chamber; they are closly spaced delimiting much higher than long subrectangular chambers. In contrast, *A. azilensis* presents shorter and very straight septa distributed more widely spaced than *N. catari*, delimiting slightly higher than long rectangular chambers and a thicker marginal cord (text-fig. 1a, c–d; pl. 1, figs. 1–2; pl. 2, fig. 3).

N. catari is closest to *N. spirectypus*, a species from the Middle Ilerdian Tethys. Their similar operculiniform growth, chamber and septa morphology, and external ornament allows *N. catari* to be considered their possible philetic ancestor.

Stratigraphic Range: According to Hottinger (pers. communication), *N. catari* is restricted to the late Thanetian corresponding to the Glomalveolina levis Biozone or to the SB 4 Biozone according to Serra-Kiel *et al.* (in press).

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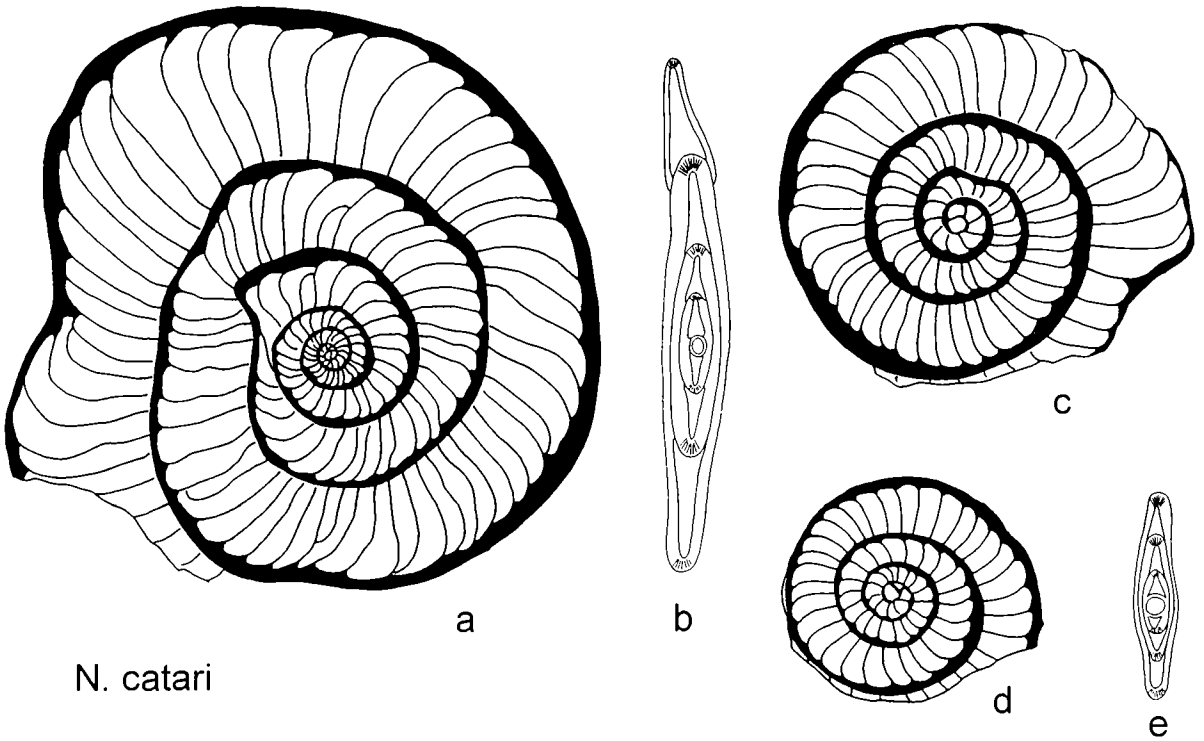

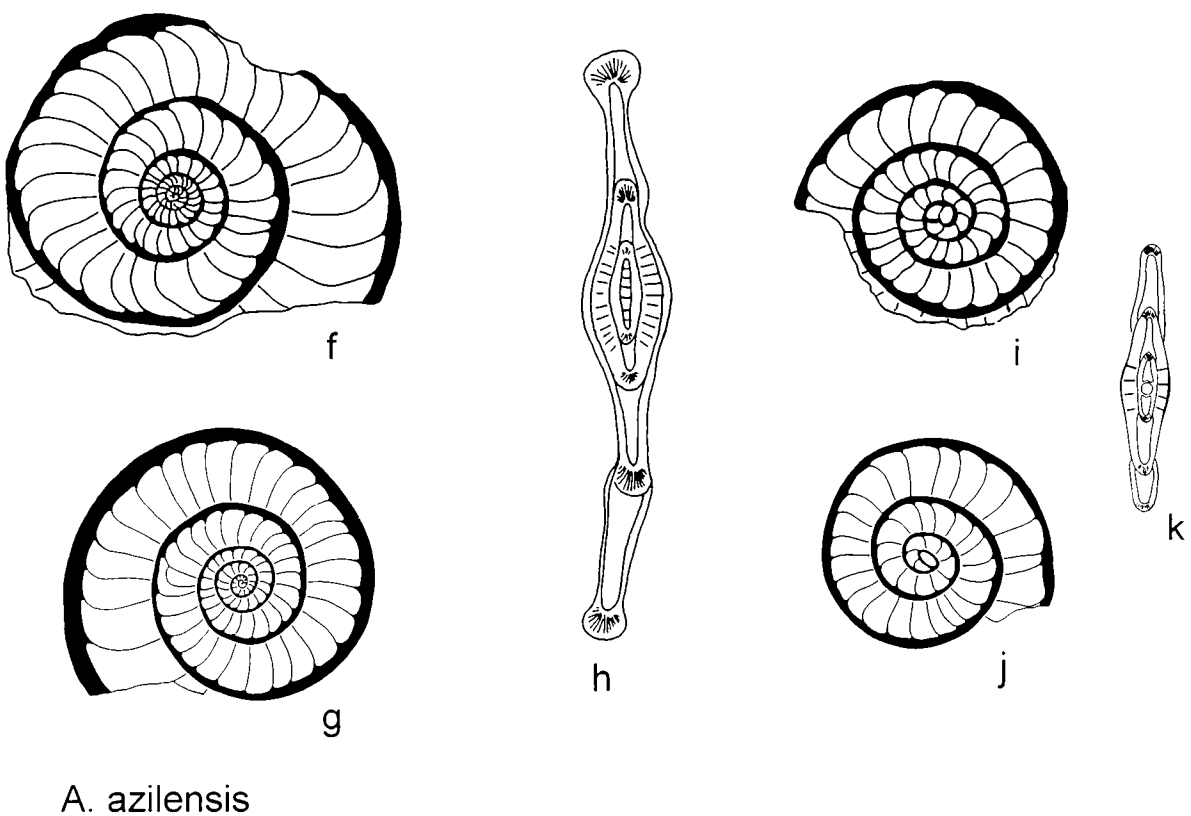

Fig. 1:

Nummulites catari
a: *B-Form, equatorial section;* ***b:*** *B-Form, axial section;* ***c–d:*** *A-Forms, equatorial sections;* ***e:*** *A-Form, axial section (× 10).*

Assilina azilensis
f–g: *B-Forms, equatorial sections;* ***h:*** *B-Form, axial section;* ***i–j:*** *A-Forms, equatorial sections;* ***k:*** *A-Form, axial section (× 10).*

PLATE 1

N. catari n. sp.:

Figs 1–2: B-Forms, equatorial section. Specimens from the Cerisols (1, holotype) and Le Quillet (2, paratype) localities (× 20).


1
2

PLATE 2

N. catari n. sp.

Fig. 1: B-Form external view.
Figs 2–3: A-Form, external view and equatorial section of the same specimen.
Fig. 4: A-Form, external view. All specimens from Cerisols locality (× 20).


1
2
3
4

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LUTETIAN ORTHOPHRAGMINAE FROM THE ISTRIAN PENINSULA (ADRIATIC SEA, CROATIA AND SLOVENIA)

Vlasta Ćosović[1] and Katica Drobne[2]

Abstract

Four foraminiferal assemblages rich in orthophragminids from Istria (Osp, Ragancini-Lišani, Šterna and Pićan) were dated as of Early and Middle Lutetian age, respectively, based on the *Alveolina* and *Nummulites* assemblages. Orthophragminids inhabited the sea-bottom (within the photic zone) of the Adriatic carbonate platform during the demise of the platform. Their abundance and diversification confirmed that nutrient cline rose over the light limit. Moreover, studies of their outer morphologies, in spite of different stratigraphic levels; showed a clear trend towards the increasing flatness of the tests with increasing depths; as well as the domination in frequency distribution of discocyclinid over astercyclinid specimens. The test's shape changes, described and named as Orthophragmina morphogroups, coincide with the stages of several evolutionary lineages (Less, 1987), implying that environmental changes during the Early and Middle Lutetian, possibly, occurred in various parts within the western Tethyan provinces.

Key words: Orthophragminae, Discocyclina, Orbitoclypeus, Lutetian, Istria.

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INTRODUCTION

Paleogene deposits are widespread in the central part of the Istrian peninsula, (NE from the Poreč-Raša line, running roughly NNW-SSE, see Figs 1 and 2 in Marjanac, this volume). The Paleogene succession transgressively overlies the Cretaceous sediments and comprises from the base upwards: the brackish lagoonal deposits of Liburnian formation, platform limestones (Alveolina-Nummulites Limestones), Transitional Beds (Globigerina Marls) and basinal sediments (Flysch). This paper deals with the micropaleontological changes of the uppermost part of the Alveolina-Nummulites Limestones, where orthophragminids represent, along with nummulitids, one of the dominant fossil groups. These deposits were accumulated during the latest stage of sedimentation on the carbonate platform. The drowning of the platform induced changes in biotic and abiotic characteristics of the sediments and caused the increase in abundance of the orthophragminids. Moreover, the frequency of planktic foraminifera, of some rotaliids and particularly of lenticulinids increased, whereas the shallow-water foraminifera such as alveolinids, and globular and spheroidal nummulitids completely disappeared. The question arises if the orthophragminids dominating the ultimate platform carbonates may allow a closer look on the conditions, under which the platform was drowned and in particular if the demise of the platform was due to sea-level rise or other factors. The drowning of the platform changed the quality and quantity of the ambient

light. This is an important environmental controlling parameter for almost all larger foraminifera because they were adapted to host photosynthesising symbiotic organisms. A eutrophication of the environment (Hallock & Schlager, 1986) or a rising sea-level caused the reduction of the water transparency, and consequently the light intensity at the bottom, reducing the number of light-dependent foraminifera in particular and of biomineralising organisms in general. The quality of the substrate, water energy, turbidity, temperature, oxygen, salinity and rate of sedimentation were all modified by the terrigenous influx, and that change might have caused alternation of the fossil associations.

This paper is an attempt to comment the biostratigraphic and paleoecologic potential of the axial (vertical) tests sections of the Middle Eocene Istrian orthophragminids, as indicated by the associated larger foraminifera (nummulitids and alveolinids).

The term "Ortophragminae" (Drooger, 1993) includes all Paleogene larger foraminifera with an architecture characterized by a main chamberlet layer and two symmetric layers of lateral chamberlets, i.e. discocyclinids, asterocyclinids, orbitoclypeids and nemkovellas (although the latter were not found in the investigated area).

MATERIALS AND METHODS

Osp, Šterna, Ragancini-Lišani and Pićan (Fig. 1) sections have been studied earlier (Drobne *et al.*, 1991, Pavlovec *et al.*, 1991) and later by the authors of this paper. In these sections, as elsewhere on the Adriatic Carbonate Platform, the orthophragminids are preserved in hard limestones. Therefore, it is very difficult to obtain precisely oriented equatorial sections. Only those orthophragminid specimens which provided axial sections in random thin-sections have been studied. From these four sections 40 rock-sample containing larger foraminifera, mainly orthophragminids and nummulitids were collected and cut into 5 parallel rock-slides. From each rock-slide one thin-section was made.

Many attempts have been made to classify the species of *Discocyclina* on the basis of outer morphology (Schweighauser, 1953), or of inner morphology emphasising equatorial chambers arrangement, size and shape of embryo (Van der Weijden, 1940; Neumann, 1958; Sirotti, 1977; Fermont, 1982; Less, 1987); or of arrangement of the microspheric nepiont (Bronnimann, 1945). These led to a confused taxonomical subdivision, where it is difficult to define outer and inner (both observable in axial and equatorial test's sections) morphology of the single *Discocyclina* species. The various approximately or perfectly axial sections encountered in the thin-sections can not be determined to species level. Therefore, we have grouped than into so-called morphogroups defined by:

1) the general shape of the test (thickly or flattened lenticular, and/or saddle-like);

2) the relation between the equatorial and axial diameter of the lens. In many species, the central part is slightly elevated forming a central portion, so called umbilical boss or umbo);

3) the thickness of the equatorial layer including the thickness of lateral walls which divide the equatorial layer from the lateral ones;

4) the shape of the equatorial chamberlets in axial section (inflated, rectangular, arched);

5) the height–length ratio of the equatorial chamberlets;

6) the way how lateral chamberlets are arranged in the lateral layers (overlap, or positioned in tiers, or overlap in a "shingle" effect);

7) the size and shape of the lateral chamberlets (fissiform, lenticular, rectangular, slit-like);

8) the numbers and size of piles.

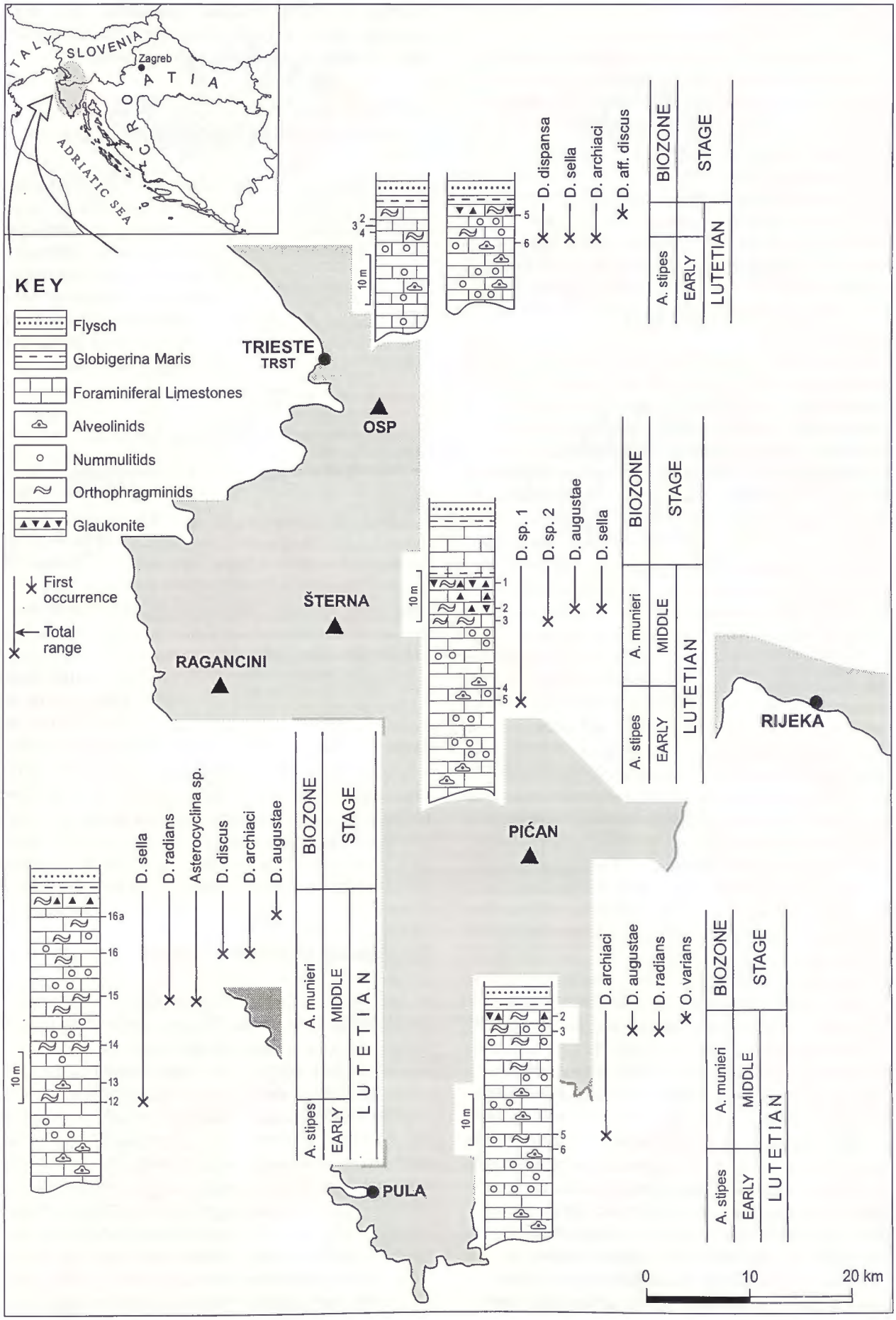
This kind of classifying axial sections into morphogroups was initiated by Fermont (1982). He recognised three different groups of *Discocyclina* from the Lower to Middle Eocene sediments in Israel, and based on their outer and inner morphology he described the following groups, referred to by the species name: *D.* sp., *D. varians* s. l., and *D. archiaci*. Fermont's groups are ecophenogroups, composed of different number of species discriminate on population species concept. Following his procedure we have determined seven morphogroups. The terminology of structural elements is after Ferrandez & Serra-Kiel (1992) (Fig. 2).

The seven morphogroups we distinguish here are different not only by their inner and outer morphology, but also with respect to their vertical distribution. Representatives of *D. sella* morphogroup are most abundant and occur throughout the three sections (Fig. 1), while *D. dispansa* and *O. varians* morphogroups are present with relatively low frequency.

SECTION DESCRIPTION

Fossiliferous (biomicite/wackestone-type) limestones from the Osp-section (Fig. 1), comprise numerous remains of nummulitids and orthophragminids. The discocyclinids assemblage embraces of *D. archiaci* and *D. dispansa morphogroups*, along with other forms. These faunas are associated with fragments of corallinaceans, echinoids and smaller benthic foraminifera. The fact that representatives of D. dispansa morphogroup are found only in this section may suggest that foraminifera

Fig. 1: Location of the four sections studied in a map of Istria with their simplified geological columns (after Drobne, 1977; Drobne et al., *1991, and modified by authors). The name of each locality indicates the geographic position of section.*


ITALY
SLOVENIA
Zagreb
CROATIA
ADRIATIC SEA
KEY
Flysch
Globigerina Maris
Foraminiferal Limestones
Alveolinids
Nummulitids
Orthophragminids
Glaukonite
First occurrence
Total range
TRIESTE
TRST
OSP
ŠTERNA
RAGANCINI
PIĆAN
RIJEKA
PULA
10 m
D. dispansa
D. sella
D. archiaci
D. aff. discus
D. sp. 1
D. sp. 2
D. augustae
D. sella
D. sella
D. radians
Asterocyclina sp.
D. discus
D. archiaci
D. augustae
D. archiaci
D. augustae
D. radians
O. varians
A. stipes
EARLY
A. munieri
MIDDLE
LUTETIAN
BIOZONE
STAGE
0
10
20 km

were transported from the environment at present unknown from other thanatocoenosis in Istria.

The Ragancini-Lišani section (Fig. 1) is characterized by the largest diversity of orthophragminid species, in terms of number of species (low number of individuals per species), and the range of morphologic diversity of them. The most common specimens are representatives of the morphogroups *D. archiaci*, *D. augustae*, *D. discus* and *D. sella*. Specimens of *D. radians* morphogroup and *Asterocyclina* sp. are frequent at the lower part of column. Sediments are packstones, generally rich in fragments of larger foraminifera, echinoids, smaller benthic foraminifera like *Cibicides*, *Lenticulina*. Planktic foraminifera are rare. Sometimes the sediment is intensively burrowed.

Less abundant orthophragminid biota is found at the Šterna-section (Fig. 1). Here, the wackestone-type limestones comprise fragments of larger benthic foraminifera (nummulitids, "operculinids", rotaliids, lenticulinids, bryozoans, echinoderms) and corallinaceans. At the centre of the rhodolites and between the successive laminae of the alga one can occasionally find representatives of orthophragminids and nummulitids. Well preserved remains of discocyclinids were determined as specimens of *D. augustae* and *D. sella* morphogroups, the former being the prevailing species. Towards the top of section, the abundance of representatives of *D. sella* morphogroup increases, and commonly occur glauconite grains.

The Pićan-section (Fig. 1) limestones show considerable differences in lithofacies. Here, the wackestones are substituted by well-sorted packstones towards the top of the section. The limestones contain rich association of orthophragminids, with the following typical morphogroups: *D. archiaci*, *D. augustae*, *D. radians* and *O. varians*. The genus *Discocyclina* is quite numerous in the upper part of the Pićan profile, so it can be referred to as *Discocyclina*-beds. Numerous planktic foraminifera occur in sediments (up to 20 % of total biota).

The age assignment was based on correlation with the alveolinas and nummulitids associated with the first orthophragminas bearing layers. Layers rich in orthophragminas in the Osp section correspond in age to the uppermost part of the *Alveolina stipes* biozone (Early Lutetian), whereas those from the Pićan, Ragancini-Lišani and Šterna sections correspond to the *Alveolina munieri* biozone (Middle Lutetian). The age difference between Osp and rest of the sections, indicates that paleontological change was basically the same, dependant on ecological gradient not on age. However, in all studied sections, numerous flattened discocyclinid specimens were found associated with numerous planktic foraminifera, lenticulinids and "operculinids", indicating greater depth within the photic zone. This contrasts the trend expected at a lower limit of the photic zone where only the few most specialized K-strategists would survive (Pecheux, 1995). Inflated discocyclinid specimens were found in association with sphaerogypsinids, corallinaceans, cibicidids, inflated nummulitids, and more abundant asterocyclinids (Ragancini-Lišani section, Fig. 1), indicating somewhat shallower water depth.

DESCRIPTION OF THE MORPHOGROUPS

The following morphogroups of orthophragminids were defined after their axial, or nearly axial (oblique) sections: *Discocyclina augustae*, *Discocyclina archiaci*, *Discocyclina sella*, *Discocyclina dispansa*, *Orbitoclypeus varians*, *Discocyclina radians*, *Discocyclina discus*, *Asterocyclina* sp. Each morphogroup is named after species-name, and they were discriminated based on their shell shapes, lateral chamberlets (their shape and volume), shape of annular septa, piles, shape of the embryo and shape of the equatorial layer.

Morphogroup *Discocyclina augustae*

The test (Fig. 2B) is characteristically thinly lenticular, with a diameter/thickness ratio between 6 : 1 and 8 : 1 (2–5 mm in diameter and up to 0.6 mm thick) (Pl. 1, figs 1, 7, 13). The test centre is slightly elevated, forming a distinctive umbilical boss. The maximum number of layers of lateral chamberlets, above and below the equatorial layer, increases from two at the test edge to fourteen at the test centre. The first equatorial chamberlets (those next to the embryo) are inflated and are followed by elongate, flattened ones, their height is constant from the central part of the test towards the periphery (up to 70 mm). The lateral chamberlets are rectangular in shape, and reach 120 mm in radial diameter and 30 mm in height. They overlap and are arranged in regular tiers. The embryo of the megalospheric generation varies from 100 to 140 mm in diameter. Piles are absent in some specimens. In specimens where they do occur, the radial piles are largest in the elevated portion of the test, but smaller piles are sparsely present in the peripheric parts of the test.

Morphogroup *Discocyclina archiaci*

The test (Fig. 2A) is robust, lenticular (Pl. 1, figs 6 and 8), saddle-form, usually 4–6 mm in diameter, exceptionally up to 8 mm, and up to 2.5 mm in thickness. Piles are more or less equal in size, evenly distributed over the whole test. All chamberlets are very thick walled. The equatorial layer gradually thickens towards the edge of the test (from 50 mm up to 100 mm). The equatorial chamberlets are rounded, partly involute and have apparently rather thick septal walls. Lateral chamberlets are slit-like in cross section, up to 120 mm in radial diameter and 40 mm high. They are arranged in rude tiers, especially over the centre. Lateral chamberlets are ten to twelve layers thick over the embryonic apparatus and two to four layers thick at the test periphery. Crystalline

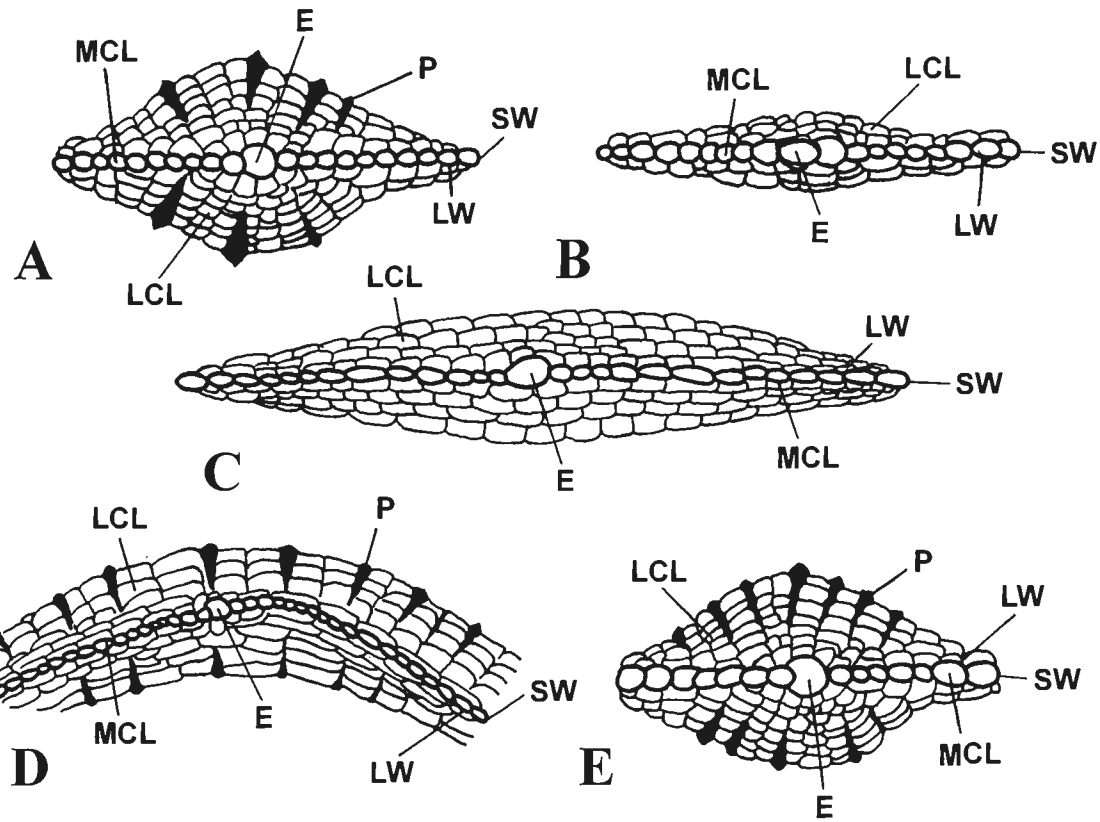


Fig. 2: Schematic drawings of some of the axial sections of the various Discocyclina morphogroups (A corresponds to D. archiaci morphogroup; B to D. augustae *morphogroup; C to* D. discus *morphogroup; D to* D. sella *morphogroup and E to* D. dispansa *morphogroup), with the equatorial main chamberlet layer (MCL), lateral chamberlet layer (LCL), lateral walls (LW), septal walls (SW), embryo (E), and crystalline piles (P). (Not in scale.)*

piles are regularly distributed over the central portion of the test. The test with extensive development of piles generally have thinner chamberlet "main layer lateral walls". The megalospheric embryonic apparatus is relatively large (600 × 200 mm).

Morphogroup *Discocyclina sella*

The irregular equatorial layer is covered on both sides by lateral layers of very low chamberlets. The equatorial layer (with wall) is about 40–50 mm in height. The test (Fig. 2D) is flattened (Pl. 1, figs 2, 3 and 10), saddle-like in shape, about 1.4 mm in the axial diameter and up to 12 mm in the equatorial diameter of adult specimens (the edges are broken in many specimens). The equatorial chamberlets are arch-shaped, the annular walls are strongly convex outward in some specimens, but often flattened. The lateral chamberlets are lenticular in shape, 120–160 mm in diameter and 20 mm high. The first few layers of lateral chamberlets directly above and /or below the equatorial layer are low and silt-like, but the fourth and the succeeding layers of lateral chamberlets are high. The lateral chamberlets are overlapping, producing a "shingle"effect. Between stocks of lateral chamberlets, weak piles occasionally are inserted. The maximum number of lateral chamberlets occurs in the broad elevated central area, where there may be up to fourteen layers of lateral chamberlets. Crystalline piles are extremely small, weak and scattered all over the test. The megalospheric embryo is about 400 mm in diameter.

Morphogroup *Discocyclina dispansa*

The axial section is characterized by the spacious architecture of both equatorial and lateral chamberlet layer (Pl. 1, fig. 11). Robust walls, although the walls which separate the equatorial layer from the lateral ones are not particularly thickened. Usually, conspicuous piles are visible, some specimens have five to six large piles in the centre of the test. Full-grown specimens (Fig. 2E) have 10–12 layers of lateral chamberlets. The equatorial diameter is up to 5 mm and its thickness is about 2.2 mm. The equatorial layer gradually thickens towards the edge of the test (from 50 mm to 80 mm). The lateral chamberlets from the central part of the test are low lenticular, getting lower and even fissiform near the edge (80 mm in radial diameter and 30 mm in hight). The megalospheric embryo varies from 120 to 240 mm in diameter.

Morphogroup *Discocyclina discus*

The thin, flattened test (Fig. 2C) is composed of a few (up to 5) lateral layers on both sides of the embryo (Pl. 1, figs 5 and 10). The maximum observed diameter is 12 mm. The equatorial layer as seen in axial section is composed of elongated, partly involute chamberlets, separated by annular walls which are strongly convex-outward (about 25 mm). The lateral chamberlets, in the central part of the test have a lenticular cross-section, getting lower and even fissiform near the shell's periphery. The lateral chamberlets overlap in a "shingle" effect. The equatorial layer is about 60 mm high at the margin of the embryonic apparatus and increases in height only slightly near the test periphery (there the total height of the equatorial layer, including walls is about 120 mm). The axial height of the embryo ranges from 200 to 250 mm, and reaches up to 800 mm in equatorial diameter.

Morphogroup *Discocyclina radians*

The small-sized flattened test has a distinctive umbo. It's most characteristic features seem to be the low, neatly defined equatorial layer with its low chamberlets, tending to develop a "chain stitch" shape. The equatorial layer itself is about 30–40 mm high at the margin of the embryonic apparatus and increases in height only slightly near the test periphery. There, the total height of the equatorial layer, including "main layer lateral walls" is about 50–60 mm. The lateral walls of the equatorial chamberlets are medium thick, while septal ones are thinner. The lateral chamberlets are 120–150 mm in width and 40 mm in height. The megalospheric embryonic apparatus is about 500 mm in diameter.

Morphogroup *Orbitoclypeus varians*

The equatorial diameter reaches 1.5 mm. The test is flat-lenticular without a central umbo (Pl. 1, fig. 12). More-or-less equidimensional piles are evenly distributed all over the test. The equatorial layer is thin with a very low lumen between fairly thick horizontal walls ("main layer lateral walls"), from 20–30 mm in height to 40 mm at the edge, vertical walls (annular septum) tending to curve outwards. The size of the lateral chamberlets is about 60 mm in width and 30 mm in height. The shape of the lateral chamberlets as seen in axial section is rectangular: They are stacked in 5–6 layers in the centre of the test. The megalospheric embryo ranges 125–250 mm in diameter.

CONCLUSION

The study of orthophragminids from four Istrian sections reveals the conditions under which Orthophragmina-bearing sediments were deposited:

1) In spite of the age difference between Osp and the other sections (Pićan, Ragancini-Lišani and Šterna), the development of the faunal succession during the demise of carbonate platform is fundamentally the same. This documents the overriding ecological control of the foraminiferal K-strategist associations during the demise of the platform.

2) The investigated samples document comparatively steep ecological gradient characterized by the rising diversity of morphogroups with progressive depth of deposition (Fig. 2). This is opposite to the trend expected at a lower limit of the photic zone where only the few most specialized K-strategists would survive. This can be explained only by an independent second ecological factor cutting away the lowest part of the depth ranges in the light gradient. Keeping in mind the increasing percentage of terrigenous material in the sediment and the appearance of glauconite, this second factor may be a nutrient cline rising over the light limit (Hottinger, 1989). Consequently, the so-called drowning of the Adriatic carbonate platform could be not only a signal of sea-level rise but also a result of tectonic movements in the hinterland altering the nutrient regime and/or coastal current pattern in the Middle Eocene Sea.

3) Flattened orthophragminids specimens were found associated with numerous planktic foraminifers, "operculinids" and lenticulinids, indicating lower limit of the photic zone. Inflated foraminifers were found in association with sphaerogypsinids, corallinaceans debris, cibicidids and numerous inflated nummulitids, indicating somewhat shallower water-depths.

4) Reduction in total number of asterocyclinids per sample is accompanied by a corresponding increase in frequency and diversity of *Discocyclina* specimens. This confirmed Fermont's (1982) assumption that these two genera preferred different depth range.

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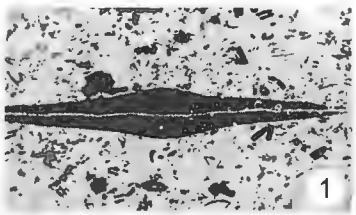
PLATE 1

Figs 1–13:

1. *Discocyclina augustae* WEIJDEN, Šterna section, Štr. 2/1726
2. *D. sella* (d'ARCHIAC), Šterna section, Štr. 2/1725
3. *D. sella* (d'ARCHIAC), Ragancini-Lišani section, RL 14/50
4. *Asterocyclina* sp., Ragancini-Lišani section, RL 15/54
5. *D. discus* (RUTIMEYER), Ragancini-Lišani section, RL 16/57
6. *D. archiaci* (SCHLUMBERGER), Ragancini-Lišani section, RL 16/57
7. *D. augustae* (WEIJDEN), Ragancini-Lišani section, RL 16a/59
8. *D. archiaci* (SCHLUMBERGER), Osp section, Osp 5/1713
9. D. sella (d'ARCHIAC), Osp section, Osp 5/1713
10. *D. sella* (d'ARCHIAC) and *D. aff. discus* (RUTIMEYER), Osp section, Osp 5/1714
11. *D. dispansa* (SOWERBY), Osp section, Osp 5/1714
12. *Orbitoclypeus varians* (KAUFFMAN), Pićan section, Pć 2/2238
13. *D. augustae* (WEIJDEN), Pićan section, Pć 3/2236

13a. *Discocyclina* sp. and *Asterocyclina* sp., Pićan section, Pć 3/2236

All enlarged × 10 in incident light. Age: Lower to Middle Lutetian (see Fig. 1).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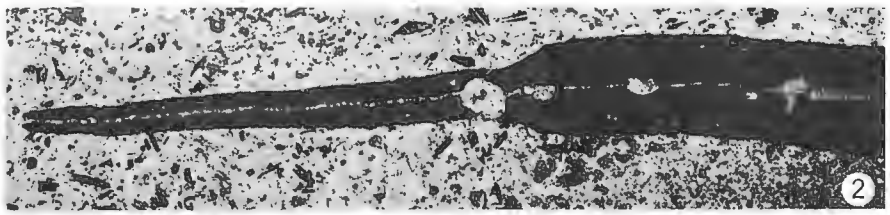
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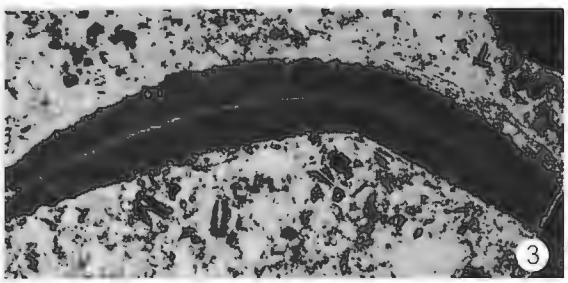
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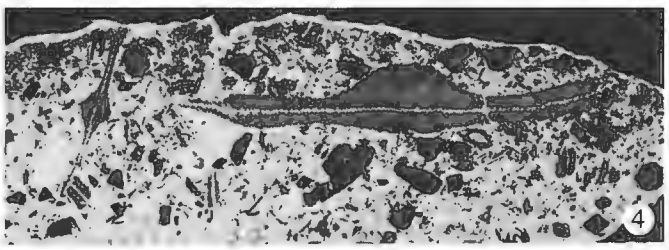
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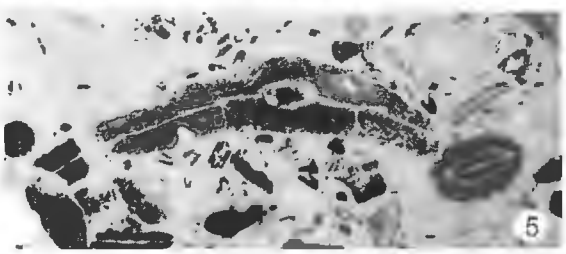
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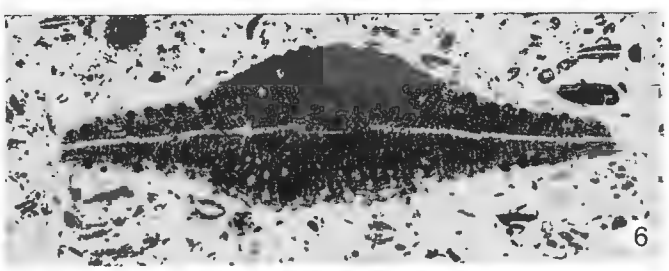
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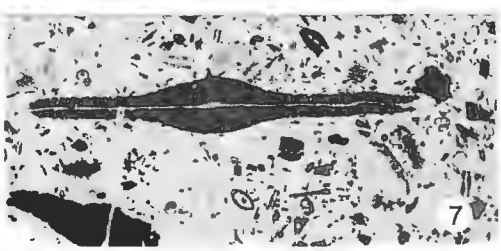
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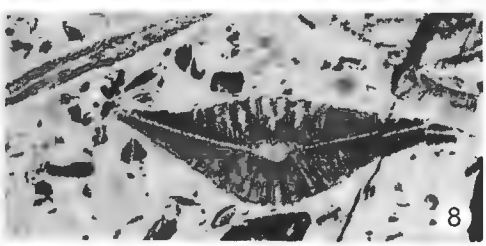
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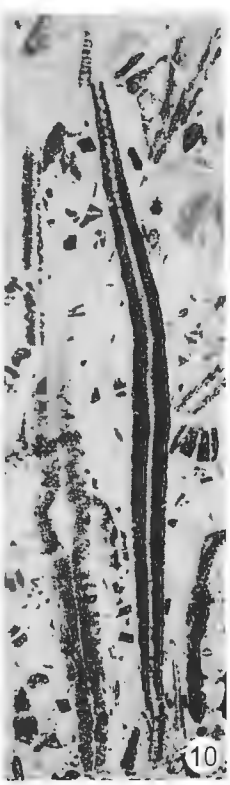
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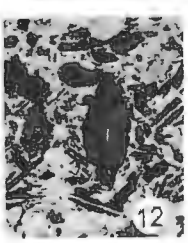
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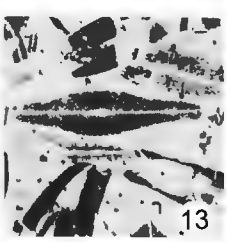
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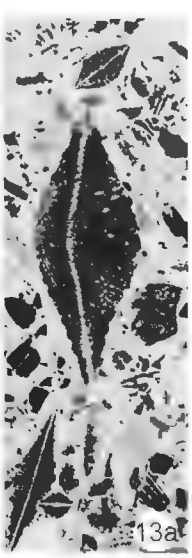
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Dela – Opera SAZU 4. razr.	34/2	183–202				Ljubljana 1998

STATISTICAL DATA OF THE INNER CROSS PROTOCONCH DIAMETER OF *NUMMULITES* AND *ASSILINA* FROM THE SCHAUB COLLECTION

György Less

Abstract

The inner cross protoconch diameter of 7453 megalosphaeric (A) specimens of *Nummulites* and *Assilina* from the Schaub collection at the Naturhistorisches Museum of Basel have been measured. The raw data by specimens are deposited at the museum. Here we present their statistical summary by taxa (grouping them into 1084 populations) and by saving Schaub's original nomenclature.

Key words: *Nummulites, Assilina*, megalosphere diameter, biostratigraphy.

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INTRODUCTION

Usually the protoconch diameter of the megalosphaeric (A) forms of Larger foraminifera is proved to be a good evolutionary marker inside particular lineages (see e.g. Less, 1987; Drooger, 1993) and, therefore, bears a significant stratigraphical value. Also, the data given by Schaub (1981) for *Nummulites* and *Assilina* strengthen this impression, however, he did not present any statistical data. In fact, he did not measure systematically this parameter having believed rather in the priority of the track of the spire (illustrated by spiral diagrams) of the microsphaeric (B) forms in determining the evolutionary degree of particular lineages.

In October and November 1996 the present author spent four weeks at the Naturhistorisches Museum of Basel in order to measure systematically the inner cross (perpendicular to the axis of the embryon) diameter of the A-forms of *Nummulites* and *Assilina* from the Schaub collection. Fortunately, Hans Schaub left his collection in an exemplary order that made very easy to achieve the given task. We measured 7453 specimens, however it does not span the whole collection. Because of the lack of time we have not managed to study about 2000 specimens that includes the whole material from the Schlierenflysch (Schaub, 1951) and also the majority of the specimens from Israel (Schaub *et al.*, 1995). Most of the localities with only one single taxon were also missed. The measured data by specimens are deposited at the Naturhistorisches Museum of Basel. Here we present the statistical summary by taxa — grouping them into 1084 populations — as they have been determined by Hans Schaub.

THE USAGE OF THE TABLE BY COLUMNS

Group/lineage: The arrangement of taxa into groups or lineages is the same as it is given by Schaub (1981,

figs 24–26, and also in the text). We followed him also in the order of the groups/lineages.

Taxon: The names of the taxa are exactly the same as it was found in the labels of the preparates written by Hans Schaub. Abbreviations: N.: *Nummulites*; A: *Assilina*.

Locality: Practically all the localities listed in the table can be found in the alphabetic list in Schaub (1981: 233–236). The exceptions: 1. The localities from Israel are in Schaub *et al.* (1995); 2. Alsina and Bergouey are missing in the alphabetic list, therefore their supplementary name(s) can be found in brackets. When there are more than one localities from the same place, they are marked by different numbers and (where it was possible) by the supplementary name of the particular locality, in brackets [e.g. Kressenberg 3. (Schwarzerz)]. Under the name of particular localities it was necessary very often to unit several samples containing practically the same fauna. In the appendix we list these samples by the localities. Samples marked by five digits have been collected mostly by Hans Schaub. Sometimes we have found only the name of the collector (Curry, Nemkov, Reguant, etc.), and very rarely even nothing. In the appendix they are marked here by "?".

Country: According to the recent (1997) political situation.

Age: For each locality we used the age given by Schaub (1981) at their description (pp. 37–72), however, they may slightly differ from the age found in the labels, and also from those at the description and illustration of the given taxon. Abbreviations: b.: basal, l.: lower, m.: middle, m1.: lower part of the middle, m2.: upper part of the middle, u: upper; B: Biarritzian, C: Cuisian, I: Ilerdian, L: Lutetian, P: Priabonian, T: Thanetian. When two ages are subdivided by "/", it means their boundary; while "-" marks the possibility of both ages.

#: The number of specimens in the given population.

Mean: The arithmetical mean in μm.

s.d.: The (so-called population) standard deviation in μm.

c.v.: The coefficient of variation (calculated as s.d./Mean) in %.

Min., Max. and Med.: The minimal, maximal and median value of the given population in μm.

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I am grateful first of all to prof. Hans Schaub who left his collection in such an exemplary order that made possible the further investigations on it. Prof. Lukas Hottinger (Geological-Paleontological Institute of the Basel University) supported me very much in the organization of this study. During my stay in Basel I enjoyed very often his and his family's hospitality. In the Naturhistorisches Museum of Basel Michael Knappertsbusch and René Panchaud assured for me all the necessary facilities. The Schweizer Nationalfond (Grant ...) and the Hungarian Scientific Research Fund (OTKA Grant T 16863) financially supported this study.

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Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
N. perforatus	N. solitarius	Orignac 1.	France	b.I	8	150.0	37.8	25.2	110	220	150
		Sant Estevé 1.	Spain	b.I	3	173.3	17.0	9.8	150	190	180
		Llimiana 1.	Spain	b.I	1	140.0	0.0	0.0	140	140	140
		Haymana 1.	Turkey	b.I	2	100.0	10.0	10.0	90	110	100
		Alsina (Tremp) 1.	Spain	l.I	9	155.6	21.3	13.7	135	200	148
		Llimiana 2.	Spain	l.I	2	137.5	2.5	1.8	135	140	138
		Campo 2.	Spain	l.I	2	210.0	30.0	14.3	180	240	210
		Farafrah	Egypt	l.I	35	126.4	19.3	15.3	90	160	120
	N. aff. solitarius	Campo 4.	Spain	u.I	1	160.0	0.0	0.0	160	160	160
		Melitta	Tunesia	u.I	3	153.3	12.5	8.1	140	170	150
	N. pernotus	Montolieu	France	m1.I	9	296.1	71.2	24.1	195	420	300
		Moussoulens	France	m1.I	2	170.0	20.0	11.8	150	190	170
		Mont Cayla 2.	France	m2.I	2	155.0	25.0	16.1	130	180	155
		Alsina (Tremp) 2.	Spain	m2.I	2	127.5	17.5	13.7	110	145	128
		Areny 4.	Spain	m2.I	6	189.2	44.8	23.7	140	250	178
		Tremp 4.	Spain	m2.I	5	91.0	9.2	10.1	75	100	90
		Alsina (Tremp) 5.	Spain	u.I	4	140.0	15.4	11.0	115	155	145
		Areny 5.	Spain	u.I	3	153.3	8.5	5.5	145	165	150
		Areny 6.	Spain	u.I	9	125.0	42.4	33.9	70	220	130
		Sant Adriá 5.	Spain	u.I	3	285.0	14.7	5.2	265	300	290
		Tremp 5.	Spain	u.I	1	145.0	0.0	0.0	145	145	145
		Campo 4.	Spain	u.I	5	147.0	2.4	1.7	145	150	145
		Haymana 2.	Turkey	u.I	7	239.3	31.7	13.2	200	300	240
		Gan 1. (Berdoulou)	France	b.C	3	193.3	4.7	2.4	190	200	190
		Encebras 1.	Spain	b.C	3	258.3	38.6	14.9	205	295	275
		Kressenberg 1. (Roterz)	Germany	l.C	1	180.0	0.0	0.0	180	180	180
		St. Pankraz 1. (Roterz)	Austria	l.C	2	235.0	25.0	10.6	210	260	235
		Alfaz	Spain	l.C	1	250.0	0.0	0.0	250	250	250
		Haymana 4.	Turkey	l.C	1	150.0	0.0	0.0	150	150	150
		Haymana 5.	Turkey	l.C	1	240.0	0.0	0.0	240	240	240
		Benidorm 2.	Spain	l/m.C	1	345.0	0.0	0.0	345	345	345
	N. aff. pernotus	San Vicente de la Barquera 2.	Spain	m.C	6	293.3	31.6	10.8	255	340	285
		Aoíz 1.	Spain	m.C	4	190.0	18.7	9.8	170	220	185
	N. burdigalensis kuepperi	Areny 5.	Spain	u.I	4	135.0	17.0	12.6	115	160	133
		Boltaña 1.	Spain	u.I/b.C	1	110.0	0.0	0.0	110	110	110
		Caravaca 1.	Spain	u.I/b.C	11	167.7	32.3	19.3	110	215	165
		Guttaring	Austria	b.C	13	148.1	34.9	23.6	95	200	145
		Sittenberg	Austria	b.C	2	202.5	7.5	3.7	195	210	203
		Gan 2. (Encot)	France	b.C	11	189.1	22.9	12.1	160	235	195
		Ossun	France	b.C	2	172.5	17.5	10.1	155	190	173
		Campo 5.	Spain	b.C	3	150.0	8.2	5.4	140	160	150
		Haymana 3.	Turkey	b.C	1	140.0	0.0	0.0	140	140	140
		Alfaz	Spain	l.C	1	240.0	0.0	0.0	240	240	240
	N. cf. burdigalensis burdigalensis	Campo 5.	Spain	b.C	1	290.0	0.0	0.0	290	290	290
	N. burdigalensis burdigalensis	Gan 1. (Berdoulou)	France	b.C	8	243.1	50.2	20.7	190	360	240
		Gan 2. (Encot)	France	b.C	4	178.8	40.4	22.6	140	240	168
		Encebras 1.	Spain	b.C	4	202.5	45.5	22.5	130	250	215
		Gan 3. (Tuilerie 1)	France	l.C	15	207.3	34.7	16.7	145	260	205
		San Vicente de la Barquera 1.	Spain	l.C	28	249.8	62.4	25.0	150	400	245
		Campo 6.	Spain	l.C	2	227.5	22.5	9.9	205	250	228
		Benidorm 1.	Spain	l.C	2	135.0	5.0	3.7	130	140	135
		Haymana 4.	Turkey	l.C	6	183.3	25.8	14.1	150	230	183
		Haymana 5.	Turkey	l.C	5	321.0	44.8	13.9	250	385	330
		Bosdarros 2.	France	m.C	8	256.9	37.3	14.5	205	315	253
		San Vicente de la Barquera 2.	Spain	m.C	2	252.5	2.5	1.0	250	255	253
	N. kapellosi	San Vicente de la Barquera 2.	Spain	m.C	9	312.8	55.3	17.7	245	430	295
		El Pocino 1.	Spain	m.C	1	470.0	0.0	0.0	470	470	470
		Campo 7.	Spain	m.C	11	298.6	49.8	16.7	200	395	300
		Buttrio	Italy	m.C	9	302.2	34.0	11.3	250	350	300
		Aoíz 2.	Spain	u.C	3	473.3	23.6	5.0	440	490	490
	N. campesinus	Kressenberg 3. (Schwarzerz)	Germany	u.C	2	315.0	20.0	6.3	295	335	315
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	58	422.9	64.2	15.2	300	590	410
		Lueza	Spain	u.C	4	338.8	47.5	14.0	290	415	325
		Tierrantona	Spain	u.C	10	492.0	100.0	20.3	395	735	458
		Campo 8.	Spain	u.C	37	377.0	69.0	18.3	225	545	385
		Benidorm 4.	Spain	u.C	5	283.0	33.1	11.7	250	340	285
N. perforatus	N. campesinus	Dobrinj	Croatia	u.C	1	550.0	0.0	0.0	550	550	550
	N. aff. campesinus	Figueras	Spain	u.C/b.L	20	400.8	73.1	18.2	250	585	395
		Huéscar 3.	Spain	b.L	3	423.3	12.5	2.9	410	440	420
	N. cf. campesinus	Samitier 1.	Spain	u.C/b.L	8	475.6	33.0	6.9	405	515	483
		Queralt p. Berga	Spain	b.L	10	463.0	90.3	19.5	340	600	438

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. aff. obesus	Sorde-l'Abbaye 1.	France	b.L	3	460.0	34.9	7.6	415	500	465
		Sorde-l'Abbaye 2.	France	l.L	10	429.0	84.3	19.6	300	605	405
	N. obesus	Châtelard-les-Bauges	France	b.L	9	497.8	101.6	20.4	360	690	490
		Chiampo	Italy	b.L	4	560.0	81.5	14.6	470	660	555
		Guiche	France	l.L	12	567.5	59.8	10.5	485	680	558
		Hastingues	France	l.L	6	474.2	34.6	7.3	420	525	473
		St-Martin-de-Seignanx	France	l.L	13	493.5	71.8	14.5	375	660	485
		Ste-Marie-de-Gosse	France	l.L	29	567.9	79.1	13.9	450	760	560
		Urcuit	France	l.L	11	520.9	58.5	11.2	450	690	505
		San Vicente de la Barquera 6.	Spain	l.L	8	590.0	59.1	10.0	490	690	600
		Bastennes 1.	France	l/m.L	4	535.0	125.2	23.4	450	750	470
		Bastennes 2.	France	m1.L	2	680.0	60.0	8.8	620	740	680
	N. tobleri	Guiche	France	l.L	1	500.0	0.0	0.0	500	500	500
		Hastingues	France	l.L	9	526.7	59.3	11.3	440	625	515
		Ste-Marie-de-Gosse	France	l.L	1	665.0	0.0	0.0	665	665	665
	N. cf. tobleri	El Far	Spain	l.L	6	568.3	63.8	11.2	440	635	598
	N. benaharnensis	Gibret	France	l/m.L	11	608.2	52.5	8.6	490	660	640
		Biron	France	m1.L	25	493.6	109.2	22.1	245	735	495
		Orthez	France	m1.L	19	693.2	109.2	15.8	520	915	700
		Peyrehorade 1. (Aspremont)	France	m1.L	1	510.0	0.0	0.0	510	510	510
	N. deshayesi	Mediano 5.	Spain	m2.L	19	509.2	84.9	16.7	330	660	500
		St-Barthélemy 2. (église)	France	m/u.L	12	602.1	29.0	4.8	560	650	600
		Jaca	Spain	u.L	6	581.7	93.3	16.0	490	750	545
	N. perforatus	La Mortola	France	u.L/B	18	927.5	143.0	15.4	640	1300	918
		San Vicente de la Barquera 7.	Spain	u.L/B	7	902.9	165.7	18.4	690	1180	885
		Avesa 3.	Italy	u.L/B	3	930.0	37.4	4.0	890	980	920
		Biarritz 2. (Peyreblanque 1)	France	B	9	745.6	79.3	10.6	600	900	750
		Biarritz 4. (Villa Marbella)	France	B	1	660.0	0.0	0.0	660	660	660
		Peyrehorade 2.	France	B	8	770.0	121.3	15.7	615	1040	770
		Arguis 2.	Spain	B	12	757.9	176.5	23.3	360	1035	740
		Carme 1. (Colbass)	Spain	B	20	883.5	121.8	13.8	550	1040	900
		Carme 2. (Col Lentilles)	Spain	B	1	1000.0	0.0	0.0	1000	1000	1000
		San Llorenç de Morunys 2.	Spain	B	2	1000.0	100.0	10.0	900	1100	1000
		Santa Margarita de Mombuy	Spain	B	13	1007.7	178.8	17.7	680	1360	945
		Grancona 2.	Italy	B	4	1093.8	57.2	5.2	1040	1190	1073
		Mossano	Italy	B	5	1290.0	263.9	20.5	950	1640	1210
		Leghia	Romania	B	7	700.0	151.3	21.6	500	920	640
N. biedai	N. hilarionis	Mediano 4.	Spain	m1.L	24	467.9	119.3	25.5	260	745	473
		San Giovanni Ilarione	Italy	m1.L	22	760.5	126.5	16.6	530	1010	785
	N. crassus	Avesa 1.	Italy	m1.L	11	675.5	94.6	14.0	540	900	650
		Bastennes 3.	France	m2.L	12	607.9	112.8	18.6	440	870	615
		Avesa 2.	Italy	m-u.L	2	845.0	45.0	5.3	800	890	845
	N. meneghinii	Sorde-l'Abbaye 3.	France	u.L	1	660.0	0.0	0.0	660	660	660
		Huéscar 4.	Spain	u.L	3	965.0	201.6	20.9	815	1250	830
	N. biedai	San Vicente de la Barquera 7.	Spain	u.L-B	3	816.7	75.9	9.3	740	920	790
		Calders	Spain	B	2	857.5	117.5	13.7	740	975	858
		Centelles	Spain	B	7	911.4	147.5	16.2	720	1110	850
		Manresa	Spain	B	4	840.0	133.6	15.9	710	1050	800
N. aturicus	N. kugleri	Hastingues	France	l.L	2	577.5	17.5	3.0	560	595	578
		St-Martin-de-Seignanx	France	l.L	12	584.6	87.7	15.0	480	740	555
		Urcuit	France	l.L	13	548.8	79.7	14.5	425	700	540
	N. praeaturicus	Bastennes 2.	France	m1.L	7	636.4	141.0	22.2	470	910	580
		Orthez	France	m1.L	6	721.7	46.8	6.5	635	785	730
	N. aturicus	Montfort-en-Chalosse	France	u.L	26	722.7	142.9	19.8	565	1305	698
		Sorde-l'Abbaye 4.	France	u.L	26	731.7	139.8	19.1	440	1060	750
N. lehneri	N. aff. lehneri	Haymana 8.	Turkey	u.C	14	561.4	148.6	26.5	290	840	575
	N. lehneri	Figueras	Spain	u.C/b.L	15	416.3	45.4	10.9	300	500	410
		Kressenberg 4.	Germany	b.L	5	488.0	75.0	15.4	350	575	510
		Balatonhegy 1.	Hungary	b.L	8	506.3	75.4	14.9	390	640	500
		La Pobla de Lillet 2.	Spain	l.L	11	418.6	58.0	13.9	340	515	420
		Vodica	Croatia	l.L	19	581.1	96.2	16.6	400	800	590
N. lehneri	N. lehneri	Haymana 10.	Turkey	l.L	6	720.8	96.5	13.4	610	920	703
		Haymana 9.	Turkey	l.L	25	607.2	187.8	30.9	350	1000	580
	N. cf. lehneri	St-Martin-de-Seignanx	France	l.L	1	390.0	0.0	0.0	390	390	390
		Formigales	Spain	l.L	2	575.0	125.0	21.7	450	700	575
	N. sismondai	Kressenberg 5. (Flöz-Nebeng.)	Germany	m1.L	6	567.5	103.6	18.3	405	730	573
	N. aspermontis	Biron	France	m1.L	14	425.4	84.3	19.8	300	570	428
		Peyrehorade 1. (Aspremont)	France	m1.L	5	400.0	100.2	25.0	290	560	400
		Ripoll	Spain	m1.L	11	372.7	59.9	16.1	260	480	390
	N. aff. aspermontis	San Llorenç de Morunys 1.	Spain	m-u.L	10	526.5	60.8	11.5	420	645	500
N. uranensis	N. burdigalensis cantabricus	Janovas 1.	Spain	l/m.C	3	281.7	4.7	1.7	275	285	285

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Haymana 6.	Turkey	l/m.C	7	298.6	53.4	17.9	210	370	315
		Kressenberg 2. (Zwischensch.)	Germany	m.C	1	340.0	0.0	0.0	340	340	340
		Colombres	Spain	m.C	2	327.5	7.5	2.3	320	335	328
		San Vicente de la Barquera 2.	Spain	m.C	50	291.3	55.8	19.1	200	500	290
		El Pocino 2.	Spain	m.C	2	232.5	2.5	1.1	230	235	233
		Campo 7.	Spain	m.C	2	270.0	10.0	3.7	260	280	270
		Aoíz 1.	Spain	m.C	4	252.5	43.1	17.1	195	315	250
		Moratalla	Spain	m.C	29	245.5	61.0	24.9	150	400	250
		Crimée 4. (distans-zone 1)	Ukraine	m.C	1	180.0	0.0	0.0	180	180	180
		Haymana 7.	Turkey	m.C	13	331.2	61.8	18.7	220	440	340
		Encebras 2.	Spain	m-u.C	2	450.0	45.0	10.0	405	495	450
	N. gallensis	St-Barthélemy 1. (Maisonnave)	France	b.L	4	346.3	9.6	2.8	335	360	345
		San Vicente de la Barquera 4.	Spain	b.L	11	428.6	56.4	13.2	335	495	450
		Vanzi 2.	Italy	b.L	10	441.0	74.7	16.9	290	565	430
	N. aff. gallensis	St. Pankraz 2. (Schwarzerz)	Austria	u.C	11	516.8	97.4	18.8	335	700	510
		St-Martin-de-Seignanx	France	l.L	2	420.0	30.0	7.1	390	450	420
		San Vicente de la Barquera 6.	Spain	l.L	3	625.0	56.1	9.0	550	685	640
	N. aff. uranensis	Mediano 2.	Spain	l.L	10	548.5	57.4	10.5	415	625	558
	N. crusafonti	Tavertet	Spain	u.L	1	460.0	0.0	0.0	460	460	460
N. verneuili	N. burdigalensis pergranulatus	Samper	Spain	l.C	6	173.3	32.1	18.5	140	235	165
		Benidorm 2.	Spain	l/m.C	1	160.0	0.0	0.0	160	160	160
		El Pocino 1.	Spain	m.C	1	250.0	0.0	0.0	250	250	250
		Buttrio	Italy	m.C	2	295.0	5.0	1.7	290	300	295
	N. friulanus	Lueza	Spain	u.C	4	283.8	26.3	9.3	240	310	293
		Dobrinj	Croatia	u.C	6	494.2	53.6	10.8	400	550	510
		Noax	Italy	u.C	5	427.0	93.7	22.0	315	585	440
		Rosazzo	Italy	u.C	7	462.9	93.5	20.2	320	590	490
	N. friulanus - verneuili	Boltaña 3.	Spain	b.L	18	480.3	73.5	15.3	320	590	498
		Urcuit	France	l.L	1	580.0	0.0	0.0	580	580	580
		Boltaña 4.	Spain	l.L	7	480.7	90.9	18.9	360	630	450
		La Pobla de Lillet 1.	Spain	l.L	10	489.0	45.2	9.2	425	560	490
	N. verneuili	Formigales	Spain	l.L	7	422.9	85.0	20.1	285	515	480
		El Far	Spain	l.L	13	566.5	76.9	13.6	495	740	540
	N. aff. verneuili	Formigales	Spain	l.L	11	510.5	90.1	17.6	350	675	500
		Mediano 3.	Spain	l.L	3	406.7	42.5	10.4	365	465	390
		Troncedo	Spain	l.L	3	325.0	22.7	7.0	295	350	330
		Boltaña 4.	Spain	l.L	4	678.8	28.4	4.2	630	700	693
		Boltaña 5.	Spain	l-m.L	5	430.0	75.6	17.6	285	490	445
	N. obtusus	Gandbo Hill	Pakistan	m.L	8	710.6	199.3	28.1	500	1140	648
	N. aff. tavertetensis	Panillo 1. (Marials)	Spain	m1.L	13	603.5	167.1	27.7	340	950	655
		Panillo 2. (Ermita)	Spain	m1.L	7	462.9	117.1	25.3	275	695	460
		Caravaca 2.	Spain	m.L	6	555.8	96.7	17.4	420	710	553
		Samitier 2.	Spain	m2.L	8	605.6	80.8	13.3	460	745	610
	N. tavertetensis	Tavertet	Spain	u.L	8	553.1	119.5	21.6	330	750	538
N. partschi	N. roselli	Campo 1.	Spain	b.I	15	317.7	48.9	15.4	240	395	340
		Campo 2.	Spain	l.I	10	388.5	87.7	22.6	240	560	365
	N. aff. praecursor	Orignac 1.	France	b.I	35	493.4	81.4	16.5	350	735	490
		Estorm	Spain	b.I	13	305.8	41.9	13.7	230	395	300
		Sant Estevé 1.	Spain	b.I	4	402.5	117.3	29.2	250	580	390
		Areny 1.	Spain	b.I	1	290.0	0.0	0.0	290	290	290
		Llimiana 1.	Spain	b.I	4	307.5	29.7	9.7	265	340	313
		Campo 1.	Spain	b.I	15	325.3	82.9	25.5	235	490	300
		Alsina (Tremp) 1.	Spain	l.I	10	421.5	79.8	18.9	340	565	428
		Llimiana 2.	Spain	l.I	18	352.8	49.3	14.0	275	470	360
		Tremp 1.	Spain	l.I	1	390.0	0.0	0.0	390	390	390
		Campo 2.	Spain	l.I	32	394.1	73.7	18.7	195	545	400
N. partschi	N. aff. praecursor	Farafrah	Egypt	l.I	5	270.0	38.1	14.1	220	335	265
	N. praecursor	Aragon	France	m1.I	12	347.1	101.4	29.2	130	520	350
		Montolieu	France	m1.I	7	428.6	55.6	13.0	340	495	440
		Campo 3.	Spain	m1.I	17	436.2	87.1	20.0	240	610	420
	N. atacicus	Couiza	France	m2.I	2	432.5	22.5	5.2	410	455	433
		Coustouge 3.	France	m2.I	56	389.6	78.3	20.1	245	565	390
		Mont Cayla 2.	France	m2.I	13	461.5	66.7	14.5	350	590	470
		Alsina (Tremp) 2.	Spain	m2.I	14	382.9	46.4	12.1	295	475	385
		Alsina (Tremp) 3.	Spain	m2.I	17	497.4	86.6	17.4	375	695	460
		Tremp 2.	Spain	m2.I	2	422.5	62.5	14.8	360	485	423
		Tremp 3.	Spain	m2.I	3	376.7	77.9	20.7	305	485	340
		Foradada de Toscar	Spain	m2.I	7	415.0	58.6	14.1	300	485	430
	N. alpinus	Aurignac 2.	France	u.I	1	185.0	0.0	0.0	185	185	185
		Sant Estevé 2.	Spain	u.I	4	392.5	43.9	11.2	355	465	375
		Tremp 5.	Spain	u.I	3	331.7	33.2	10.0	285	360	350

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. ornatus	Ager	Spain	u.I	2	355.0	40.0	11.3	315	395	355
		Gan 1. (Berdoulou)	France	b.C	2	272.5	12.5	4.6	260	285	273
		Valdeforte	Italy	b.C	2	312.5	32.5	10.4	280	345	313
	N. partschi	Gan 1. (Berdoulou)	France	b.C	32	359.5	54.8	15.3	245	515	355
		Valdeforte	Italy	b.C	14	374.6	33.0	8.8	300	440	380
		Bolca	Italy	l.C	8	330.0	43.1	13.1	250	400	340
		Haymana 5.	Turkey	l.C	2	450.0	60.0	13.3	390	510	450
	N. cf. partschi	Huéscar 2.	Spain	l/m.C	5	422.0	102.1	24.2	220	490	475
	N. aff. partschi	Zin 2.	Israel	m.C	4	415.0	37.7	9.1	360	450	425
		St-Barthélemy 1. (Maisonnave)	France	b.L	3	423.3	27.2	6.4	395	460	415
	N. partschi-gruppe	Zin 2.	Israel	m.C	23	434.1	86.8	20.0	300	620	400
	N. pavloveci	Melitta	Tunesia	u.I	11	344.5	105.3	30.6	235	600	325
		Guttaring	Austria	b.C	7	417.1	49.7	11.9	370	500	385
		Gan 1. (Berdoulou)	France	b.C	6	406.7	106.8	26.3	250	570	403
		Encebras 1.	Spain	b.C	7	345.0	52.6	15.2	250	400	345
		San Vicente de la Barquera 1.	Spain	l.C	3	508.3	56.6	11.1	450	585	490
		Janovas 2.	Spain	l/m.C	1	290.0	0.0	0.0	290	290	290
		Benidorm 2.	Spain	l/m.C	6	454.2	69.9	15.4	360	535	455
		Huéscar 2.	Spain	l/m.C	7	532.9	118.8	22.3	340	700	530
		Sfax	Tunesia	l-m.C	5	428.0	96.8	22.6	300	600	420
		Aoíz 1.	Spain	m.C	1	540.0	0.0	0.0	540	540	540
		Encebras 2.	Spain	m-u.C	2	655.0	265.0	40.5	390	920	655
	N. cf. pavloveci	Benidorm 4.	Spain	u.C	2	262.5	22.5	8.6	240	285	263
	N. aff. obsoletus?	Huéscar 3.	Spain	b.L	3	553.3	90.3	16.3	450	670	540
	N. gracilis	Syrte 3.	Libya	m-u.C	6	234.2	59.5	25.4	190	360	203
		Syrte 4.	Libya	b.L	1	440.0	0.0	0.0	440	440	440
	N. aff. tauricus	Buttrio	Italy	m.C	4	478.8	134.4	28.1	335	660	460
		Zin 2.	Israel	m.C	7	364.3	40.2	11.0	320	450	355
	N. cf. tauricus	Huéscar 2.	Spain	l/m.C	3	578.3	67.1	11.6	485	640	610
		Crimée 4. (distans-zone 1)	Ukraine	m.C	4	541.3	88.3	16.3	445	680	520
	N. tauricus	Bosdarros 1. (Rigabert)	France	l.C	2	382.5	32.5	8.5	350	415	383
		Huéscar 2.	Spain	l/m.C	8	538.8	86.9	16.1	390	715	535
		El Pocino 2.	Spain	m.C	7	492.9	69.6	14.1	380	590	500
		Moratalla	Spain	m.C	2	775.0	325.0	41.9	450	1100	775
		Buttrio	Italy	m.C	4	545.0	23.2	4.3	505	560	558
		Encebras 2.	Spain	m-u.C	2	510.0	20.0	3.9	490	530	510
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	9	530.0	99.8	18.8	420	690	470
		Aoíz 2.	Spain	u.C	1	345.0	0.0	0.0	345	345	345
		Benidorm 4.	Spain	u.C	3	366.7	95.7	26.1	280	500	320
		Dobrinj	Croatia	u.C	2	560.0	60.0	10.7	500	620	560
		Noax	Italy	u.C	2	477.5	12.5	2.6	465	490	478
		Boltaña 3.	Spain	b.L	3	550.0	67.2	12.2	455	600	595
	N. tauricus - praelorioli	Bergouey (Gas, Malaou, Peyrat)	France	u.C	6	410.8	44.0	10.7	340	460	415
		Noax	Italy	u.C	1	580.0	0.0	0.0	580	580	580
		Perrarua	Spain	u.C/b.L	3	478.3	70.3	14.7	380	540	515
	N. aff. praelorioli	Figueras	Spain	u.C/b.L	8	598.8	118.5	19.8	410	800	555
	N. praelorioli	Encebras 2.	Spain	m-u.C	2	495.0	135.0	27.3	360	630	495
		Boltaña 3.	Spain	b.L	7	588.6	122.9	20.9	345	730	635
		Huéscar 3.	Spain	b.L	3	475.0	68.2	14.4	385	550	490
		Chiampo	Italy	b.L	8	572.5	77.3	13.5	460	660	588
		Hastingues	France	l.L	4	597.5	48.8	8.2	520	650	610
N. partschi	N. praelorioli	St-Martin-de-Seignanx	France	l.L	5	513.0	78.3	15.3	410	645	515
		Urcuit	France	l.L	8	603.8	97.8	16.2	465	780	588
		Sorde-l'Abbaye 2.	France	l.L	6	380.8	61.5	16.2	340	515	355
		La Pobla de Lillet 1.	Spain	l.L	6	638.3	112.3	17.6	460	800	628
		Bastennes 1.	France	l/m.L	8	593.1	108.8	18.3	505	860	565
	N. cf. praelorioli	St-Martin-de-Seignanx	France	l.L	1	610.0	0.0	0.0	610	610	610
		Gibret	France	l/m.L	1	640.0	0.0	0.0	640	640	640
		Bastennes 2.	France	m1.L	2	642.5	92.5	14.4	550	735	643
	N. syrticus	Syrte 5.	Libya	l.L	24	470.8	73.7	15.7	370	650	455
		Matsuba	Israel	m.L	12	412.9	167.0	40.4	120	700	450
	N. carteri	Gandbo Hill	Pakistan	m.L	8	557.5	182.1	32.7	250	800	595
	N. aff. boussaci	Samitier 1.	Spain	u.C/b.L	3	550.0	122.5	22.3	400	700	550
		Mediano 4.	Spain	m1.L	7	615.0	70.2	11.4	530	730	610
	N. boussaci	Ste-Marie-de-Gosse	France	l.L	18	648.9	74.1	11.4	545	795	643
		Formigales	Spain	l.L	20	758.0	97.5	12.9	590	950	758
		Mediano 2.	Spain	l.L	11	676.8	129.3	19.1	465	930	660
		Mediano 3.	Spain	l.L	7	730.7	111.5	15.3	545	915	730
		Troncedo	Spain	l.L	1	430.0	0.0	0.0	430	430	430
		Boltaña 4.	Spain	l.L	6	575.8	61.9	10.8	460	660	590
		Biron	France	m1.L	11	603.2	55.8	9.2	525	685	610

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Orthez	France	m1.L	1	650.0	0.0	0.0	650	650	650
		San Giovanni Ilarione	Italy	m1.L	6	651.7	50.7	7.8	580	730	655
		Samitier 2.	Spain	m2.L	4	747.5	58.0	7.8	680	810	750
	N. aff. lorioli	Caupenne 1. (Jeangazé)	France	u.C	9	767.8	87.6	11.4	685	960	745
		Huéscar 3.	Spain	b.L	3	573.3	33.0	5.8	550	620	550
	N. sp. cf. lorioli I.	Boltaña 5.	Spain	l-m.L	4	623.8	71.7	11.5	540	735	610
	N. sp. cf. lorioli II.	Boltaña 5.	Spain	l-m.L	4	418.8	55.4	13.2	345	495	418
	N. lorioli	Caravaca 2.	Spain	m.L	4	617.5	117.1	19.0	510	800	580
		Bastennes 3.	France	m2.L	25	677.4	108.3	16.0	500	940	660
		Donzacq 2.	France	m2.L	22	703.0	103.3	14.7	560	990	690
		St-Barthélemy 2. (église)	France	m/u.L	2	727.5	37.5	5.2	690	765	728
	N. aff. hottingeri	Mediano 6.	Spain	m2.L	4	700.0	55.2	7.9	610	750	720
	N. hottingeri	Carme 1. (Colbass)	Spain	B	4	817.5	82.6	10.1	690	900	840
		Carme 2. (Col Lentilles)	Spain	B	6	606.7	82.3	13.6	495	695	628
		Santa Margarita de Mombuy	Spain	B	11	665.5	86.0	12.9	500	800	680
		Santa Maria de Miralles	Spain	B	4	633.8	47.1	7.4	555	680	650
N. gizehensis	N. cf. bakhchisaraiensis	Huéscar 2.	Spain	l/m.C	7	580.0	80.4	13.9	490	730	550
	N. bakhchisaraiensis	Syrte 4.	Libya	b.L	17	722.1	112.3	15.6	390	880	750
	N. aff. bakhchisaraiensis	Syrte 4.	Libya	b.L	18	742.2	222.8	30.0	490	1550	705
	N. cf. gizehensis	Syrte 4.	Libya	b.L	8	743.1	65.4	8.8	640	860	735
		Syrte 5.	Libya	l.L	11	859.5	138.4	16.1	720	1150	815
	N. gizehensis	Syrte 6.	Libya	m.L	2	495.0	45.0	9.1	450	540	495
		Matsuba	Israel	m.L	19	722.6	130.4	18.0	515	1040	710
		Gizeh	Egypt	u.L	6	770.0	112.4	14.6	650	950	745
		Syrte 7.	Libya	u.L	30	800.0	179.8	22.5	510	1330	800
N. lyelli	Avesa 4.	Italy	B	8	1155.6	188.8	16.3	940	1485	1103	
		Grancona 1.	Italy	B	14	996.8	147.9	14.8	730	1280	983
		Syrte 8.	Libya	B	5	1168.0	173.7	14.9	950	1380	1150
		Har Horsha	Israel	B	3	1193.3	41.9	3.5	1150	1250	1180
N. leupoldi	N. gamardensis	Gamarde	France	b.I	17	84.7	13.6	16.0	65	115	80
		Orignac 1.	France	b.I	4	118.8	23.0	19.4	80	140	128
		Mur	Spain	b.I	3	228.3	37.0	16.2	195	280	210
	N. praelucasi	Areny 3.	Spain	m2.I	1	105.0	0.0	0.0	105	105	105
		Sant Adriá 2.	Spain	m2.I	9	106.7	28.7	26.9	65	160	95
		Sant Adriá 3.	Spain	m2.I	3	141.7	23.2	16.4	110	165	150
		Orignac 2.	France	u.I	6	212.5	29.5	13.9	180	255	203
		Sant Adriá 5.	Spain	u.I	5	170.0	52.7	31.0	95	255	165
		Campo 4.	Spain	u.I	1	235.0	0.0	0.0	235	235	235
		Caravaca 1.	Spain	u.I/b.C	1	300.0	0.0	0.0	300	300	300
		Gan 1. (Berdoulou)	France	b.C	1	290.0	0.0	0.0	290	290	290
		Campo 5.	Spain	b.C	1	235.0	0.0	0.0	235	235	235
		Crimée 2. (placentula-zone)	Ukraine	b.C	10	187.5	42.9	22.9	100	240	193
		St. Pankraz 1. (Roterz)	Austria	l.C	3	208.3	42.9	20.6	155	260	210
		Gan 3. (Tuilerie 1)	France	l.C	11	71.4	11.3	15.8	55	95	70
		Benidorm 2.	Spain	l/m.C	1	140.0	0.0	0.0	140	140	140
		Sfax	Tunesia	l-m.C	1	170.0	0.0	0.0	170	170	170
N. leupoldi	N. praelucasi	Crimée 4. (distans-zone 1)	Ukraine	m.C	1	235.0	0.0	0.0	235	235	235
	N. praelucasi - leupoldi	Port Louis	France	b.C	1	440.0	0.0	0.0	440	440	440
	N. cf. leupoldi	Haymana 2.	Turkey	u.I	5	193.0	41.9	21.7	120	240	200
		Crimée 6. (polygyratus-zone)	Ukraine	u.C	5	213.0	19.4	9.1	180	240	215
	N. leupoldi	Gan 1. (Berdoulou)	France	b.C	1	335.0	0.0	0.0	335	335	335
		Valdeforte	Italy	b.C	3	286.7	20.5	7.2	260	310	290
		Crimée 2. (placentula-zone)	Ukraine	b.C	1	235.0	0.0	0.0	235	235	235
		Flibach	Switzerl.	l.C	3	141.7	23.2	16.4	110	165	150
		Samper	Spain	l.C	1	110.0	0.0	0.0	110	110	110
		Janovas 1.	Spain	l/m.C	7	221.4	98.9	44.7	160	460	190
		Benidorm 2.	Spain	l/m.C	1	95.0	0.0	0.0	95	95	95
		Bosdarros 2.	France	m.C	1	205.0	0.0	0.0	205	205	205
		Aoíz 1.	Spain	m.C	3	151.7	13.1	8.7	140	170	145
		Boltaña 2.	Spain	m.C	6	208.3	6.2	3.0	200	220	208
		Janovas 3.	Spain	m/u.C	3	180.0	29.4	16.4	140	210	190
		Syrte 3.	Libya	m-u.C	1	300.0	0.0	0.0	300	300	300
		Samitier 1.	Spain	u.C/b.L	2	285.0	25.0	8.8	260	310	285
	N. aff. leupoldi	Zin 1.	Israel	m.C	2	235.0	5.0	2.1	230	240	235
		Donzacq 1.	France	l/m.L	6	108.3	19.3	17.8	80	145	108
		Nousse	France	l/m.L	1	390.0	0.0	0.0	390	390	390
		Orthez	France	m1.L	8	127.5	18.2	14.3	90	145	135
		Avesa 2.	Italy	m-u.L	1	140.0	0.0	0.0	140	140	140
	N. sp. aff. leupoldi	Encebras 1.	Spain	b.C	3	163.3	26.2	16.1	140	200	150
		Boltaña 3.	Spain	b.L	4	286.3	48.3	16.9	240	365	270
		Syrte 4.	Libya	b.L	2	432.5	187.5	43.4	245	620	433

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Boltaña 4.	Spain	l.L	1	865.0	0.0	0.0	865	865	865
		Syrte 6.	Libya	m.L	2	195.0	5.0	2.6	190	200	195
		Samitier 2.	Spain	m2.L	4	240.0	220.0	91.7	95	620	123
	N. biarritzensis	Sorde-l'Abbaye 5.	France	u.L	4	265.0	9.4	3.5	250	275	268
		Huéscar 4.	Spain	u.L	5	213.0	77.7	36.5	130	345	190
		La Mortola	France	u.L/B	7	268.6	16.2	6.0	235	290	270
		San Vicente de la Barquera 7.	Spain	u.L-B	4	265.0	56.8	21.4	170	320	285
		Biarritz 1. (Gourèpe)	France	B	8	241.3	20.7	8.6	210	280	238
		Biarritz 3. (Peyreblanque 2)	France	B	5	242.0	106.7	44.1	145	450	210
		Carme 1. (Colbass)	Spain	B	3	200.0	36.7	18.4	155	245	200
		La Fonollera	Spain	B	3	226.7	45.5	20.1	185	290	205
		Grancona 1.	Italy	B	13	300.0	39.9	13.3	240	375	300
		Soave	Italy	B	1	230.0	0.0	0.0	230	230	230
N. fabianii	N. praebullatus	Syrte 4.	Libya	b.L	7	96.4	13.6	14.1	80	120	95
	N. aff. bullatus	Mediano 5.	Spain	m2.L	6	80.8	11.3	14.0	70	105	78
	N. bullatus	Syrte 7.	Libya	u.L	9	106.1	25.9	24.4	75	150	100
	N. aff. ptukhiani	Syrte 7.	Libya	u.L	1	115.0	0.0	0.0	115	115	115
		Biarritz 2. (Peyreblanque 1)	France	B	11	95.5	14.5	15.2	70	120	100
	N. ptukhiani	Calders	Spain	B	5	191.0	8.0	4.2	180	200	190
		Monells	Spain	B	3	223.3	23.2	10.4	200	255	215
		Syrte 8.	Libya	B	3	141.7	33.0	23.3	105	185	135
	N. aff. fabianii	La Fonollera	Spain	B	8	166.3	35.0	21.0	105	240	168
		Ullastret	Spain	B	8	210.6	12.9	6.1	195	235	208
	N. fabianii	Grancona 3.	Italy	P	8	240.6	29.0	12.0	190	290	245
N. rotularius	N. bigurdensis	Orignac 1.	France	b.I	32	409.8	88.5	21.6	150	565	420
		Estorm	Spain	b.I	3	333.3	20.9	6.3	305	355	340
	N. praevius	Alsina (Tremp) 3.	Spain	m2.I	6	207.5	60.9	29.4	95	295	213
		Alsina (Tremp) 4.	Spain	m2.I	1	190.0	0.0	0.0	190	190	190
		Areny 6.	Spain	u.I	5	306.0	43.2	14.1	270	390	290
		Sant Adriá 5.	Spain	u.I	1	240.0	0.0	0.0	240	240	240
		Mediano 1.	Spain	u.I	3	323.3	23.9	7.4	290	345	335
		Melitta	Tunesia	u.I	3	320.0	120.8	37.8	150	420	390
	N. rotularius	Gan 1. (Berdoulou)	France	b.C	1	460.0	0.0	0.0	460	460	460
		Encebras 1.	Spain	b.C	1	310.0	0.0	0.0	310	310	310
		Valdeforte	Italy	b.C	1	390.0	0.0	0.0	390	390	390
		Crimée 2. (placentula-zone)	Ukraine	b.C	16	308.8	39.7	12.9	235	400	303
		Haymana 3.	Turkey	b.C	2	352.5	7.5	2.1	345	360	353
		Samper	Spain	l.C	1	340.0	0.0	0.0	340	340	340
		Crimée 3. (nemkovi-zone)	Ukraine	l.C	18	343.9	96.3	28.0	145	500	355
		Haymana 4.	Turkey	l.C	7	410.0	38.9	9.5	360	460	390
		Janovas 2.	Spain	l/m.C	2	282.5	2.5	0.9	280	285	283
N. rotularius	N. rotularius	Vanzi 1.	Italy	l-m.C	2	255.0	10.0	3.9	245	265	255
		Sfax	Tunesia	l-m.C	8	358.8	68.7	19.1	285	500	335
		Bärlaui	Switzerl.	m.C	2	240.0	45.0	18.8	195	285	240
		Aoíz 1.	Spain	m.C	3	306.7	45.0	14.7	250	360	310
		Crimée 4. (distans-zone 1)	Ukraine	m.C	10	327.0	126.1	38.6	175	570	290
		Crimée 5. (distans-zone 2)	Ukraine	m.C	10	255.5	57.9	22.7	150	375	253
		Syrte 3.	Libya	m-u.C	11	311.4	101.0	32.5	200	510	285
		Caupenne 1. (Jeangazé)	France	u.C	2	435.0	45.0	10.3	390	480	435
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	8	348.8	32.7	9.4	310	410	343
		San Vicente de la Barquera 3.	Spain	u.C	1	340.0	0.0	0.0	340	340	340
		Azarlîc	Romania	u.C	3	240.0	32.7	13.6	200	280	240
		Crimée 6. (polygyratus-zone)	Ukraine	u.C	23	301.1	60.9	20.2	200	480	290
	N. cf. rotularius	Tierrantona	Spain	u.C	3	495.0	105.9	21.4	390	640	455
	N. perplexus	Vanzi 2.	Italy	b.L	9	587.8	49.1	8.4	520	660	590
		Syrte 5.	Libya	l.L	30	687.7	90.2	13.1	500	890	670
	N. vasseuri	Syrte 6.	Libya	m.L	15	649.3	163.3	25.2	420	1050	600
N. discorbinus	N. praediscorbinus	Campo 7.	Spain	m.C	5	79.0	12.4	15.7	60	95	75
		Syrte 3.	Libya	m-u.C	3	115.0	24.8	21.6	95	150	100
		Tierrantona	Spain	u.C	10	111.0	45.0	40.5	55	175	113
		Boltaña 3.	Spain	b.L	5	77.0	49.9	64.8	25	170	70
		Darvastó	Hungary	b.L	1	65.0	0.0	0.0	65	65	65
		Syrte 4.	Libya	b.L	10	197.0	28.7	14.5	165	270	193
		Formigales	Spain	l.L	4	85.0	9.4	11.0	70	95	88
		El Far	Spain	l.L	2	120.0	10.0	8.3	110	130	120
		Syrte 5.	Libya	l.L	17	146.8	49.3	33.6	55	220	150
		Boltaña 5.	Spain	l-m.L	7	155.0	66.1	42.7	75	295	125
		Ripoll	Spain	m1.L	3	80.0	16.3	20.4	60	100	80
	N. discorbinus	Panillo 2. (Ermita)	Spain	m1.L	2	160.0	30.0	18.8	130	190	160
		Avesa 2.	Italy	m-u.L	2	250.0	50.0	20.0	200	300	250
		Sorde-l'Abbaye 4.	France	u.L	1	140.0	0.0	0.0	140	140	140

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Syrte 7.	Libya	u.L	14	185.0	36.4	19.6	140	285	185
		Avesa 3.	Italy	u.L-B	2	350.0	25.0	7.1	325	375	350
		Biarritz 2. (Peyreblanque 1)	France	B	9	138.9	18.2	13.1	110	175	135
		Carme 1. (Colbass)	Spain	B	13	258.8	29.4	11.3	185	290	265
		Carme 2. (Col Lentilles)	Spain	B	2	157.5	22.5	14.3	135	180	158
		La Fonollera	Spain	B	3	258.3	60.6	23.5	195	340	240
		San Llorenç de Morunys 2.	Spain	B	6	203.3	56.8	27.9	100	260	225
		Ullastret	Spain	B	2	302.5	42.5	14.0	260	345	303
		Soave	Italy	B	1	235.0	0.0	0.0	235	235	235
		Syrte 8.	Libya	B	6	290.8	40.3	13.8	250	345	280
	N. cyrenaicus	Carme 2. (Col Lentilles)	Spain	B	5	416.0	82.5	19.8	255	490	440
		La Fonollera	Spain	B	1	460.0	0.0	0.0	460	460	460
		Monells	Spain	B	2	440.0	10.0	2.3	430	450	440
		Santa Maria de Miralles	Spain	B	1	305.0	0.0	0.0	305	305	305
		Ullastret	Spain	B	6	436.7	93.2	21.3	330	590	433
		Grancona 2.	Italy	B	13	530.0	132.7	25.0	290	780	515
		Syrte 8.	Libya	B	1	360.0	0.0	0.0	360	360	360
N. beaumonti	N. migiurtinus	Boltaña 3.	Spain	b.L	2	105.0	30.0	28.6	75	135	105
		Syrte 4.	Libya	b.L	1	95.0	0.0	0.0	95	95	95
		Syrte 5.	Libya	l.L	29	115.3	29.6	25.7	70	190	115
		Mediano 4.	Spain	m1.L	7	104.3	23.8	22.8	70	140	110
		Panillo 1. (Marials)	Spain	m1.L	3	113.3	36.8	32.5	70	160	110
		Mediano 5.	Spain	m2.L	3	116.7	19.3	16.5	90	135	125
		Tavertet	Spain	u.L	3	106.7	20.1	18.9	90	135	95
	N. aff. beaumonti	Matsuba	Israel	m.L	2	230.0	50.0	21.7	180	280	230
	N. beaumonti	Syrte 6.	Libya	m.L	1	115.0	0.0	0.0	115	115	115
		Syrte 7.	Libya	u.L	10	161.0	53.8	33.4	90	270	158
		Carme 1. (Colbass)	Spain	B	7	271.4	72.9	26.9	200	435	250
	N. vicaryi	Syrte 8.	Libya	B	20	226.3	47.7	21.1	125	350	230
N.minervensis	N. minervensis	Orignac 1.	France	b.I	12	177.1	46.2	26.1	115	270	175
		Mur	Spain	b.I	1	190.0	0.0	0.0	190	190	190
		Minerve	France	l.I	6	189.2	28.5	15.1	160	245	183
		Mont Cayla 1.	France	l.I	3	261.7	37.9	14.5	230	315	240
	N. aff. minervensis	Fabas 1. (Larue)	France	m1.I	7	246.4	13.0	5.3	230	265	245
		Fabas 2. (Bardau)	France	m1.I	9	243.9	46.8	19.2	175	340	255
		Meting	Pakistan	m.I	12	271.3	41.5	15.3	230	380	260
N.minervensis	N. carcasonensis	Alsina (Tremp) 1.	Spain	l.I	5	236.0	38.4	16.3	190	285	240
		Llimiana 2.	Spain	l.I	40	234.8	57.8	24.6	140	345	225
		Montolieu	France	m1.I	2	272.5	27.5	10.1	245	300	273
		Moussoulens	France	m1.I	27	220.9	41.6	18.8	90	290	220
		Campo 3.	Spain	m1.I	5	157.0	40.1	25.5	95	215	155
	N. cf. carcasonensis	Huéscar 1.	Spain	m.I	4	205.0	18.4	9.0	190	235	198
	N. increscens	Areny 6.	Spain	u.I	5	263.0	8.1	3.1	250	275	265
		Sant Adriá 4.	Spain	u.I	12	193.8	30.6	15.8	155	250	185
		Tremp 5.	Spain	u.I	3	150.0	21.6	14.4	130	180	140
		Melitta	Tunesia	u.I	1	260.0	0.0	0.0	260	260	260
		Gan 1. (Berdoulou)	France	b.C	1	240.0	0.0	0.0	240	240	240
		Encebras 1.	Spain	b.C	6	371.7	103.8	27.9	250	510	365
		Valdeforte	Italy	b.C	1	210.0	0.0	0.0	210	210	210
		Crimée 2. (placentula-zone)	Ukraine	b.C	7	278.6	45.7	16.4	205	340	285
		San Vicente de la Barquera 1.	Spain	l.C	7	378.6	103.2	27.2	205	490	435
		Sfax	Tunesia	l-m.C	1	310.0	0.0	0.0	310	310	310
		Bärlaui	Switzerl.	m.C	1	180.0	0.0	0.0	180	180	180
	N. aff. increscens	Aoíz 1.	Spain	m.C	3	403.3	67.1	16.6	310	465	435
N. globulus	N. deserti	Estorm	Spain	b.I	1	240.0	0.0	0.0	240	240	240
		Sant Estevé 1.	Spain	b.I	1	195.0	0.0	0.0	195	195	195
		Llimiana 1.	Spain	b.I	2	225.0	35.0	15.6	190	260	225
		Haymana 1.	Turkey	b.I	1	125.0	0.0	0.0	125	125	125
		Syrte 1.	Libya	l.I	5	128.0	47.8	37.4	90	210	95
		Coustouge 1.	France	l.I	16	195.0	30.3	15.5	140	245	190
		Mont Cayla 1.	France	l.I	2	220.0	20.0	9.1	200	240	220
		Alsina (Tremp) 1.	Spain	l.I	13	195.8	26.7	13.7	155	260	190
		Llimiana 2.	Spain	l.I	7	147.1	42.3	28.8	95	220	135
		Campo 2.	Spain	l.I	8	225.0	57.7	25.7	95	290	243
		Farafrah	Egypt	l.I	33	137.7	22.2	16.1	100	190	145
	N. aff. deserti	Sant Estevé 1.	Spain	b.I	4	217.5	35.1	16.1	165	260	223
		Areny 2.	Spain	l.I	1	150.0	0.0	0.0	150	150	150
		Montolieu	France	m1.I	3	190.0	37.4	19.7	150	240	180
		Sant Adriá 1.	Spain	m2.I	3	93.3	12.5	13.4	80	110	90
		Sant Adriá 2.	Spain	m2.I	1	140.0	0.0	0.0	140	140	140
		Sant Adriá 3.	Spain	m2.I	2	130.0	20.0	15.4	110	150	130

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Areny 5.	Spain	u.I	8	121.3	42.6	35.2	55	205	115
		Areny 6.	Spain	u.I	4	202.5	48.7	24.0	130	260	210
		Sant Adriá 5.	Spain	u.I	5	217.0	18.9	8.7	180	230	225
		Tremp 5.	Spain	u.I	2	162.5	22.5	13.8	140	185	163
		Mediano 1.	Spain	u.I	2	135.0	5.0	3.7	130	140	135
	N. cf. deserti	Orignac 1.	France	b.I	6	157.5	48.0	30.5	100	250	155
	N. cf. globulus	Syrte 1.	Libya	l.I	2	137.5	52.5	38.2	85	190	138
		Fabas 1. (Larue)	France	m1.I	6	162.5	57.1	35.1	95	260	165
		Fabas 2. (Bardau)	France	m1.I	2	212.5	22.5	10.6	190	235	213
	N. globulus	Coustouge 2.	France	m1.I	24	191.5	36.2	18.9	140	245	195
		Aurignac 1.	France	m2.I	8	171.3	33.8	19.7	120	230	173
		Montberaud	France	m2.I	18	203.9	54.4	26.7	110	295	193
		Coustouge 3.	France	m2.I	11	191.4	39.2	20.5	110	250	195
		Mont Cayla 2.	France	m2.I	14	177.1	56.2	31.8	100	280	158
		Alsina (Tremp) 2.	Spain	m2.I	15	192.3	35.3	18.4	140	270	185
		Alsina (Tremp) 3.	Spain	m2.I	1	300.0	0.0	0.0	300	300	300
		Alsina (Tremp) 4.	Spain	m2.I	8	168.8	18.5	11.0	140	210	168
		Areny 4.	Spain	m2.I	16	174.7	54.3	31.1	110	280	160
		Llimiana 3.	Spain	m2.I	10	209.0	35.1	16.8	160	280	210
		Sant Adriá 1.	Spain	m2.I	6	177.5	39.3	22.2	135	240	165
		Sant Adriá 3.	Spain	m2.I	5	215.0	19.2	8.9	185	245	215
		Tremp 3.	Spain	m2.I	11	175.0	45.5	26.0	100	260	180
		Alsina (Tremp) 5.	Spain	u.I	16	208.1	31.3	15.0	145	250	200
		Areny 6.	Spain	u.I	4	196.3	25.8	13.2	175	240	185
		Sant Adriá 4.	Spain	u.I	10	184.0	40.4	22.0	100	240	183
		Sant Adriá 5.	Spain	u.I	12	201.3	41.6	20.7	150	290	195
	N. aff. globulus	Huéscar 1.	Spain	m.I	2	257.5	67.5	26.2	190	325	258
		Areny 6.	Spain	u.I	12	233.8	32.8	14.0	170	315	240
	N. aff. globulus (increscens?)	Sittenberg	Austria	b.C	4	185.0	51.4	27.8	140	265	168
	N. aff. globulus - cf. increscens	Aurignac 1.	France	m2.I	1	275.0	0.0	0.0	275	275	275
	N. aff. globulus - subramondi	Aurignac 1.	France	m2.I	7	216.4	43.0	19.9	140	280	200
N. globulus	N. globulus nanus	Sant Adriá 3.	Spain	m2.I	3	131.7	42.5	32.3	90	190	115
		Alsina (Tremp) 5.	Spain	u.I	2	122.5	32.5	26.5	90	155	123
		Sant Adriá 4.	Spain	u.I	10	140.5	37.2	26.5	90	190	135
	N. globulus laxiformis	Areny 3.	Spain	m2.I	3	105.0	10.8	10.3	90	115	110
		Areny 4.	Spain	m2.I	14	112.1	30.9	27.6	60	185	108
		Sant Adriá 3.	Spain	m2.I	16	120.9	35.1	29.0	70	180	115
		Tremp 3.	Spain	m2.I	7	231.4	25.6	11.1	190	280	230
		Tremp 4.	Spain	m2.I	23	178.7	46.2	25.9	95	250	180
		Areny 5.	Spain	u.I	3	220.0	14.1	6.4	210	240	210
		Areny 6.	Spain	u.I	7	167.1	26.7	16.0	135	210	180
		Llimiana 4.	Spain	u.I	2	302.5	17.5	5.8	285	320	303
		Tremp 5.	Spain	u.I	16	202.8	41.9	20.6	110	260	205
	N. globulus latior	Alsina (Tremp) 2.	Spain	m2.I	6	261.7	16.7	6.4	235	285	263
		Areny 3.	Spain	m2.I	19	189.7	37.6	19.8	110	275	190
		Areny 4.	Spain	m2.I	7	276.4	37.9	13.7	200	320	290
		Sant Adriá 2.	Spain	m2.I	6	185.0	27.4	14.8	150	235	185
		Sant Adriá 3.	Spain	m2.I	6	223.3	75.0	33.6	140	350	218
		Tremp 3.	Spain	m2.I	3	190.0	16.3	8.6	170	210	190
	N. crimensis	Crimée 1. (crimensis-zone)	Ukraine	u.I	7	139.3	28.0	20.1	90	185	140
	N. aff. soerenbergensis	Tremp 4.	Spain	m2.I	4	107.5	20.5	19.0	90	140	100
	N. soerenbergensis	Areny 4.	Spain	m2.I	5	245.0	24.1	9.8	205	280	250
		Sant Adriá 3.	Spain	m2.I	3	175.0	18.7	10.7	150	195	180
		Tremp 3.	Spain	m2.I	14	179.3	45.1	25.1	120	300	170
		Tremp 4.	Spain	m2.I	8	197.5	38.9	19.7	145	285	200
		Sant Adriá 4.	Spain	u.I	8	148.8	18.0	12.1	130	185	145
		Sant Adriá 5.	Spain	u.I	3	211.7	34.7	16.4	170	255	210
		Tremp 5.	Spain	u.I	13	256.9	51.2	19.9	140	340	270
N. nitidus	N. laxus	Alsina (Tremp) 4.	Spain	m2.I	4	251.3	22.5	8.9	235	290	240
		Areny 3.	Spain	m2.I	3	238.3	14.3	6.0	220	255	240
		Sant Adriá 3.	Spain	m2.I	1	250.0	0.0	0.0	250	250	250
		Sant Adriá 5.	Spain	u.I	12	235.8	53.7	22.8	95	340	245
		Tremp 5.	Spain	u.I	7	241.4	31.0	12.8	205	300	235
		Melitta	Tunesia	u.I	27	226.7	62.6	27.6	110	350	230
	N. sp. aff. laxus III.	Mediano 1.	Spain	u.I	1	515.0	0.0	0.0	515	515	515
	N. sp. aff. laxus VI.	Mediano 1.	Spain	u.I	1	570.0	0.0	0.0	570	570	570
	N. aff. laxus	Encebras 1.	Spain	b.C	1	140.0	0.0	0.0	140	140	140
		Alfaz	Spain	l.C	1	270.0	0.0	0.0	270	270	270
		Bolca	Italy	l.C	2	250.0	10.0	4.0	240	260	250
		Huéscar 2.	Spain	l/m.C	4	313.8	79.5	25.3	200	420	318
	N. aff. nitidus	Zin 1.	Israel	m.C	1	325.0	0.0	0.0	325	325	325

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. aff. formosus	Buttrio	Italy	m.C	1	530.0	0.0	0.0	530	530	530
	N. formosus	Caupenne 1. (Jeangazé)	France	u.C	8	478.8	88.2	18.4	320	590	495
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	28	513.8	73.6	14.3	340	675	513
	N. cf. formosus	San Vicente de la Barquera 3.	Spain	u.C	1	455.0	0.0	0.0	455	455	455
		San Vicente de la Barquera 4.	Spain	b.L	4	400.0	71.0	17.7	330	515	378
	N. caupennensis	Caupenne 1. (Jeangazé)	France	u.C	6	418.3	68.7	16.4	350	560	390
N. pustulosus	N. subramondi	Areny 4.	Spain	m2.I	10	252.5	52.1	20.6	190	370	253
		Tremp 3.	Spain	m2.I	6	238.3	24.9	10.5	210	290	233
		Orignac 2.	France	u.I	1	300.0	0.0	0.0	300	300	300
		Areny 6.	Spain	u.I	3	290.0	24.8	8.6	255	310	305
		Sant Adriá 4.	Spain	u.I	3	246.7	45.0	18.2	190	300	250
		Tremp 5.	Spain	u.I	11	226.4	34.0	15.0	145	285	230
		Melitta	Tunesia	u.I	37	332.7	60.8	18.3	170	450	340
		Guttaring	Austria	b.C	16	258.1	35.2	13.6	205	335	263
		Ossun	France	b.C	1	250.0	0.0	0.0	250	250	250
		Valdeforte	Italy	b.C	2	335.0	45.0	13.4	290	380	335
		Syrte 2.	Libya	l.C	1	290.0	0.0	0.0	290	290	290
	N. subramondi thalmanni	Sfax	Tunesia	l-m.C	13	369.2	79.5	21.5	250	490	345
		Syrte 3.	Libya	m-u.C	6	297.5	53.9	18.1	215	365	303
	N. aff. subramondi	Syrte 4.	Libya	b.L	7	394.3	112.7	28.6	260	600	340
	N. pustulosus	Gan 1. (Berdoulou)	France	b.C	8	344.4	126.4	36.7	185	570	300
		Encebras 1.	Spain	b.C	11	428.6	79.2	18.5	280	560	435
		Gan 3. (Tuilerie 1)	France	l.C	8	418.8	80.0	19.1	300	530	435
		Alfaz	Spain	l.C	6	397.5	86.7	21.8	290	560	405
		Benidorm 1.	Spain	l.C	1	245.0	0.0	0.0	245	245	245
		Haymana 4.	Turkey	l.C	1	750.0	0.0	0.0	750	750	750
N. pustulosus	N. pustulosus	Haymana 5.	Turkey	l.C	1	540.0	0.0	0.0	540	540	540
		Huéscar 2.	Spain	l/m.C	8	511.3	105.3	20.6	255	590	550
		El Pocino 2.	Spain	m.C	1	280.0	0.0	0.0	280	280	280
		Aoíz 1.	Spain	m.C	1	300.0	0.0	0.0	300	300	300
		Moratalla	Spain	m.C	7	383.6	43.2	11.3	320	450	380
		Benidorm 4.	Spain	u.C	3	456.7	40.3	8.8	400	490	480
	N. pustulosus, engspiralig	Benidorm 2.	Spain	l/m.C	5	371.0	18.5	5.0	350	400	360
	N. pustulosus, weitspiralig	Benidorm 2.	Spain	l/m.C	10	345.5	56.5	16.4	200	410	350
	N. aff. pustulosus	Zin 1.	Israel	m.C	7	345.0	99.5	28.8	255	580	310
	N. escheri	Gan 1. (Berdoulou)	France	b.C	3	376.7	104.4	27.7	230	465	435
		Bosdarros 2.	France	m.C	8	248.8	48.7	19.6	150	315	260
		Gan 5. (Tuilerie 2)	France	m.C	3	195.0	10.8	5.5	180	205	200
		Aoíz 1.	Spain	m.C	3	198.3	47.3	23.9	145	260	190
	N. aff. escheri	Zin 1.	Israel	m.C	1	210.0	0.0	0.0	210	210	210
	N. aff. dolloti	Zin 1.	Israel	m.C	5	373.0	89.6	24.0	250	480	410
	N. aff. arnii	Zin 1.	Israel	m.C	3	370.0	63.8	17.2	280	420	410
	N. arnii	Syrte 4.	Libya	b.L	3	361.7	53.3	14.7	300	430	355
N. garnieri	N. praegarnieri	San Llorenç de Morunys 2.	Spain	B	3	78.3	8.5	10.8	70	90	75
	N. praegarnieri	Santa Maria de Miralles	Spain	B	2	70.0	5.0	7.1	65	75	70
	N. aff. garnieri	Arguis 3.	Spain	P	5	76.0	24.8	32.6	50	115	75
	N. garnieri	Grancona 3.	Italy	P	5	138.0	26.9	19.5	85	160	150
N. striatus	N. striatus	La Fonollera	Spain	B	3	396.7	43.7	11.0	350	455	385
N. puschi	N. fraasi	Oiching	Austria	b.I	5	143.0	16.9	11.8	115	165	150
		Estorm	Spain	b.I	2	245.0	0.0	0.0	245	245	245
		Mur	Spain	b.I	1	175.0	0.0	0.0	175	175	175
		Areny 1.	Spain	b.I	2	150.0	10.0	6.7	140	160	150
		Campo 1.	Spain	b.I	3	111.7	19.3	17.3	85	130	120
		Coustouge 1.	France	l.I	3	176.7	34.7	19.7	135	220	175
		Llimiana 2.	Spain	l.I	2	157.5	2.5	1.6	155	160	158
		Farafrah	Egypt	l.I	21	147.1	29.8	20.2	110	210	145
	N. aff. fraasi	Orignac 1.	France	b.I	3	276.7	46.4	16.8	230	340	260
	N. robustiformis	Mur	Spain	b.I	1	275.0	0.0	0.0	275	275	275
		Alsina (Tremp) 1.	Spain	l.I	4	173.8	31.1	17.9	120	195	190
		Llimiana 2.	Spain	l.I	2	210.0	10.0	4.8	200	220	210
		Aragon	France	m1.I	4	225.0	21.5	9.6	195	250	228
		Montolieu	France	m1.I	4	235.0	52.8	22.5	150	290	250
	N. aff. robustiformis	Areny 2.	Spain	l.I	10	112.0	24.4	21.8	70	165	108N.
	cf. robustiformis	Huéscar 1.	Spain	m.I	2	147.5	2.5	1.7	145	150	148
	N. robustus	Fabas 1. (Larue)	France	m1.I	18	265.3	55.0	20.7	190	390	250
		Fabas 2. (Bardau)	France	m1.I	18	248.9	33.9	13.6	195	335	248
	N. aff. exilis (klein)	Campo 2.	Spain	l.I	2	195.0	15.0	7.7	180	210	195
	N. exilis	Coustouge 2.	France	m1.I	3	190.0	37.4	19.7	150	240	180
		Couiza	France	m2.I	2	305.0	35.0	11.5	270	340	305
		Coustouge 3.	France	m2.I	4	213.8	22.7	10.6	190	250	208
		Alsina (Tremp) 2.	Spain	m2.I	11	276.4	49.5	17.9	190	380	295

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Alsina (Tremp) 4.	Spain	m2.I	11	151.8	25.2	16.6	90	195	155
		Areny 3.	Spain	m2.I	14	155.7	30.1	19.3	100	200	155
		Areny 4.	Spain	m2.I	6	193.3	54.9	28.4	90	265	190
		Sant Adriá 1.	Spain	m2.I	5	210.0	66.9	31.9	140	315	195
		Sant Adriá 2.	Spain	m2.I	11	183.2	23.2	12.7	135	210	195
		Tremp 2.	Spain	m2.I	12	230.0	61.8	26.9	140	360	228
	N. involutus	Areny 6.	Spain	u.I	4	235.0	57.6	24.5	145	305	245
		Sant Adriá 4.	Spain	u.I	6	208.3	27.6	13.3	175	260	200
		Sant Adriá 5.	Spain	u.I	14	310.7	36.7	11.8	245	370	308
		Campo 4.	Spain	u.I	1	290.0	0.0	0.0	290	290	290
	N. cf. involutus	Orignac 2.	France	u.I	2	495.0	50.0	10.1	445	545	495
	N. vonderschmitti	Campo 5.	Spain	b.C	3	250.0	44.2	17.7	190	295	265
	N. planulatus	Aizy-Jouy	France	b.C	17	329.4	80.5	24.4	200	440	325
		Amigny-Rouy	France	b.C	5	407.0	52.2	12.8	310	450	435
		Cuise-la-Motte	France	b.C	3	436.7	155.5	35.6	305	655	350
		Pierrefonds	France	b.C	3	410.0	101.6	24.8	300	545	385
		Port Louis	France	b.C	15	433.7	57.1	13.2	345	580	435
		Campo 5.	Spain	b.C	2	407.5	37.5	9.2	370	445	408
		Bosdarros 1. (Rigabert)	France	l.C	1	375.0	0.0	0.0	375	375	375
		San Vicente de la Barquera 1.	Spain	l.C	6	465.0	42.4	9.1	410	550	458
		Campo 6.	Spain	l.C	3	380.0	116.7	30.7	295	545	300
N. puschi	N. planulatus	Huéscar 2.	Spain	l/m.C	4	275.0	47.2	17.2	230	340	265
		Vanzi 1.	Italy	l-m.C	1	535.0	0.0	0.0	535	535	535
	N. aff. planulatus	Buttrio	Italy	m.C	1	700.0	0.0	0.0	700	700	700
	N. manfredi	Lueza	Spain	u.C	12	612.5	113.0	18.5	400	790	623
		Tierrantona	Spain	u.C	1	520.0	0.0	0.0	520	520	520
		Campo 8.	Spain	u.C	11	518.6	99.7	19.2	400	780	500
	N. aff. manfredi	Aoíz 2.	Spain	u.C	2	670.0	30.0	4.5	640	700	670
	N. cf. manfredi	Boltaña 3.	Spain	b.L	3	531.7	54.8	10.3	455	580	560
	N. britannicus	Brecklesham Bay	England	b.L	9	468.9	57.0	12.2	360	570	480
		Selsey	England	b.L	12	552.5	153.9	27.9	400	1000	530
		Whitecliff Bay 2.	England	b.L	5	464.0	97.5	21.0	350	580	490
	N. cf. messinae	Samitier 1.	Spain	u.C/b.L	1	515.0	0.0	0.0	515	515	515
		Boltaña 3.	Spain	b.L	9	345.0	72.3	20.9	250	470	320
	N. messinae	Balatonhegy 1.	Hungary	b.L	2	595.0	50.0	8.4	545	645	595
		Hastingues	France	l.L	8	623.8	116.9	18.7	480	835	580
		St-Martin-de-Seignanx	France	l.L	3	610.0	53.5	8.8	550	680	600
		Ste-Marie-de-Gosse	France	l.L	11	651.4	111.9	17.2	535	930	600
		Urcuit	France	l.L	4	817.5	116.7	14.3	620	920	865
		Formigales	Spain	l.L	15	527.0	150.1	28.5	360	920	450
		Mediano 2.	Spain	l.L	4	458.8	49.0	10.7	400	535	450
		Troncedo	Spain	l.L	9	502.2	73.3	14.6	390	600	510
		Boltaña 5.	Spain	l-m.L	1	375.0	0.0	0.0	375	375	375
	N. aff. messinae	Formigales	Spain	l.L	5	529.0	106.7	20.2	390	660	515
	N. aff. messinae (engspiralig)	Formigales	Spain	l.L	9	530.0	96.7	18.2	360	710	530
	N. stephani	Panillo 2. (Ermita)	Spain	m1.L	16	617.2	128.5	20.8	385	870	593
	N. praepuschi	Sorde-l'Abbaye 3.	France	u.L	2	585.0	15.0	2.6	570	600	585
		Reehegy	Hungary	u.L	1	645.0	0.0	0.0	645	645	645
	N. puschi	Sorde-l'Abbaye 4.	France	u.L	2	1130.0	90.0	8.0	1040	1220	1130
		Peyrehorade 2.	France	B	10	1095.0	168.4	15.4	910	1530	1055
N. jacquoti	N. couisensis	Couiza	France	m2.I	11	174.1	31.8	18.2	120	220	180
		Llimiana 3.	Spain	m2.I	1	110.0	0.0	0.0	110	110	110
		Sant Adriá 1.	Spain	m2.I	4	166.3	47.1	28.3	85	200	190
		Sant Adriá 3.	Spain	m2.I	2	105.0	5.0	4.8	100	110	105
		Tremp 2.	Spain	m2.I	6	234.2	29.1	12.4	180	265	243
	N. aff. couisensis	Orignac 2.	France	u.I	8	230.6	29.1	12.6	190	270	243
	N. bearnensis	Gan 2. (Encot)	France	b.C	15	263.7	36.4	13.8	195	340	260
	N. aff. bearnensis	Gan 1. (Berdoulou)	France	b.C	1	460.0	0.0	0.0	460	460	460
	N. aff. bearnensis - cf. jacquoti	Sittenberg	Austria	b.C	10	238.0	55.4	23.3	135	365	233
		Ossun	France	b.C	12	281.3	50.5	18.0	150	350	283
	N. jacquoti	Gan 3. (Tuilerie 1)	France	l.C	3	338.3	71.9	21.3	285	440	290
N. brongniarti	N. aquitanicus	Whitecliff Bay 1.	England	b.C	1	270.0	0.0	0.0	270	270	270
		Campo 5.	Spain	b.C	4	265.0	48.2	18.2	210	340	255
		Bosdarros 1. (Rigabert)	France	l.C	3	363.3	82.2	22.6	270	470	350
		San Vicente de la Barquera 1.	Spain	l.C	1	520.0	0.0	0.0	520	520	520
	N. cf. praelaevigatus	Haymana 7.	Turkey	m.C	9	533.3	62.0	11.6	480	660	485
	N. praelaevigatus	Colombres	Spain	m.C	4	330.0	34.8	10.6	280	365	338
		San Vicente de la Barquera 2.	Spain	m.C	3	488.3	137.0	28.1	315	650	500
		Campo 7.	Spain	m.C	3	418.3	81.1	19.4	340	530	385
		Moratalla	Spain	m.C	1	520.0	0.0	0.0	520	520	520
		Aoíz 2.	Spain	u.C	1	560.0	0.0	0.0	560	560	560

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. quasilaevigatus	Caupenne 1. (Jeangazé)	France	u.C	2	545.0	175.0	32.1	370	720	545
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	2	465.0	25.0	5.4	440	490	465
		Lueza	Spain	u.C	2	597.5	72.5	12.1	525	670	598
		Tierrantona	Spain	u.C	5	531.0	73.9	13.9	400	625	555
		Campo 8.	Spain	u.C	7	457.9	115.9	25.3	230	560	520
		Rosazzo	Italy	u.C	9	431.1	84.0	19.5	280	525	450
		Perrarua	Spain	u.C/b.L	3	606.7	128.7	21.2	445	760	615
		Figueras	Spain	u.C/b.L	30	523.7	75.5	14.4	360	710	515
		Boltaña 3.	Spain	b.L	10	459.0	98.3	21.4	255	590	480
		Queralt p. Berga	Spain	b.L	1	435.0	0.0	0.0	435	435	435
		Boltaña 4.	Spain	l.L	2	560.0	30.0	5.4	530	590	560
	N. laevigatus (cf. hagni)	Sorde-l'Abbaye 1.	France	b.L	1	650.0	0.0	0.0	650	650	650
	N. laevigatus	Samitier 1.	Spain	u.C/b.L	7	517.1	107.2	20.7	370	700	500
		Mont Ganelon	France	b.L	17	592.4	91.2	15.4	435	770	575
		St-Gobain	France	b.L	23	619.1	126.9	20.5	430	950	630
		Chiampo	Italy	b.L	4	741.3	233.8	31.5	480	1120	683
N. brongniarti	N. laevigatus	Vanzi 2.	Italy	b.L	11	578.2	96.0	16.6	390	750	625
		Balatonhegy 1.	Hungary	b.L	11	589.1	141.4	24.0	390	855	535
		Darvastó	Hungary	b.L	5	548.0	78.6	14.3	400	630	570
N.allobrogensis		Châtelard-les-Bauges	France	b.L	4	815.0	73.9	9.1	745	925	795
	N. gratus	Panillo 1. (Marials)	Spain	m1.L	11	670.5	106.5	15.9	390	790	715
		Panillo 2. (Ermita)	Spain	m1.L	6	565.0	49.6	8.8	480	640	565
	N. sordensis	St-Barthélemy 2. (église)	France	m/u.L	9	821.7	137.4	16.7	500	1050	840
		Reehegy	Hungary	u.L	2	562.5	12.5	2.2	550	575	563
	N. aff. sordensis	Sorde-l'Abbaye 3.	France	u.L	1	510.0	0.0	0.0	510	510	510
	N. brongniarti	Biarritz 2. (Peyreblanque 1)	France	B	5	732.0	129.2	17.7	550	950	700
		Roncà	Italy	B	3	750.0	193.0	25.7	530	1000	720
		Soave	Italy	B	22	670.7	101.4	15.1	540	1030	650
N. carpenteri	N. aff. laevigatus	Haymana 8.	Turkey	u.C	2	1050.0	20.0	1.9	1030	1070	1050
		Haymana 9.	Turkey	l.L	4	1062.5	167.7	15.8	920	1330	1000
	N. scaber	Mont Ganelon	France	b.L	8	489.4	92.8	19.0	390	705	450
		St-Gobain	France	b.L	1	450.0	0.0	0.0	450	450	450
	N. aff. scaber	Formigales	Spain	l.L	5	525.0	71.0	13.5	450	615	510
		Mediano 2.	Spain	l.L	6	508.3	88.2	17.4	340	640	510
		Mediano 3.	Spain	l.L	2	607.5	192.5	31.7	415	800	608
	N. aff. carpenteri	Panillo 2. (Ermita)	Spain	m1.L	4	555.0	39.1	7.0	500	610	555
		San Giovanni Ilarione	Italy	m1.L	3	1196.7	456.4	38.1	830	1840	920
		Mediano 6.	Spain	m2.L	2	515.0	45.0	8.7	470	560	515
		Jaca	Spain	u.L	3	666.7	17.0	2.5	650	690	660
	N. carpenteri	Sorde-l'Abbaye 3.	France	u.L	1	480.0	0.0	0.0	480	480	480
		Huéscar 4.	Spain	u.L	2	767.5	82.5	10.7	685	850	768
		Monte Sant Angelo	Italy	u.L	9	629.4	161.3	25.6	420	1020	615
N. spirectypus	N. pontis	Gamarde	France	b.I	11	157.3	26.1	16.6	120	210	150
	N. aff. rockallensis	Orignac 1.	France	b.I	5	257.0	15.4	6.0	240	285	250
	N. spirectypus	Coustouge 3.	France	m2.I	9	214.4	36.6	17.1	160	280	200
		Areny 3.	Spain	m2.I	1	230.0	0.0	0.0	230	230	230
		Sant Adriá 1.	Spain	m2.I	6	197.5	58.4	29.6	95	250	230
		Tremp 2.	Spain	m2.I	12	246.7	39.2	15.9	190	295	243
		Tremp 3.	Spain	m2.I	1	250.0	0.0	0.0	250	250	250
		Melitta	Tunesia	u.I	12	250.4	68.9	27.5	130	350	265
	N. bombitus	Gan 1. (Berdoulou)	France	b.C	1	340.0	0.0	0.0	340	340	340
		Benidorm 2.	Spain	l/m.C	1	190.0	0.0	0.0	190	190	190
		Huéscar 2.	Spain	l/m.C	1	305.0	0.0	0.0	305	305	305
N. irregularis	N. irregularis	Horsarrieu	France	b.C	2	182.5	72.5	39.7	110	255	183
		Gan 1. (Berdoulou)	France	b.C	1	200.0	0.0	0.0	200	200	200
		Flibach	Switzerl.	l.C	4	255.0	27.6	10.8	230	300	245
		Bosdarros 2.	France	m.C	1	205.0	0.0	0.0	205	205	205
		Gan 4. (Le Chesnay)	France	m.C	6	224.2	32.6	14.5	185	280	223
		Gan 5. (Tuilerie 2)	France	m.C	19	239.5	26.5	11.1	200	300	240
		Aoíz 1.	Spain	m.C	1	370.0	0.0	0.0	370	370	370
		Buttrio	Italy	m.C	1	180.0	0.0	0.0	180	180	180
		Crimée 5. (distans-zone 2)	Ukraine	m.C	11	322.3	37.3	11.6	255	385	315
		Azarlîc	Romania	u.C	1	440.0	0.0	0.0	440	440	440
	N. cf. irregularis	Crimée 6. (polygyratus-zone)	Ukraine	u.C	2	475.0	10.0	2.1	465	485	475
	N. maior	Bastennes 2.	France	m1.L	9	347.2	39.2	11.3	280	395	350
		Caupenne 2. (Sarthou)	France	m1.L	6	423.3	69.4	16.4	340	500	430
N. distans	N. haymanensis	Haymana 2.	Turkey	u.I	10	343.0	36.8	10.7	290	400	350
		Gan 1. (Berdoulou)	France	b.C	30	262.8	38.3	14.6	190	365	260
		Encebras 1.	Spain	b.C	3	433.3	23.6	5.4	400	450	450
		Valdeforte	Italy	b.C	3	276.7	37.9	13.7	225	315	290
		Bolca	Italy	l.C	12	325.0	50.5	15.5	250	430	323

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. nemkovi	Crimée 3. (nemkovi-zone)	Ukraine	l.C	11	497.7	71.2	14.3	400	645	495
		Benidorm 2.	Spain	l/m.C	26	491.2	86.3	17.6	350	745	485
		Bärlaui	Switzerl.	m.C	2	447.5	27.5	6.1	420	475	448
		Encebras 2.	Spain	m-u.C	11	392.7	21.6	5.5	340	420	395
	N. aff. nemkovi	Crimée 4. (distans-zone 1)	Ukraine	m.C	10	603.0	82.5	13.7	440	740	600
	N. cf. nemkovi	Buttrio	Italy	m.C	2	612.5	72.5	11.8	540	685	613
	N. kaufmanni	Flibach	Switzerl.	l.C	4	590.0	112.0	19.0	490	780	545
		Aoíz 1.	Spain	m.C	2	600.0	50.0	8.3	550	650	600
		Haymana 7.	Turkey	m.C	3	440.0	115.8	26.3	330	600	390
	N. cf. kaufmanni	Caupenne 1. (Jeangazé)	France	u.C	29	433.4	70.4	16.2	310	640	410
	N. distans	Crimée 5. (distans-zone 2)	Ukraine	m.C	14	597.5	137.4	23.0	370	950	570
N. distans	N. distans	Crimée 6. (polygyratus-zone)	Ukraine	u.C	9	717.2	95.8	13.4	545	900	710
	N. cf. polygyratus	Benidorm 4.	Spain	u.C	2	515.0	75.0	14.6	440	590	515
	N. polygyratus	Caupenne 1. (Jeangazé)	France	u.C	20	745.5	132.0	17.7	400	900	750
		San Vicente de la Barquera 3.	Spain	u.C	3	638.3	75.8	11.9	550	735	630
		Crimée 6. (polygyratus-zone)	Ukraine	u.C	47	591.7	128.7	21.8	360	860	600
	N. aff. polygyratus	Crimée 6. (polygyratus-zone)	Ukraine	u.C	3	421.7	50.7	12.0	350	460	455
		Boltaña 3.	Spain	b.L	1	720.0	0.0	0.0	720	720	720
		Huéscar 3.	Spain	b.L	16	421.6	54.0	12.8	350	530	400
		Guiche	France	l.L	2	800.0	0.0	0.0	800	800	800
		Urcuit	France	l.L	4	693.8	18.5	2.7	670	720	693
		Mediano 2.	Spain	l.L	5	711.0	71.7	10.1	625	810	710
	N. cf. alponensis	San Vicente de la Barquera 6.	Spain	l.L	2	727.5	27.5	3.8	700	755	728
		Formigales	Spain	l.L	5	841.0	130.5	15.5	750	1100	780
		Mediano 6.	Spain	m2.L	1	750.0	0.0	0.0	750	750	750
	N. alponensis	Vodica	Croatia	l.L	10	544.5	78.2	14.4	430	690	523
		Bastennes 1.	France	l/m.L	8	737.5	92.5	12.5	590	840	783
		Donzacq 1.	France	l/m.L	1	905.0	0.0	0.0	905	905	905
		Gibret	France	l/m.L	30	517.7	137.8	26.6	385	1000	478
		Bastennes 2.	France	m1.L	5	642.0	101.0	15.7	450	740	665
		San Giovanni Ilarione	Italy	m1.L	9	692.8	106.1	15.3	600	890	660
		Matsuba	Israel	m.L	7	684.3	132.3	19.3	490	900	700
		Avesa 2.	Italy	m-u.L	2	860.0	40.0	4.7	820	900	860
	N. aff. millecaput	Ste-Marie-de-Gosse	France	l.L	17	715.9	159.8	22.3	500	1110	700
	N. millecaput	Bastennes 2.	France	m1.L	14	737.9	122.7	16.6	550	1100	715
		Orthez	France	m1.L	2	907.5	57.5	6.3	850	965	908
		Caravaca 2.	Spain	m.L	8	916.3	71.2	7.8	750	1000	950
		Bastennes 3.	France	m2.L	7	829.3	96.0	11.6	705	990	800
		Donzacq 2.	France	m2.L	24	822.7	125.2	15.2	560	1050	803
		Samitier 2.	Spain	m2.L	1	910.0	0.0	0.0	910	910	910
	N. maximus	Monte Sant Angelo	Italy	u.L	5	561.0	230.0	41.0	355	1010	480
	N. aff. dufrenoyi	Samitier 2.	Spain	m2.L	1	1160.0	0.0	0.0	1160	1160	1160
	N. cf. dufrenoyi	St-Barthélemy 2. (église)	France	m/u.L	2	745.0	65.0	8.7	680	810	745
	N. dufrenoyi	Huéscar 4.	Spain	u.L	3	670.0	72.6	10.8	570	740	700
		San Vicente de la Barquera 7.	Spain	u.L-B	2	1265.0	185.0	14.6	1080	1450	1265
		Avesa 3.	Italy	u.L-B	14	1031.4	163.5	15.9	710	1350	1020
		Biarritz 3. (Peyreblanque 2)	France	B	5	1192.0	247.7	20.8	900	1570	1250
		Grancona 1.	Italy	B	2	745.0	5.0	0.7	740	750	745
N. pratti	N. subdistans	Gan 1. (Berdoulou)	France	b.C	2	257.5	7.5	2.9	250	265	258
		St. Pankraz 1. (Roterz)	Austria	l.C	8	569.4	87.3	15.3	440	710	565
		Bolca	Italy	l.C	4	295.0	83.8	28.4	240	440	250
	N. aff. subdistans	Huéscar 2.	Spain	l/m.C	2	540.0	60.0	11.1	480	600	540
		Aoíz 1.	Spain	m.C	3	265.0	32.4	12.2	235	310	250
		Benidorm 3.	Spain	m.C	2	255.0	15.0	5.9	240	270	255
		Crimée 4. (distans-zone 1)	Ukraine	m.C	1	460.0	0.0	0.0	460	460	460
	N. cf. archiaci	St. Pankraz 1. (Roterz)	Austria	l.C	2	612.5	27.5	4.5	585	640	613
	N. archiaci	Flibach	Switzerl.	l.C	2	375.0	35.0	9.3	340	410	375
		St. Pankraz 1. (Roterz)	Austria	l.C	2	285.0	5.0	1.8	280	290	285
		Haymana 4.	Turkey	l.C	1	565.0	0.0	0.0	565	565	565
		Benidorm 2.	Spain	l/m.C	4	451.3	34.3	7.6	400	485	460
		Bosdarros 2.	France	m.C	58	474.9	94.7	19.9	210	740	458
		Gan 4. (Le Chesnay)	France	m.C	1	400.0	0.0	0.0	400	400	400
		Gan 5. (Tuilerie 2)	France	m.C	3	426.7	89.6	21.0	300	490	490
		Aoíz 1.	Spain	m.C	5	505.0	90.6	17.9	390	595	560
		Crimée 5. (distans-zone 2)	Ukraine	m.C	7	512.1	82.8	16.2	410	690	490
	N. aff. archiaci	Zin 1.	Israel	m.C	1	600.0	0.0	0.0	600	600	600
	N. pratti	Huéscar 2.	Spain	l/m.C	4	562.5	72.2	12.8	490	680	540
		Moratalla	Spain	m.C	3	536.7	102.1	19.0	450	680	480
		Crimée 5. (distans-zone 2)	Ukraine	m.C	2	545.0	65.0	11.9	480	610	545
		St. Pankraz 2. (Schwarzerz)	Austria	u.C	1	490.0	0.0	0.0	490	490	490
N. indet. phyl.	N. rollandi	Sfax	Tunesia	l-m.C	1	660.0	0.0	0.0	660	660	660

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
	N. tenuilamellatus	Sfax	Tunesia	l-m.C	3	165.0	7.1	4.3	155	170	170
	N. sp. aff. pomeli	Buttrio	Italy	m.C	4	402.5	65.6	16.3	305	490	408
	N. sp. mit dünner spirale	Zin 1.	Israel	m.C	2	245.0	15.0	6.1	230	260	245
	N. sp. sehr flach	Zin 1.	Israel	m.C	3	356.7	73.2	20.5	300	460	310
	N. sp. aff. planissimus	Syrte 4.	Libya	b.L	2	745.0	15.0	2.0	730	760	745
A. spira	A. yvettae	Quillet	France	u.T	8	146.3	16.5	11.3	120	165	150
	A. prisca	Mur	Spain	b.I	6	165.8	18.1	10.9	140	190	170
		Sant Estevé 1.	Spain	b.I	5	164.0	29.6	18.0	125	200	160
		Areny 1.	Spain	b.I	8	168.8	19.0	11.3	140	195	163
		Llimiana 1.	Spain	b.I	2	152.5	2.5	1.6	150	155	153
		Campo 1.	Spain	b.I	29	152.8	38.6	25.3	90	260	145
		San Llorenç de la Muga	Spain	b.I	1	140.0	0.0	0.0	140	140	140
		Haymana 1.	Turkey	b.I	8	128.1	17.7	13.8	105	155	128
	A. aff. prisca	Alsina (Tremp) 1.	Spain	l.I	4	192.5	45.3	23.6	140	265	183
	A. ranikoti	Hyderabad	Israel	b.I	6	71.7	14.0	19.6	50	95	70
	A. arenensis	Minerve	France	l.I	2	172.5	27.5	15.9	145	200	173
		Mont Cayla 1.	France	l.I	12	190.8	38.5	20.2	140	280	180
		Areny 2.	Spain	l.I	15	141.3	61.0	43.2	60	285	145
		Campo 2.	Spain	l.I	3	203.3	25.9	12.8	185	240	185
		Campo 3.	Spain	m1.I	2	190.0	5.0	2.6	185	195	190
	A. cf. arenensis	Coustouge 1.	France	l.I	1	160.0	0.0	0.0	160	160	160
		Aragon	France	m1.I	11	128.2	28.1	22.0	90	175	115
		Moussoulens	France	m1.I	11	152.7	21.7	14.2	105	185	160
		Campo 3.	Spain	m1.I	1	185.0	0.0	0.0	185	185	185
		Huéscar 1.	Spain	m.I	2	115.0	15.0	13.0	100	130	115
	A. spinosa	Meting	Pakistan	m.I	2	200.0	50.0	25.0	150	250	200
	A. cf. leymeriei	Fabas 1. (Larue)	France	m1.I	8	195.0	32.1	16.5	145	240	200
		Aurignac 1.	France	m2.I	6	150.0	37.7	25.2	110	230	138
		Montberaud	France	m2.I	1	135.0	0.0	0.0	135	135	135
		Campo 4.	Spain	u.I	9	161.7	54.6	33.8	105	285	150
		Crimée 1. (crimensis-zone)	Ukraine	u.I	1	300.0	0.0	0.0	300	300	300
	A. leymeriei	Coustouge 3.	France	m2.I	6	146.7	35.3	24.1	95	195	145
		Mont Cayla 2.	France	m2.I	2	145.0	5.0	3.4	140	150	145
		Alsina (Tremp) 2.	Spain	m2.I	10	199.5	32.0	16.0	130	250	200
		Alsina (Tremp) 3.	Spain	m2.I	2	100.0	0.0	0.0	100	100	100
		Sant Adriá 1.	Spain	m2.I	11	156.8	28.9	18.5	105	210	150
		Tremp 2.	Spain	m2.I	34	184.6	36.9	20.0	90	245	190
		Tremp 3.	Spain	m2.I	8	206.9	81.6	39.5	90	300	243
		Sant Adriá 5.	Spain	u.I	3	170.0	8.2	4.8	160	180	170
	A. aff. leymeriei	Boltaña 1.	Spain	u.I/b.C	2	192.5	7.5	3.9	185	200	193
	A. adrianensis	Alsina (Tremp) 2.	Spain	m2.I	6	155.0	20.4	13.2	140	200	148
		Alsina (Tremp) 4.	Spain	m2.I	6	94.2	3.4	3.6	90	100	95
		Sant Adriá 1.	Spain	m2.I	4	235.0	28.7	12.2	210	280	225
		Tremp 2.	Spain	m2.I	1	190.0	0.0	0.0	190	190	190
		Tremp 3.	Spain	m2.I	5	230.0	44.0	19.2	190	305	205
		Sant Estevé 2.	Spain	u.I	8	193.1	30.5	15.8	150	240	193
		Alsina (Tremp) 5.	Spain	u.I	1	240.0	0.0	0.0	240	240	24
	A. cf. plana	Caravaca 1.	Spain	u.I/b.C	3	193.3	20.1	10.4	165	210	205
	A. plana	Gan 1. (Berdoulou)	France	b.C	10	345.5	39.6	11.5	250	395	345
		Encebras 1.	Spain	b.C	4	386.3	71.8	18.6	275	475	398
		Crimée 2. (placentula-zone)	Ukraine	b.C	1	345.0	0.0	0.0	345	345	345
		Flibach	Switzerl.	l.C	2	232.5	17.5	7.5	215	250	233
		San Vicente de la Barquera 1.	Spain	l.C	17	290.6	62.4	21.5	185	420	295
		Samper	Spain	l.C	3	310.0	61.6	19.9	240	390	300
		Alfaz	Spain	l.C	3	280.0	109.8	39.2	170	430	240
		Bolca	Italy	l.C	25	255.0	37.4	14.7	170	340	250
		Crimée 3. (nemkovi-zone)	Ukraine	l.C	7	356.4	59.7	16.7	250	430	390
		Benidorm 2.	Spain	l/m.C	14	315.7	41.8	13.2	260	435	315
		Huéscar 2.	Spain	l/m.C	1	370.0	0.0	0.0	370	370	370
		San Vicente de la Barquera 2.	Spain	m.C	6	329.2	64.8	19.7	230	410	338
	A. laxispira	Crimée 3. (nemkovi-zone)	Ukraine	l.C	1	560.0	0.0	0.0	560	560	560
		Janovas 1.	Spain	l/m.C	2	345.0	5.0	1.4	340	350	345
		Janovas 2.	Spain	l/m.C	1	305.0	0.0	0.0	305	305	305
		Huéscar 2.	Spain	l/m.C	2	360.0	40.0	11.1	320	400	360
		Bosdarros 2.	France	m.C	29	340.7	54.1	15.9	245	450	330
		Gan 4. (Le Chesnay)	France	m.C	4	315.0	26.2	8.3	295	360	303
		Gan 5. (Tuilerie 2)	France	m.C	7	269.3	27.8	10.3	240	310	265
		San Vicente de la Barquera 2.	Spain	m.C	4	551.3	89.0	16.2	465	700	520
		Campo 7.	Spain	m.C	8	395.6	92.9	23.5	270	560	368
		Aoíz 1.	Spain	m.C	2	365.0	35.0	9.6	330	400	365
		Boltaña 2.	Spain	m.C	3	481.7	38.8	8.1	435	530	480

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
A. spira	A. laxispira	Moratalla	Spain	m.C	2	295.0	5.0	1.7	290	300	295
		Crimée 5. (distans-zone 2)	Ukraine	m.C	1	450.0	0.0	0.0	450	450	450
		Janovas 3.	Spain	m/u.C	1	385.0	0.0	0.0	385	385	385
	A. cf. laxispira	San Vicente de la Barquera 2.	Spain	m.C	7	434.3	126.5	29.1	260	690	405
	A. laxispira - maior	Buttrio	Italy	m.C	4	440.0	115.8	26.3	360	640	380
		Crimée 5. (distans-zone 2)	Ukraine	m.C	4	390.0	55.2	14.2	300	440	410
		Caupenne 1. (Jeangazé)	France	u.C	2	385.0	5.0	1.3	380	390	385
		Benidorm 4.	Spain	u.C	1	550.0	0.0	0.0	550	550	550
		Azarlîc	Romania	u.C	2	437.5	2.5	0.6	435	440	438
		Crimée 6. (polygyratus-zone)	Ukraine	u.C	25	430.2	61.6	14.3	305	560	430
	A. maior	Janovas 3.	Spain	m/u.C	4	348.8	50.8	14.6	295	430	335
		Encebras 2.	Spain	m-u.C	2	372.5	12.5	3.4	360	385	373
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	21	523.1	56.7	10.8	430	660	530
		Lueza	Spain	u.C	2	517.5	32.5	6.3	485	550	518
		Tierrantona	Spain	u.C	5	486.0	52.4	10.8	430	580	470
		Campo 8.	Spain	u.C	3	690.0	24.5	3.5	660	720	690
		Dobrinj	Croatia	u.C	4	601.3	28.8	4.8	560	640	603
		Noax	Italy	u.C	1	690.0	0.0	0.0	690	690	690
		Crimée 6. (polygyratus-zone)	Ukraine	u.C	13	429.6	64.9	15.1	320	550	450
		Samitier 1.	Spain	u.C/b.L	1	700.0	0.0	0.0	700	700	700
		Figueras	Spain	u.C/b.L	10	508.5	102.7	20.2	355	680	473
		Châtelard-les-Bauges	France	b.L	2	582.5	72.5	12.4	510	655	583
		San Vicente de la Barquera 4.	Spain	b.L	2	525.0	175.0	33.3	350	700	525
		Boltaña 3.	Spain	b.L	3	425.0	35.4	8.3	400	475	400
		Queralt p. Berga	Spain	b.L	9	527.8	38.0	7.2	460	595	520
		Huéscar 3.	Spain	b.L	1	600.0	0.0	0.0	600	600	600
		Vanzi 2.	Italy	b.L	7	595.0	89.5	15.0	440	750	585
		Balatonhegy 1.	Hungary	b.L	2	552.5	2.5	0.5	550	555	553
		Darvastó	Hungary	b.L	1	600.0	0.0	0.0	600	600	600
	A. aff. maior	Gandbo Hill	Pakistan	m.L	8	625.6	146.8	23.5	415	830	620
	A. maior punctulata	Noax	Italy	u.C	3	706.7	30.9	4.4	680	750	690
	A. maior - spira	Caupenne 1. (Jeangazé)	France	u.C	3	598.3	73.5	12.3	495	660	640
	A. spira abrardi	St-Martin-de-Seignanx	France	l.L	7	476.4	43.9	9.2	395	540	475
		Ste-Marie-de-Gosse	France	l.L	1	450.0	0.0	0.0	450	450	450
		Formigales	Spain	l.L	1	540.0	0.0	0.0	540	540	540
		Mediano 2.	Spain	l.L	2	500.0	70.0	14.0	430	570	500
		Boltaña 4.	Spain	l.L	1	680.0	0.0	0.0	680	680	680
		Vodica	Croatia	l.L	5	645.0	116.4	18.1	550	870	595
		Balatonhegy 2.	Hungary	l.L	3	490.0	45.5	9.3	440	550	480
		Gibret	France	l/m.L	4	487.5	42.1	8.6	440	550	480
		Arguis 1.	Spain	u.L	1	500.0	0.0	0.0	500	500	500
	A. spira spira	Bastennes 2.	France	m1.L	6	516.7	57.9	11.2	440	620	510
		Orthez	France	m1.L	1	570.0	0.0	0.0	570	570	570
		Caravaca 2.	Spain	m.L	1	640.0	0.0	0.0	640	640	640
	A. spira planospira	Bastennes 3.	France	m2.L	10	582.0	168.0	28.9	450	1060	520
	A. papillata	Gandbo Hill	Pakistan	m.L	3	278.3	40.1	14.4	250	335	250
A. exponens	A. dandotica	Estorm	Spain	b.I	1	105.0	0.0	0.0	105	105	105
		Mur	Spain	b.I	1	115.0	0.0	0.0	115	115	115
		San Llorenç de la Muga	Spain	b.I	2	122.5	7.5	6.1	115	130	123
		Hyderabad	Israel	b.I	1	75.0	0.0	0.0	75	75	75
	A. aff. pustulosa	Coustouge 1.	France	l.I	2	132.5	7.5	5.7	125	140	133
		Llimiana 2.	Spain	l.I	12	140.8	23.5	16.7	85	175	143
		Campo 2.	Spain	l.I	9	168.9	26.1	15.5	145	235	160
		Aragon	France	m1.I	1	190.0	0.0	0.0	190	190	190
	A. pustulosa	Coustouge 2.	France	m1.I	2	182.5	27.5	15.1	155	210	183
		Aurignac 1.	France	m2.I	27	142.4	18.6	13.1	110	180	145
		Montberaud	France	m2.I	28	167.5	36.7	21.9	115	290	163
		Couiza	France	m2.I	1	130.0	0.0	0.0	130	130	130
		Coustouge 3.	France	m2.I	7	157.1	43.0	27.4	85	200	165
		Mont Cayla 2.	France	m2.I	4	133.8	9.6	7.2	120	145	135
		Alsina (Tremp) 3.	Spain	m2.I	1	105.0	0.0	0.0	105	105	105
		Alsina (Tremp) 4.	Spain	m2.I	2	147.5	32.5	22.0	115	180	148
		Areny 3.	Spain	m2.I	20	111.0	23.1	20.8	65	150	108
		Sant Adriá 2.	Spain	m2.I	13	115.4	29.1	25.2	60	160	105
		Tremp 3.	Spain	m2.I	5	87.0	6.8	7.8	75	95	90
		Tremp 4.	Spain	m2.I	8	130.0	14.4	11.0	105	150	133
A. exponens	A. pomeroli	Sant Adriá 3.	Spain	m2.I	18	117.8	29.6	25.2	65	180	123
		Orignac 2.	France	u.I	8	168.1	27.1	16.1	115	215	165
		Ager	Spain	u.I	1	150.0	0.0	0.0	150	150	150
		Alsina (Tremp) 5.	Spain	u.I	14	138.2	30.3	21.9	100	200	138
		Areny 5.	Spain	u.I	22	95.9	34.9	36.4	55	195	85

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Areny 6.	Spain	u.I	35	120.4	28.4	23.6	65	170	130
		Sant Adriá 5.	Spain	u.I	3	156.7	23.9	15.3	135	190	145
		Tremp 5.	Spain	u.I	21	130.2	26.0	19.9	95	195	135
		Crimée 1. (crimensis-zone)	Ukraine	u.I	14	164.6	28.9	17.5	115	205	170
	A. cf. pomeroli	Haymana 2.	Turkey	u.I	7	213.6	30.8	14.4	180	250	200
	A. aff. pomeroli	Haymana 3.	Turkey	b.C	2	247.5	7.5	3.0	240	255	248
	A. pomeroli-placentula	Orignac 2.	France	u.I	3	233.3	24.6	10.5	205	265	230
		Campo 4.	Spain	u.I	1	225.0	0.0	0.0	225	225	225
		Guttaring	Austria	b.C	6	226.7	33.5	14.8	180	285	223
		Sittenberg	Austria	b.C	11	190.5	38.1	20.0	115	250	200
		Gan 2. (Encot)	France	b.C	4	160.0	6.1	3.8	155	170	158
		Ossun	France	b.C	13	193.8	48.8	25.2	140	325	190
		Campo 5.	Spain	b.C	26	179.8	39.4	21.9	105	245	175
	A. placentula	Boltaña 1.	Spain	u.I/b.C	2	242.5	57.5	23.7	185	300	243
		Caravaca 1.	Spain	u.I/b.C	13	225.4	45.8	20.3	165	330	205
		Guttaring	Austria	b.C	6	215.0	35.2	16.4	170	265	208
		Sittenberg	Austria	b.C	3	236.7	28.7	12.1	200	270	240
		Gan 1. (Berdoulou)	France	b.C	5	250.0	39.1	15.6	190	300	255
		Ossun	France	b.C	5	233.0	31.1	13.3	195	285	230
		Port Louis	France	b.C	4	272.5	23.8	8.8	240	300	275
		Campo 5.	Spain	b.C	21	225.5	28.6	12.7	165	280	220
		Encebras 1.	Spain	b.C	5	232.0	48.8	21.1	155	290	245
		Crimée 2. (placentula-zone)	Ukraine	b.C	34	268.1	44.6	16.6	180	390	255
		Haymana 3.	Turkey	b.C	7	230.0	23.0	10.0	185	260	235
		St. Pankraz 1. (Roterz)	Austria	l.C	3	298.3	40.3	13.5	265	355	275
		Bosdarros 1. (Rigabert)	France	l.C	31	284.5	42.0	14.8	210	375	290
		Gan 3. (Tuilerie 1)	France	l.C	38	255.4	47.7	18.7	160	370	253
		San Vicente de la Barquera 1.	Spain	l.C	29	284.3	47.4	16.7	205	370	285
		Samper	Spain	l.C	6	300.8	68.6	22.8	195	380	320
		Campo 6.	Spain	l.C	13	275.8	50.6	18.4	160	355	275
		Benidorm 1.	Spain	l.C	2	182.5	12.5	6.8	170	195	183
		Haymana 4.	Turkey	l.C	4	296.3	19.5	6.6	270	315	300
		Janovas 2.	Spain	l/m.C	5	222.0	22.3	10.0	195	245	235
		Bärlaui	Switzerl.	m.C	3	303.3	53.1	17.5	240	370	300
		Gan 5. (Tuilerie 2)	France	m.C	2	280.0	20.0	7.1	260	300	280
		San Vicente de la Barquera 2.	Spain	m.C	9	300.6	63.0	20.9	195	390	300
	A. cf. placentula	Caravaca 1.	Spain	u.I/b.C	2	205.0	40.0	19.5	165	245	205
		Encebras 1.	Spain	b.C	1	240.0	0.0	0.0	240	240	240
		Huéscar 2.	Spain	l/m.C	2	277.5	32.5	11.7	245	310	278
	A. aff. placentula	Crimée 3. (nemkovi-zone)	Ukraine	l.C	10	299.5	78.8	26.3	160	400	290
		Janovas 1.	Spain	l/m.C	7	271.4	44.0	16.2	200	340	280
		San Vicente de la Barquera 2.	Spain	m.C	1	320.0	0.0	0.0	320	320	320
		El Pocino 1.	Spain	m.C	2	252.5	22.5	8.9	230	275	253
		Crimée 4. (distans-zone 1)	Ukraine	m.C	13	350.4	85.6	24.4	195	520	330
	A. cuvillieri	Encebras 2.	Spain	m-u.C	1	260.0	0.0	0.0	260	260	260
		Caupenne 1. (Jeangazé)	France	u.C	8	362.5	50.7	14.0	290	470	360
		Bergouey (Gas, Malaou, Peyrat)	France	u.C	26	391.7	40.7	10.4	305	485	390
		San Vicente de la Barquera 3.	Spain	u.C	16	363.4	41.8	11.5	300	450	350
		Lueza	Spain	u.C	4	301.3	22.5	7.5	285	340	290
		Tierrantona	Spain	u.C	4	321.3	79.2	24.7	250	455	290
		Campo 8.	Spain	u.C	1	410.0	0.0	0.0	410	410	410
		Dobrinj	Croatia	u.C	2	332.5	17.5	5.3	315	350	333
		Boltaña 3.	Spain	b.L	5	349.0	35.0	10.0	320	415	340
	A. tenuimarginata	San Vicente de la Barquera 5.	Spain	b.L	9	476.1	67.7	14.2	335	550	495
	A. aff. tenuimarginata	Boltaña 3.	Spain	b.L	7	460.0	57.8	12.6	380	540	460
		Crimée 7. (Bodrakian)	Ukraine	b.L	7	349.3	48.7	13.9	265	395	360
		Urcuit	France	l.L	1	445.0	0.0	0.0	445	445	445
		Formigales	Spain	l.L	1	465.0	0.0	0.0	465	465	465
		Donzacq 1.	France	l/m.L	4	391.3	45.2	11.6	335	460	385
		Boltaña 5.	Spain	l-m.L	1	440.0	0.0	0.0	440	440	44
	A. aff. exponens	Mediano 2.	Spain	l.L	5	578.0	36.1	6.3	540	635	560
A. exponens	A. exponens	Donzacq 1.	France	l/m.L	4	450.0	40.0	8.9	410	490	450
		Gibret	France	l/m.L	12	548.8	73.3	13.4	435	655	538
		Nousse	France	l/m.L	15	552.7	74.9	13.5	400	660	550
		Biron	France	m1.L	7	490.7	65.2	13.3	410	580	470
		Avesa 1.	Italy	m1.L	1	590.0	0.0	0.0	590	590	590
		Préchacq	France	u.L	4	483.8	66.8	13.8	400	585	475
		La Mortola	France	u.L/B	5	522.0	48.3	9.3	470	580	500
		Grancona 1.	Italy	B	1	700.0	0.0	0.0	700	700	700
A. reicheli	A. luterbacheri	Coustouge 3.	France	m2.I	1	100.0	0.0	0.0	100	100	100
		Alsina (Tremp) 4.	Spain	m2.I	6	157.5	12.5	7.9	140	175	158

Group/lineage	Taxon	Locality	Country	Age	#	Mean	s.d.	c.v.	Min	Max	Med
		Areny 3.	Spain	m2.I	3	109.0	11.0	10.1	95	122	110
		Sant Adriá 2.	Spain	m2.I	9	91.1	19.7	21.6	70	133	86
		Tremp 3.	Spain	m2.I	18	103.3	23.2	22.5	55	140	100
		Orignac 2.	France	u.I	2	187.5	2.5	1.3	185	190	188
		Ager	Spain	u.I	1	133.0	0.0	0.0	133	133	133
		Alsina (Tremp) 5.	Spain	u.I	9	127.2	18.3	14.4	100	150	130
	A. reicheli	Haymana 6.	Turkey	l/m.C	1	485.0	0.0	0.0	485	485	485
		Campo 7.	Spain	m.C	1	410.0	0.0	0.0	410	410	410
		Crimée 5. (distans-zone 2)	Ukraine	m.C	1	500.0	0.0	0.0	500	500	500
		Haymana 7.	Turkey	m.C	1	480.0	0.0	0.0	480	480	480
		Campo 8.	Spain	u.C	1	725.0	0.0	0.0	725	725	725
		Aoíz 2.	Spain	u.C	1	460.0	0.0	0.0	460	460	460
	A. cf. suteri	Vanzi 2.	Italy	b.L	4	611.3	78.3	12.8	510	690	623
	A. suteri	Figueras	Spain	u.C/b.L	13	524.6	70.1	13.4	440	725	530
		Queralt p. Berga	Spain	b.L	13	388.1	80.5	20.7	290	560	360
		Vodica	Croatia	l.L	8	392.5	49.2	12.5	350	490	375
	A. aff. medanica	Tierrantona	Spain	u.C	2	265.0	5.0	1.9	260	270	265
	A. medanica	Ste-Marie-de-Gosse	France	l.L	13	323.8	32.8	10.1	265	390	325
	A. convexa	Gandbo Hill	Pakistan	m.L	8	570.0	81.8	14.4	410	680	550

APPENDIX: List of the localities and of the samples belonging to them (the explanation see at the "Locality")

Locality	Samples
Ager	67443, -5-6
Aizy-Jouy	?
Alfaz	60138
Alsina 1.	67556
Alsina 2.	67554-55, -58-62, -77, -79-80
Alsina 3.	67563, -66-68
Alsina 4.	67569-72
Alsina 5.	67573-6
Amigny-Rouy	62046
Aoíz 1.	68044
Aoíz 2.	68017
Aragon	54518-9
Areny 1.	67492-4, -9
Areny 2.	67500-3
Areny 3.	67504-9
Areny 4.	67510-5
Areny 5.	67519, -21-23
Areny 6.	67007, 67526-28, -30-31
Arguis 1.	68036
Arguis 2.	68037
Arguis 3.	68038, 73010
Aurignac 1.	53370, -5
Aurignac 2.	74033
Avesa 1.	55002, 58107
Avesa 2.	59052
Avesa 3.	58108-9
Avesa 4.	58115
Azarlîc	Bombiþã
Balatonhegy 1.	69223
Balatonhegy 2.	69225
Bärlaui	53130
Bastennes 1.	56054
Bastennes 2.	56053, -8-9
Bastennes 3.	55222, 56056
Benidorm 1.	60140-1
Benidorm 2.	67331
Benidorm 3.	60142
Benidorm 4.	60143
Bergouey (Gas, Malaou, ...)	54017, 55208-11, 56089-91
Biarritz 1. (Gourèpe)	54113
Biarritz 2. (Peyreblanque 1)	54106-7
Biarritz 3. (Peyreblanque 2)	54109
Biarritz 4. (Villa Marbella)	54114
Biron	54311, 55251-2
Bolca	55020, -33, -38, 75010-1
Boltaña 1.	73002
Boltaña 2.	68032, 73003
Boltaña 3.	67311-2, -7
Boltaña 4.	67318, 68031
Boltaña 5.	68040
Bosdarros 1. (Rigabert)	54314-15, -26-27
Bosdarros 2.	54313
Brecklesham Bay	Curry
Buttrio	55067
Calders	56255
Campo 1.	66003, 70111-2, -2a, -3
Campo 2.	66009-11, 70123
Campo 3.	67301-2, -4-5, 70133
Campo 4.	62008, 72081, 73107
Campo 5.	62006-7, 72078-9
Campo 6.	62003, -5, 72076
Campo 7.	62001, 70148, 72071, -4
Campo 8.	63001, -03-04, -08-09, -12, -14, -19
Caravaca 1.	60133-5
Caravaca 2.	60131
Carme 1. (Colbass)	70001-2
Carme 2. (Col Lentilles)	70173
Caupenne 1. (Jeangazé)	55216-8, 56075, 56083
Caupenne 2. (Sarthou)	56085
Centelles	70165, Reguant
Châtelard-les-Bauges	65001-3
Chiampo	55025-6
Colombres	60116
Couiza	54503, 74018
Coustouge 1.	73208
Coustouge 2.	73209, -11
Coustouge 3.	54530, -34, -39, -40, 55444, 73205, -12-15, -17, -20
Crimée 1. (crimensis-zone)	65120, 71217-8
Crimée 2. (placentula-zone)	65103, 71219, -21-23

Locality	Samples
Crimée 3. (nemkovi-zone)	71224, -43a
Crimée 4. (distans-zone 1)	65104, 71244
Crimée 5. (distans-zone 2)	65105, 71245, Nemkov
Crimée 6. (polygyratus-z.)	65106-8, -11, 71227
Crimée 7. (Bodrakian)	71249
Cuise-la-Motte	62041
Darvastó	69228a
Dobrinj	77016, -19-20
Donzacq 1.	54034
Donzacq 2.	55223
El Far	56251, -3
El Pocino 1.	72011-2
El Pocino 2.	72062-3
Encebras 1.	67334-5
Encebras 2.	67333
Estorm	60270
Fabas 1. (Larue)	54458
Fabas 2. (Bardau)	54428, 73194
Farafrah	61187, -92, -95-96, -98, 61201-2
Figueras	56241, -3, 68052-7
Flibach	68001-2
Foradada de Toscar	67306
Formigales	72016-7, -67-70, 73114, 74040
Gamarde	54023, 73145
Gan 1. (Berdoulou)	50031-2, 54329, 55261, Leupold
Gan 2. (Encot)	50007
Gan 3. (Tuilerie 1)	50001, -4, 54318-21
Gan 4. (Le Chesnay)	54312, 72056
Gan 5. (Tuilerie 2)	62009
Gandbo Hill	60160
Gibret	54029, -31, 55202-3, 60014, 73177-8
Gizeh	?
Grancona 1.	48002, 75030, -2
Grancona 2.	48020-1
Grancona 3.	59064, 75036
Guiche	56097, -9, 73188
Guttaring	61201, 63100, -02, -09, -15
Har Horsha	88161
Hastingues	56096
Haymana 1.	57000
Haymana 2.	57001
Haymana 3.	57002
Haymana 4.	57003
Haymana 5.	57005
Haymana 6.	57007
Haymana 7.	57009-10
Haymana 8.	57011
Haymana 9.	57012-3
Haymana 10.	57014
Horsarrieu	57103
Huéscar 1.	60148
Huéscar 2.	60147, -9
Huéscar 3.	60145
Huéscar 4.	60146
Hyderabad	59109
Jaca	68014
Janovas 1.	67316, -9
Janovas 2.	68026
Janovas 3.	67315, 68042
Kressenberg 1. (Roterz)	58011
Kressenberg 2. (Zwischen.)	79120
Kressenberg 3. (Schwarzerz)	79116
Kressenberg 4.	79114
Kressenberg 5. (Flöz-Neb.)	79119
La Fonollera	71351-2
La Mortola	55103-4, -6, 68102
La Pobla de Lillet 1.	70161
La Pobla de Lillet 2.	64021
Leghia	75146
Llimiana 1.	67533-4
Llimiana 2.	67535-37, -47-48
Llimiana 3.	67538-40, -42
Llimiana 4.	67544
Lueza	72013, -84
Manresa	56256
Matsuba	89069
Mediano 1.	68033
Mediano 2.	66034-5
Mediano 3.	72116
Mediano 4.	68022
Mediano 5.	66028, -33
Mediano 6.	68020, 72022
Melitta	66102-11
Meting	59111-2
Minerve	60020-2
Monells	71350
Mont Cayla 1.	60019, -23
Mont Cayla 2.	55468, 60018
Mont Ganelon	62040
Montberaud	54432-4
Monte Sant Angelo	56211
Montfort-en-Chalosse	54001-2, -6
Montolieu	55460-1
Moratalla	60136-7
Mossano	48029
Moussoulens	55464, Buxtorf
Mur	60266
Noax	55065-6, 75041
Nousse	56051
Oiching	63041
Orignac 1.	54406, -9, 61009
Orignac 2.	61003, -05, -35-36, -55
Orthez	54304, 56004
Ossun	61050
Panillo 1. (Marials)	68021, 72020, 73111
Panillo 2. (Ermita)	68020, 70151-2
Perrarua	66020, -4
Peyrehorade 1. (Aspremont)	55234
Peyrehorade 2.	54214
Pierrefonds	62042
Port Louis	62092
Préchacq	56045
Queralt p. Berga	56247
Quillet	72008, 72121
Reehegy	69221
Ripoll	70169
Roncà	48034, 59075
Rosazzo	55061, -4, 75042
Samitier 1.	72021
Samitier 2.	66032
Samper	67308
San Giovanni Ilarione	55012
San Llorenç de la Muga	71349
San Llorenç de Morunys 1.	70162
San Llorenç de Morunys 2.	70172
San Vicente de la Barq. 1.	56231, -4, 60102, -4, 69001, 73135
San Vicente de la Barq. 2.	56230, 60103, -13, 73133-4
San Vicente de la Barq. 3.	60112, 73132
San Vicente de la Barq. 4.	60110
San Vicente de la Barq. 5.	60106, 73129
San Vicente de la Barq. 6.	60108
San Vicente de la Barq. 7.	69003
Sant Adriá 1.	67449-52, -54-55, -57, -59-60
Sant Adriá 2.	67461, -3-6
Sant Adriá 3.	67468-75, -77
Sant Adriá 4.	67479, -81-82, -84
Sant Adriá 5.	67002-3, 67486-9
Sant Estevé 1.	67550-2, 74036-7

Locality	Samples
Sant Estevé 2.	67554
Santa Margarita de Mombuy	56257-8
Santa Maria de Miralles	56263, 73102
Selsey	?
Sfax	66116-9
Sittenberg	61202
Soave	48040, 59058-59, -62
Sorde-l'Abbaye 1.	56020
Sorde-l'Abbaye 2.	56021
Sorde-l'Abbaye 3.	56013, -8
Sorde-l'Abbaye 4.	56027-31, -36, -41
Sorde-l'Abbaye 5.	56011
St-Barthélemy 1. (Maison.)	54204
St-Barthélemy 2. (église)	54212
St-Gobain	62011, -3, -5
St-Martin-de-Seignanx	55226, -8, 73183
St. Pankraz 1. (Roterz)	63036
St. Pankraz 2. (Schwarzerz)	63038
Ste-Marie-de-Gosse	54207, 55229
Syrte 1.	68164, -6
Syrte 2.	68615
Syrte 3.	68119, 68596, -8
Syrte 4.	60320, 68117a-b, -19, -60-62, 68598
Syrte 5.	60302, -09-13, 68111-12, -16a-c, -33
Syrte 6.	68593, 68611
Syrte 7.	60303-4, 68114-15, -26-27, -29-30, 68594, 68610
Syrte 8.	60305-8, 68113, -25
Tavertet	70163, -75
Tierrantona	72014, -83
Tremp 1.	62203
Tremp 2.	67402, -4-9
Tremp 3.	62206-7, 67413, -16, -18, -20-21, 74035
Tremp 4.	67423, -26, -28-29, -31
Tremp 5.	67433-37, -39, -41
Troncedo	72018-9, 74039
Ullastret	71358-9
Urcuit	54202, 73187
Valdeforte	48045, 62080
Vanzi 1.	75019
Vanzi 2.	55017
Vodica	77001-2
Whitecliff Bay 1.	62138
Whitecliff Bay 2.	61141
Zin 1.	88110-2, -4-5
Zin 2.	88116-7, -9

Dela – Opera SAZU 4. razr.	34/2	203–242	19 Figs	15 Plates		Ljubljana 1998

STRATIGRAPHIC ANALYSIS OF PALEOGENE BEDS IN SOME OFF-SHORE WELLS (CENTRAL ADRIATIC AREA, CROATIA)

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Abstract

Paleogene sedimentary series deposited in the central Adriatic area should be separated into two different sedimentary realms (tectonostratigraphic units). In the western realm the stratigraphic succession of the deep marine sediments ranges from the Upper Cretaceous to the Middle-Upper Eocene. Carbonate turbidites deposited on the deeper part of a platform slope are characterized by the rhythmic exchange of wackestones/ mudstone, rich with planktonic foraminifers, and of packstone/ rudstone with shallow-water, platform derived detritus (benthic fossils) in the wells Koraljka-1, Ksenija-1, Jadran-1, Jadran-2, Jadran-21/1, Jadran-22/1 and Jadran-10. At the end of the Upper Eocene (Priabonian) period the area was drowned and covered by siliciclastic turbidites. According to the distribution of nannofossils and planktonic foraminifera chronostratigraphic continuity is presumed, although there are several hiatuses in the sedimentary record. Nevertheless, this is the most complete succession of Cretaceous to Paleocene sediments ever found in the area of the Outer Dinarides which has no on-shore equivalent.

In the eastern realm Paleogene deposits are part of the thick stack of shallow-water carbonates within the Adriatic carbonate platform of the Outer Dinarides. In most profiles a long hiatus between the Upper Cretaceous and the Cuisian is evident (Jadran-9, Jadran-3, Kornati more-4, Susak more-1 wells). Only in the area of Kate-1 well a particular depositional environment, of Maastrichtian and Paleocene age indicates the presence of shallow restricted lagoons that were repeatedly interrupted by short phases of an intertidal regime of emersion and locally influenced by fresh water, at the time of overall regional emersion in Early Paleogene. In the rest of the platform the stratigraphic succession typically starts with a transgression of the uppermost ?Paleocene and/or Cuisian limestone which overlies carstified Upper Cretaceous limestones. After that, a rhythmic change of two different facies within the Cuisian indicates high and low regimes of a tidal flat environment. During Lutetian times, the deposits were sedimented on the shallow, occasionally open platform environment. They were followed by later Lutetian and Bartonian sediments, characteristic of a platform margin. Carbonate deposition stopped at the end of the Lutetian, when the area was drowned under the siliciclastic turbidite deposits.

Key words: Paleogene, Stratigraphy, Paleoecology, Tectonics, Off-shore wells, Central Adriatic Area, Croatia.

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INTRODUCTION

Present knowledge of the off-shore geology in the Central Adriatic area (Fig. 1) is the result of twenty years of exploration for oil and gas by off-shore drilling and seismic prospecting. About twenty wells have penetrated the Paleogene deposits. The present study undertakes their biostratigraphic and paleoenvironmental interpretation.

There are many unpublished company reports and the few following published papers which describe the structure of the Adriatic subsea: Jenko & Bistričić (1976), Turk (1981), Vlašić *et al.* (1982), Frank *et al.* (1983). Several recent papers concerning well data from this area are dealing in particular with the stratigraphy: Kalac & Tari-Kovačić (1986), Kalac *et al.* (1990, 1991), Lučić *et al.* (1991, 1993), Veseli *et al.* (1991), Lučić (1993, 1994, 1996). Facies analyses and structure of the Eocene carbonate platform were given by Tari-Kovačić (1992, 1997), Tari-Kovačić & Ćosović (1995).

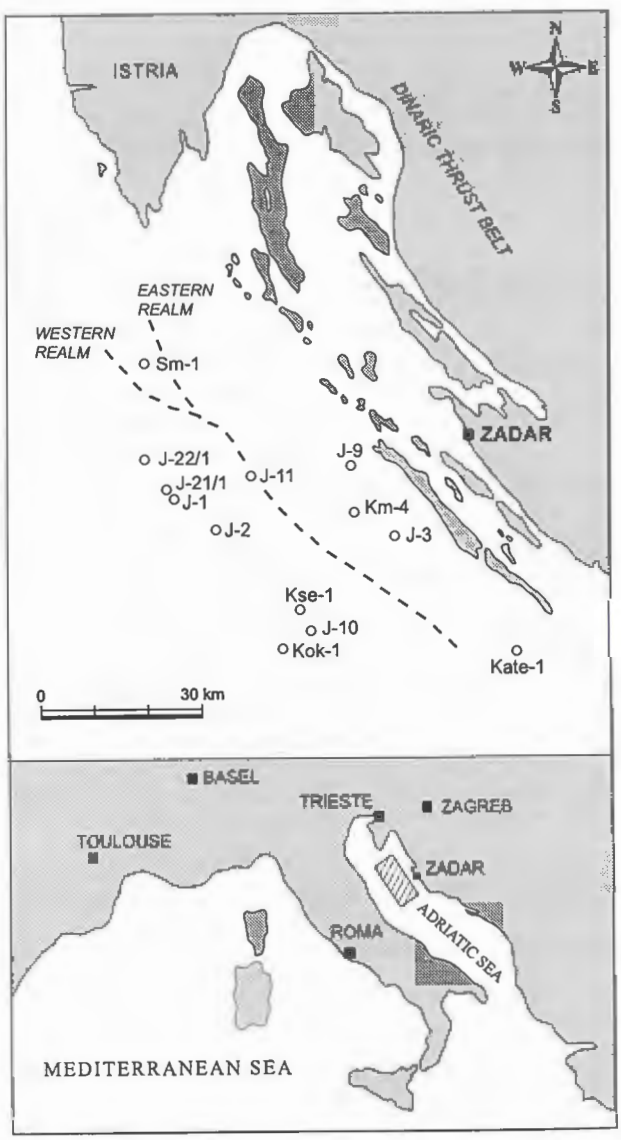

Fig. 1: Location maps

Interpretation of the depositional environment was based on a biostratigraphic analysis of the foraminifera prepared by K. Kalac and D. Lučić and calcareous nannoplankton by J. Benić, as well as biostratigraphical, chronostratigraphical, sedimentological and paleoecological interpretation. Interpretation of the wireline logs and seismostratigraphic interpretation and relevant model explaining the stratigraphic and tectonic relationship was prepared by V. Tari-Kovačić.

The great number of the identified foraminifera is the solid base for the biostratigraphic subdivision of the Paleogene succession, and also for paleoecological deduction, and correlation with Mediterranean area.

METHODS AND MATERIAL

More than 1500 samples from twelve wells have been collected for petrographical, micropaleontogical and sedimentological analysis.

The micropaleontological and petrographical analysis have been carried on conventional core samples and mud cuttings prepared as thin sections and some as outwash samples. Due to the usual sample contamination with cuttings from higher bore hole horizons caused by drilling technology, it was difficult to establish a biostratigraphic zonation with full precision. Deposits were biostratigraphically subdivided, according to the distribution of planktonic and benthic foraminifera or their association as well as of calcareous nannoplankton using of the following literature: Smout (1954), Luterbacher & Premoli-Silva (1964), Postuma (1971), Bignot (1972), Premoli-Silva *et al.* (1976), Drobne (1977, 1985), Haq (1978), Fleury (1980), Hottinger & Drobne (1980), Müller-Merz (1980), Billote (1985), Tourmarkine & Luterbacher (1985), Perch-Nielsen (1985), Keller (1988), Berggren & Miller (1988), Drobne *et al.* (1990), Seyve (1990), D'hondt & Keller (1991), Macleod & Keller (1991), Olsson *et al.* (1992), Canudo *et al.* (1991), Molina *et al.* (1992), Canudo & Molina (1992a, b), Shahin (1992), De Castro *et al.* (1994).

Sedimentological interpretation was based on Dunham (1962) and Folk (1959).

Based on the results of the micropaleontological analysis of planktonic and benthic foraminifers and their association, as well as calcareous nannoplankton it has been possible to determine the age, facies, environment, relations and correlation of the Paleogene deposits. The data were applied to the wireline logs providing relevant time–space correlation of the whole area.

The interpretation of the Eocene carbonate platform facies is based on the analysis of the wireline log facies (Selley, 1985) compared with the geological information's acquired by drilling and by transforming the physical properties of the sediments (wireline log facies) into geological categories (sedimentary facies). The wireline

log facies interpretation was carried out on the logs that primarily depend on the lithological characteristics of the observed sediments; natural radioactivity (gamma rays and spectralog) and the porosity logs (neutron, density and sonic logs). The technique is primarily qualitative and relies heavily on the visual identification of the coherent units. The criteria used for separating the units depends on the geological data acquired by drilling. There is no standard procedure for separating certain wireline log facies, although it would be logical to separate the obvious coherent rocks unites first, and then in correlation with the same of neighboring wells, gradually perform the detailed separation.

As much as it was possible the deposits were correlated with well defined onshore outcrops as described by Alvarez *et al.* (1985), Arthur (1976), Premoli-Silva *et al.* (1976), Drobne *et al.* (1988).

STRATIGRAPHY

The area under consideration can be divided in two different tectonostratigraphic units which are separated by a significant tectonic break (Fig. 19a–c).

The western unit correspond to the area known as Central Adriatic uplift with its associated facies. The continuity of sedimentation is preserved from Maastrichtian through the Paleogene under the deep water conditions. Throughout the entire succession of the western unite Maastrichtian, Paleocene and Eocene marine carbonate turbidites predominate. Deep wells Jadran-1 (J-1), Jadran-2 (J-2), Jadran-21/1 (J-21/1), Jadran-22/1 (J-22/1), Jadran-10 (J-10), Ksenija-1 (Kse-1) and Koraljka-1 (Kok-1) present the best record of that units' history (Fig. 15).

In the eastern unit the deposits consist of shallow marine Upper Cretaceous and Eocene carbonates. They are the part of the typical Adriatic carbonate platform. Paleocene deposits occur sporadically, only in the Kate-1 well surrounding (Fig. 15). During Late Eocene and more so during Miocene, those carbonates were tectonically imbricated, forming a particular zone in front of the Dinaric thrust belt (Fig. 19). The best records of the stratigraphic development of this unit are produced by the wells Jadran-3 (J-3), Jadran-9 (J-9), Kornati more-4 (KM-4), Kate-1 and Susak more-1 (SM-1).

Western realm

Deposits from all of the wells in this area display similar sedimentary features, i. e. a rhythmical alternation of mudstone/wackestone and allochtonous bioclastic limestones (packstone/grainstone to rudstone), same as in the underlying Cretaceous deposits. According to their content of planktonic and benthic foraminifera as well as to the plankton-benthos ratio and to the lithological features it is presumed that their deposition during the Paleocene and the Eocene took place on the deeper part of a continental slope. The sporadic occurrence of redeposited benthic remains indicate gravity induced depositional mechanisms, i. e. turbidity currents. This process will be described elsewhere in details but it has to be stressed that it takes place at the later time than on the carbonate platform farther east.

Maastrichtian age of the succession underlying Paleocene deposits is well dated by planktonic foraminifera and nannofossil assemblage (Fig. 5, 7, 8; Pl. 14, Fig. 1–20).

The oldest Paleogene deposits are related to the Danian stage. Note the Danian age in wells documented by the presence of:

Morozovella pseudobulloides (Plummer) (Fig. 3, 4, 7, 8, Pl. 3, Fig. 3, 6),

Planorotalites compressa (Plummer) (Fig. 3 and 4, Pl. 3, Fig. 4, 5),

Morozovella trinidadensis (Bolli) (Fig. 7, 8).

Planktonic foraminifera dominated in well records also in Thanetian:

Globigerina triloculinoides (Plummer) (Fig. 3, 8; Pl. 4, Fig. 2, Pl. 5, Fig. 1),

Morozovella angulata (White) (Fig. 3, 4, 7, 8; Pl. 4, Fig. 2, 3),

Planorotalites pseudomenardii Bolli (Fig. 3, 4),

Acarinina mckannai (White) (Fig. 3, 4).

Nannofossil assamblage of the Paleocene deposits is represented on the Plate 15.

The Ilerdian, Cuisian and Lutetian part of the succession is fairly well dated by planktonic and sinsedimentary redeposited benthic foraminifera (Fig. 3, 4, 8 and 9). For the wells J-21/1, J-7 and J-10 the stratigraphic divisions are based on the wireline logs and lithologic correlation, due to the lack of fossil data.

Bartonian deposits are documented by planktonic foraminifera:

Orbulinoides beckmanni (Saito),

Globigerapsis index (Finlay),

Turborotalia centralis (Cushman),

Dentoglobigerina yeguaensis (Weinzierl et Applin),

Hantkenina alabamensis (Cushman) (Fig. 3 and 4),

and nannofossil assemblage (Fig. 4).

Priabonian carbonate turbidites are well dated only in the wells J-1 and J-2 by the presence of planktonic foraminifera:

Turborotalia cerroazulensis cerroazulensis (Cole),

Dentoglobigerina yeguaensis (Weinzierl et Applin),

Globigerinatheca mexicana (Fig. 3),

Globigerinatheca kugleri (Bolli, Loeblich & Tappan), (Fig. 4).

The first dated Paleogene benthic foraminifera (*Kathina* sp., *Daviesina* sp.) transported from the platform into the basin occured at the end of Thanetian (Fig. 8) or the others even later during the Eocene (Figs 10–14).

Main lithological change from carbonate into siliciclastic turbidites occurred during Priabonian (Fig. 3, 4 and 7). It is related to the tectonic event that locally produced a sedimentary break which lasted till Oligocene (Fig. 5 and 9), Miocene (Fig. 8) or even Pliocene (Fig. 6). This process is not the matter of this article but it has to be stressed that it takes place at a later time than on the carbonate platform on the East.

Eastern realm

The eastern tectonostratigraphic unit constitutes an area in which the Paleogene beds are tectonically imbricated during Late Eocene in front of the Dinaric thrust belt (Fig. 1). The best record of the stratigraphic development in this unit was produced by the wells J-3, J-9, KM-4, Kate-1 and SM-1 (Figs 10, 11, 12, 13, 14,). The position of J-11 in respect to two units is uncertain because drilling was stopped in Lutetian carbonates sedimented of the deep marine basin floor, close to the position of the major tectonic break (Fig, 19). Except J-11 all other wells penetrated a transgressive sequence of Eocene carbonate platform limestones as clearly demonstrated by cores, mud cuttings and wireline logs. In SM-1 well total lost of drilling mud in circulation occurred at the depth 755 m. Because of lack of any rock sample the interpretation of the Paleogene sequence was made from log correlation. It is composed only by Cuisian facies pattern (X, A, B+C). Lutetian part of the sequence is probably eroded or not sedimented, but tectonically repeated.

The succession of the wireline log facies is almost the same in all the wells (Figs 10–14). It starts with facies X reflecting mudstone and mudstone/wackestone limestones that overlies eroded and carstified Late Cretaceous (Senonian and Turonian) carbonates. Facies A is similar to the facies X, but natural radioactivity is very high (>70 API on gamma ray curve) due to an unusually high content of uranium. The presence of uranium could be explained by high contents of organic matter. The next facies in the sequence is B+C reflecting an alteration of tidal flat packstone/grainstone (B) and mudstone/wackestone (C) limestones what is good expressed on porosity, density and sonic logs. Facies Y was isolated only on SM-1 well only on the wireline logs. There is the assumption that the low gamma radiation and high acoustic value respond to the porous limestone (?grainstone) sedimented in the high energy environment as the shoals on the beach. It presents the final member of the regressive sequence that ends with long lasting emersion (Figs 15–18). Facies D corresponds to the clean and tight fossiliferous mudstone and packstone limestones of restricted carbonate environments, what is characterized on the logs as low radioactivity and porosity, high density and sonic values. Facies E is composed of algal boundstones (bindstones) and wackestone. The wireline response of the facies is characterized with changeable, "nervous" outlook of all the curves, except gamma ray log values that are low, referring to the clean, washout limestone. Facies F of foraminiferal mudstone and packstone and facies G of floatstone/packstone and grainstone/rudstone crowded with *Nummulites* and *Discocyclina* represent respectively reef front, forereef and shoal deposits on a platform edge. Facies F is expressed as low porosity and high density and sonic intervals on the logs, while facies G has higher porosity, lower density and sonic values.

According to the paleontological data the age of the complete carbonate sequence is dated as Cuisian — facies A and B+C (Fig. 17) and Lutetian-Bartonian — facies D, E, F and G (Fig. 18).

The oldest ?Paleogene deposits, penetrated only by Kate-1 well, below facies X (Fig. 13) consist of the peritidal carbonate deposits, similar to the younger Eocene B+C facies. The scarce flora and fauna are not representative either for Cretaceous or for Paleocene deposits. For the facies X there are no reliable biostratigraphic indications too. The small rotalid foraminifera, discorbids occur in the sections studied on land to levels located at the end of the Cretaceous sedimentary cycle or at the beginning of the Early Paleogene Thanetian or Ilerdian global sea level rises. All those deposits were sedimented under a very shallow intertidal and supratidal regime with numerous emersions (Fig. 15).

The age of the facies X is also undocumented because of the scarce fauna consisting of miliolids, discorbids and ostracods, but those deposits present the first unite of the transgressive cycle that ends at the end of the Middle Eocene. They are genetically related to the overlying deposits of the facies B+C which age is attributed to the Cuisian by presence of *Coskinolina perpera* Hottinger et Drobne, *Pfendericonus makarskae* (van Soest), *Periloculina dalmatina* Drobne and *Coskinolina liburnica* Stache (Figs 10, 11 and 13, Pls. 6, 7, 8).

The age boundary between Cuisian and Lutetian follows the facies change from facies B+C (coastal environment) into facies D (shallow platform environment). The Lutetian age is also attributed to the facies E, F and G (Figs 10–12, Pls. 9, 11). It is dated by presence of benthic foraminifera *Asterodiscus stellatus* Gümbel, *Discocyclina sella* D'Archiac, *Sphaerogypsina globula* (Reuss), *Asterigerina rotula* (Kaufmann) *Nummulites* sp. and *Alveolina* sp., as well as planktonic foraminifera *Globigerina eocena* (Gümbel), *Globigerina tripartita* Koch, *Catapsidrax dissimilis* (Cush. et Berm.), *Globigerina boweri* (Bolli), *Turborotalia cerroazulensis* (Cole) and *Turborotalia centralis* (Cushman).

During the Lutetian the carbonate platform around J-3 well was drowned by siliciclastic turbidites as well documented by benthic and planktonic foraminifera (Fig. 10). Note that the carbonate platform around Kata-1 well was drowned some later in Bartonian (Fig. 15) as documented by presence of *Operculina bericensis* Oppenheim, *Nummulites millecaput* Boubee and *Nummulites dufrenoy* D'Arch. et Haime.

GEOLOGICAL CONSIDERATION

The Adriatic, where the considered area is situated, is the part of the Outer Dinarides, and consequently belongs to the Alpine Orogenic System which extends over large parts of Southern and Central Europe.

From the aspect of plate tectonics Dinaric thrust belt is overthrusted on to imbricated zone of the Adriatic. It is documented by deep refraction seismics (Aljinović & Blašković, 1981) by the presence of more or less steeply deeping fault zone in front of the belt, and considered as the main subduction zone by Herak (1986). However in front of the Dinaric thrust belt and of the previously mentioned fault zone there is the imbricated zone of the Cretaceous and Eocene platform carbonates. The later belong to the Dinarides according to their stratigraphy and even more according to their structural style of folded and reverse faulted structures. Cuisian and Lutetian platform carbonates are affected in the same way by tectonics in the off-shore wells as in the outcrops found in the mainland from the Istrian peninsula to the South Dalmatia, i.e. by low angle reverse faulting in Kate-1 well, and by folding and reverse faulting J-9 well. The facies development on the platform in all studied wells is almost identical to the one along the Adriatic coast and islands shown by Tari-Kovačić (1992, 1997).

Thus, the eastern unit of the subsurface area considered here represents the continuation of the Dinaric platform as known on land along the Adriatic coast from the Istrian peninsula to Split.

The western unite occupies the zone of tectonic inversion known as Central Adriatic Uplift plunging from Istrian peninsula toward South through the middle of Adriatic subsea. Since Maastrichtian through Paleogene it was the part of the continental slope or basin plane. The log correlation along the slope is favorable and suggests the presence of the broad, thick and long fan aprons. The movement of turbiditic currents was synchronous, mostly produced by tectonic stresses.

It is out of question that the western unit represents the immediate continuation of the platform as its westward-directed slope. Comparing the development of the sedimentary record during Paleocene in the wells from the western unit with the eastern one, the lack of facies belt corresponding to platform edge and upper slope is evident. Moreover, the calcareous turbidites of the western unit exhibit too well sorted, too uniform and too small grain sizes for representing truly proximal slope facies types such as they are known for Pyrenean realm during the same time interval. Considering the "tectonic environment" of Alpine movements in this area, the missing facies belt was destroyed by tectonic compression in late Eocene (Fig. 19) which created the imbricated structures eastward from the major tectonic break (or the pinching out zone of the Dinaric thrust belt sole fault). The Central Adriatic Uplift on the West was formed later, during Oligocene and Miocene, in the next compressional phase when the tectonic inversion affected the area westward from major tectonic break, creating horst-like structures plunging from Istrian peninsula toward the South.

CONCLUSIONS

The sedimentological and structural characteristics of the Paleogene beds represent the key for identification of regional geological history of Adriatic and Dinaric realm. They are recognized as two main tectonostratigraphic units:

— Western unit of the Maastrichtian to Priabonian predominantly carbonate turbidites, embraced in complex structural unit known as Central Adriatic Uplift. The age and the sedimentary environment are well dated by planktonic foraminifera and nannofossils which predominate in pelagic or hemipelagic part of the turbiditic sequences. Benthic foraminifera, redeposited by turbiditic currents from the shallow carbonate shelf, are most common in the packstone-grainstone part of the sequences.

— Eastern unit of the ?Paleocene, Cuisian and Lutetian shallow carbonate platform, that was drowned by flysch deposits through Late Lutetian and Priabonian. Paleocene age refers to the sediments above well dated Late Cretaceous and below well dated Cuisian limestones. Sedimentary environment of the supratidal and shallow occasionally anoxic intertidal events caused scares biota preserved in the rock records. During Cuisian and Lutetian transgresive sequence of slowly sinking carbonate platform sediments contain abundant biota comparable to the outcrops along the Adriatic coast and on the islands.

Each of the units is characterized by different specific facies development and structures of particular tectonic styles. They are brought together in present day position by compressional tectonic event which lasted, generally speaking, from Late Eocene to the end of Miocene.

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THE LIST OF FOSSILS

A

Aberisphaera gambanica XIAOQIAO, Ksenija-1
Acarinina bullbrooki (BOLLI)j-2
Acarinina mckannai (WHITE), Jadran-1, Jadran-2
Alveolina sp., Jadran-3, Jadran-9,
Arcaeolithotamnium sp., Kate-1
Arkhangelskiella cymbiformis VEKSHINA, Koraljka-1, Ksenija-1
Astericyclina sp., Kate-1
Asterigerina rotula (KAUFMANN), Jadran-9, Jadran-3
Asterigerina sp., Kate-1
Asterocyclina sp., Jadran-1, Jadran-10, Kate-1
Asterocyclina stellata (D'ARCHIAC), Jadran-3
Asterodiscus stellatus GUEMBEL, Jadran-22/1

C

Catapsidrax dissimilis (CUSHMAN & BERMUDEZ), Jadran-9, Jadran-3
Chapmanina gasinensis (SILVESTRI), Jadran-1
Chapmanina sp., Jadran-10, Kornati More-1
Chiasmolithus danicus (BROTZEN) Koraljka-1, Ksenija-1
Chiloguembelina sp., Koraljka-1
Chrysalidina sp., Kornati More-1, Jadran-9
Contusotruncana contusa (CUSHMAN), Koraljka-1
Coskinolina douvillei (DAVIES), Jadran-9
Coskinolina liburnica STACHE, Jadran-3, Jadran-9
Coskinolina sp., Kornati More-1
Cribrocentrum reticulatum PERCH-NIELSEN, Jadran-2
Cruciplacolithus tenuis (STRADNER), Koraljka-1
Cuvilierina sp., Jadran-3

D

Dentoglobigerina yeguaensis (WEINYIERL & APPLIN), Jadran-10
Dictyococcites bisectus BUKRY & PERCIVAL, Jadran-1, Jadran-2, Jadran-10, Jadran-11
Discoaster barbadiensis TAN, Jadran-2, Jadran-10, Jadran-11
Discoaster delicatus BRAMLETTE & SULLIVANKS, Kate-1
Discoaster distypus BRAMLETTE & SULLIVANKS, Kate-1
Discoaster multiradiatus BRAMMLETE & RIEDELKS, Kate-1
Discoaster saipanensis, BRAMLETTE & RIEDEL, Jadran-11
Discocyclina div. sp., Jadran-1),
Discocyclina sella (D'ARCHIAC), Jadran-1, Ksenija-1, Kornati more-1, Jadran-3, -10
Discocyclina sp., Jadran-3, Jadran-9, Ksenija-1, Kate-1

E

Elianella elegans PFENDER & BASSE Kate-1
Epimastoporia sp., Jadran-9
Ericsonia formosa HAQ, Jadran-1, Jadran-10, Jadran-11, Ksenija-1

F

Fabiania sp., Jadran-3
Fallotella sp., Jadran-3, Jadran-9, Kate-1
Fasciculithus tympaniformis HAY & MOHLER, Ksenija-1

G

Globigerinatheca mexicana barri BRONNIMAN, Koraljka-1
Globigerapsis index (FINLAY), Koraljka-1, Jadran-2, Jadran-1
Globigerapsis sp., Jadran-21, Jadran-3
Globigerapsis tropicalis (BLOW & BANNER), Jadran-10
Globigerina boweri (BOLLI), Jadran-3
Globigerina cf. eoceana GÜMBEL), Jadran-9, Jadran-10
Globigerina corpulenta SUBBOTINA, Jadran-21
Globigerina lineaperta FINLAY, Jadran-9
Globigerina senni (BECKMANN), Jadran-21
Globigerina triloculinoides (PLUMMER), Jadran-1, Jadran-2, Koraljka-1, Ksenija-1
Globigerina tripartita KOCH, Jadran-9
Globigerina yeguaensis (WEINZIERL & APPLIN). Jadran-2, Jadran-3, Koraljka-1
Globigerinatheka mexicana (CUSHMAN), Koraljka-1
Globigerinatheka mexicana kugleri (BOLLI, LOEBLICH & TAPPAN), Jadran-2
Globigerinatheka sp., Jadran-3, Jadran-10
Globotruncana gr. lapparenti-linneiana (BROTZEN & D'ORBIGNY), Ksenija-1
Globotruncana arca (CUSHMAN), Ksenija-1
Globotruncana calcarata CUSHMAN, Ksenija-1
Globotruncana lapparenti BROTZEN, Koraljka-1
Globotruncanita stuarti (DE LAPPARENT), Koraljka-1
Gypsina sp. Jadran-3

H

Hantkenina alabamensis (CUSHMAN), Jadran-1
Helicosphaera compacta BRAMMLETTE & WILCOXON, Jadran-2, Jadran-10

K

Kathina selveri SMOUT, Koraljka-1
Kathina sp., Ksenija-1

M

Markalius inversus (DEFLANDRE), Ksenija-1
Micula decussata VEKSHINA, Jadran-10
Micula murus (MARTINI), Koraljka-1, Ksenija-1
Miscellanea sp., Koraljka-1
Morozovela angulata (WHITE), Jadran-1, Jadran-2, Koraljka-1, Ksenija-1
Morozovella abundocamerata (BOLLI), Koraljka-1
Morozovella aequa (CUSHMAN & RENZ), Jadran-1, Jadran-2, Koraljka-1, Ksenija-1
Morozovella aragonensis (NUTTALL), Kate-1
Morozovella gracilis (BOLLI), Ksenija-1
Morozovella inconstans SUBBOTINA, Koraljka-1
Morozovella pseudobulloides (PLUMMER), Jadran-1, Jadran-2, Koraljka-1, Ksenija-1
Morozovella spinulosa (CUSHMAN), Ksenija-1
Morozovella subbotinae (MOROZOVA), Ksenija-1
Morozovella trinidadensis (BOLLI), Jadran-1, Jadran-2, Koraljka-1, Ksenija-1
Morozovella velascoensis (CUSHMAN), Jadran-1, Koraljka-1

N

Nummulites dufrenoyi D'ARCHIAC & HAIME, Kate-1
Nummulites discorbinus (SCHLOTHEIM), Kate-1
Nummulites millecaput BOUBEE, Kate-1
Nummulites sp., Jadran-9, Jadran-10, Ksenija-1, Kornati More-1, Jadran-3

O

"Operculina" bericensis, OPPENHEIM, Jadran-9, Kate-1
"Operculina" roselli, HOTTINGER, Kate-1
"Operculina" sp., Jadran-3, Kornati More-1, Ksenija-1
Orbitoides media (D'ARCHIAC), Koraljka-1
Orbitoides sp., Ksenija-1
Orbitolites sp., Jadran-9
Orbulinoides beckmanni (SAITO), Jadran-2
Orbulinoides sp., Jadran-1, Jadran-3
Ortophragmina sp., Kate-1

P

Pellatispira sp., Kornati More-1
Periloculina dalmatina DROBNE, Jadran-3, Jadran-9
Peyssonelia antiqua JOHNSON, Kate-1
Pfendericonus makarskae (VAN SOEST), Kate-1
Planorbulina cretacea (MARISSON), Kate-1
Planorotalites compressa (PLUMMER), Jadran-1, Jadran-2
Planorotalites ehrenbergii (BOLLI), Koraljka-1
Planorotalites pseudomenardii BOLLI, Jadran-1, Jadran-2
Prediscosphaera cretacea (ARKHANGELSKY), Jadran-10, Ksenija-1
Prediscosphaera grandis PERCH-NIELSEN, Jadran-10
Pseudohastigerina cf. wilcoxensis (CUSHMAN & PONTON), Koraljka-1
Pseudohastigerina micra (COLE), Koraljka-1

Q

Quadrum qothicum (DEFLANDRE), Ksenija-1

R

Reticulofenestra hillae, Jadran-11
Reticulofenestra umbilica (LEVIN), Ksenija-1, Jadran-10
Reusella sp., Jadran-3
Rotalia sp., Jadran-3, Koraljka-1
Rotalia trochidiformis, Jadran-3, Kate-1
Rupertia sp., Jadran-10

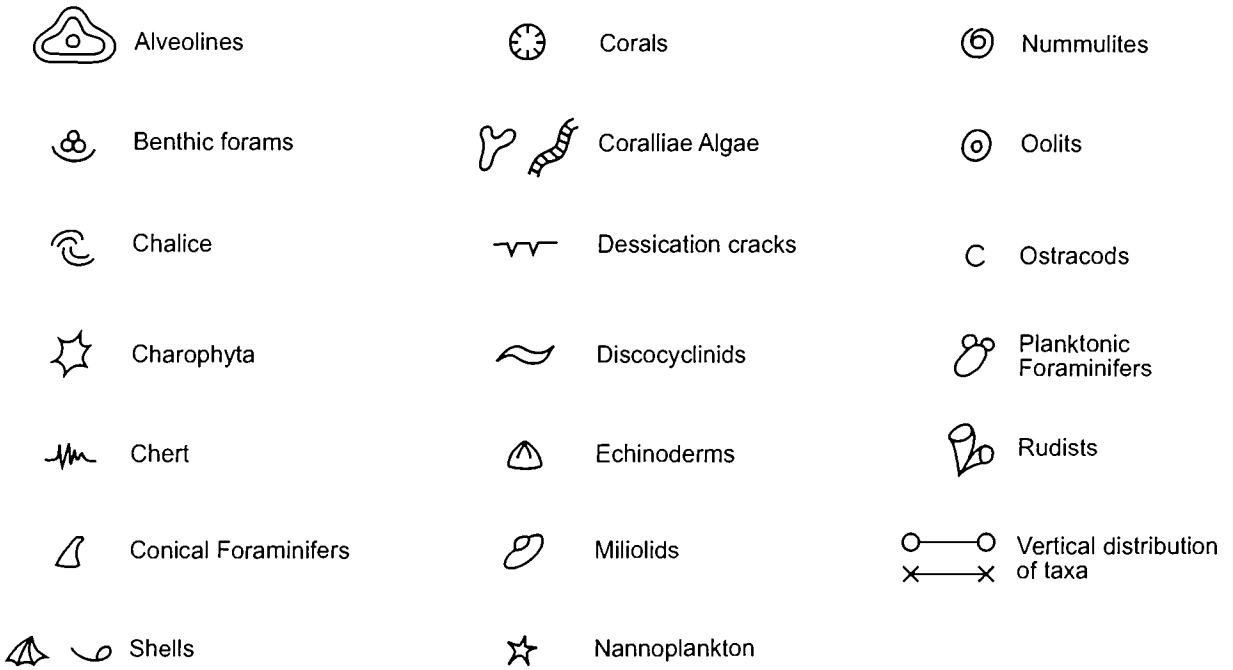
S

Siderolites calcitrapoides LAMARCK, Koraljka-1, Ksenija-1
Sphaerogypsina globula (REUSS), Jadran-10, Kornati More-1

T

Truncorotalides topilensis (CUSHMAN), Jadran-21
Truncorotaloides rohri BRÖNNIMAN & BERMUDEZ, Ksenija-1, Jadran-2
Turborotalia cerroazulensis cerroazulensis (COLE), Jadran-1, Jadran-3, Koraljka-1
Turboroalia cerroazulensis coacoensis (CUSHMAN), Koraljka-1
Turborotalia centralis (CUSHMAN), Jadran-2, Jadran-10

Fig. 2: Legend for figs 3–15



1 – Facies of fenestral and Charophyta limestone (*X*); salt and brackish marshes, tidal flat environment.

2 – Facies of foraminiferal wackestone-packstone, marl with ostracods and fine grained breccia conglomerate (*A*); coastal environment with repeated shallowing and emersions.

3 – Facies of foraminiferal packstone-grainstone limestone and miliolidal mudstone-wackestone limestone (*B*) and (*C*); coastal environment with repeated shallowing and emersions.

4 – Facies of porous limestone -? grainstone? (*Y*); ? beaches.

5 – Facies of fossiliferous mudstone-packstone limestone (*D*); shallow platform and mud mounds environment.

6 – Facies of algal boundstone (bindstone) and wackestone (*E*); platform margin buildups.

7 – Facies of the foraminiferal mudstone-packstone (*F*); fore slope environment.

8 – Facies of Nummulites-Discocyclina floatstone-packstone and grainstone-rudstone (*G*); fore slope environment.

9 – Shallow marine mudstone-wackestone.

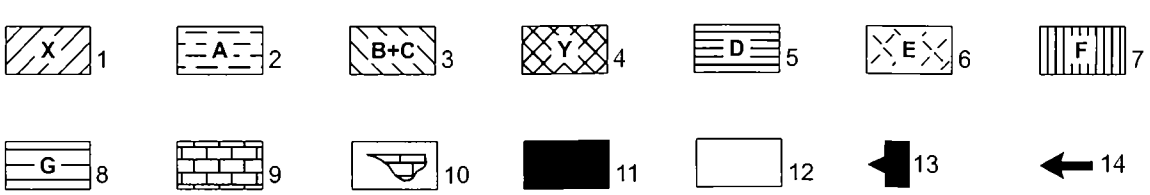
10 – Shallow marine packstone-grainstone.

11 – Deep marine mudstone-wackestone.

12 – Deep marine wackestone-packstone.

13 – Core samples.

14 – Mud samples.



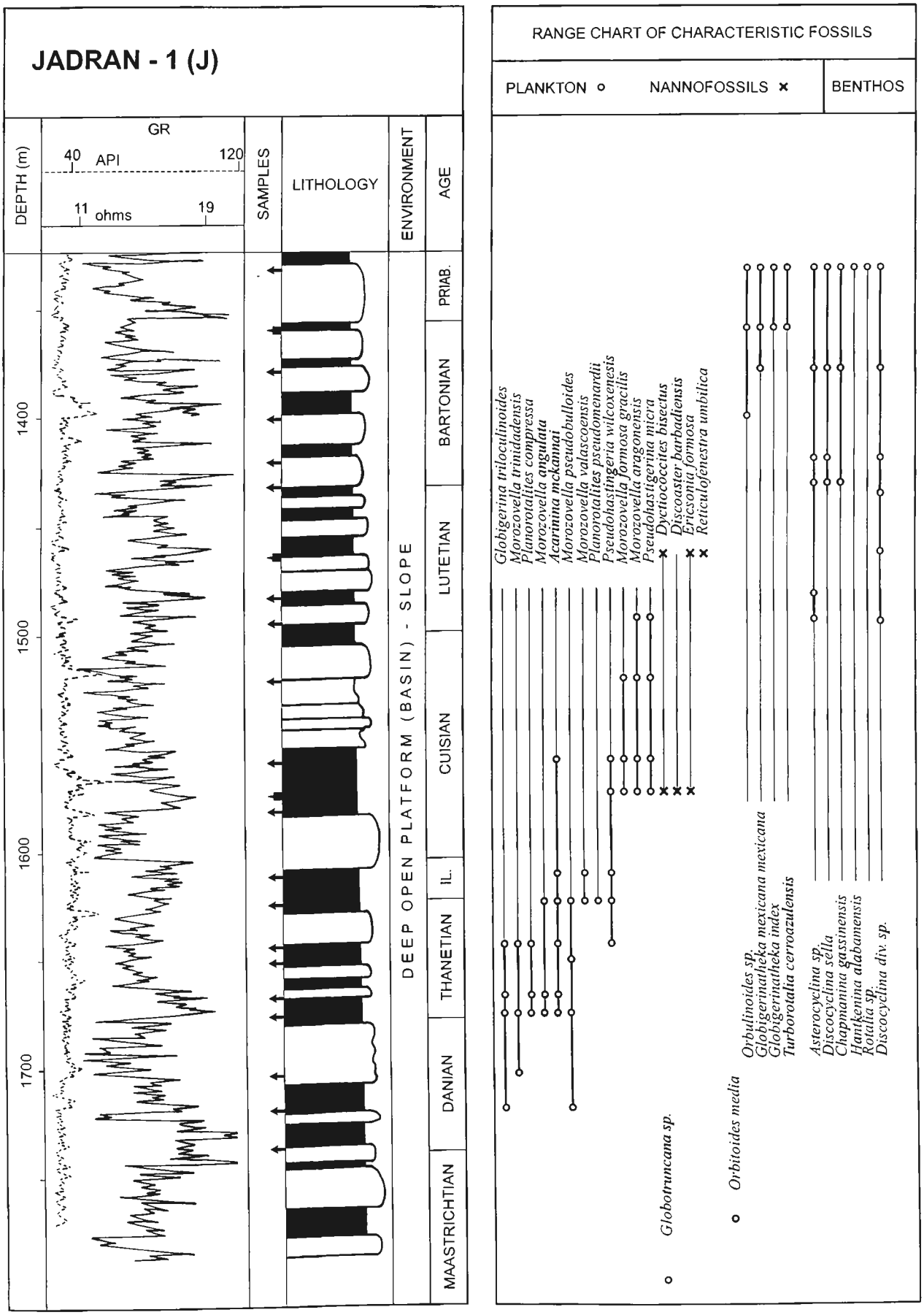


Fig. 3: Sequence of Paleogene strata in the deep well Jadran-1. (Plate 3, fig. 7; Plate 4, fig. 9; Plate13, fig. 4).

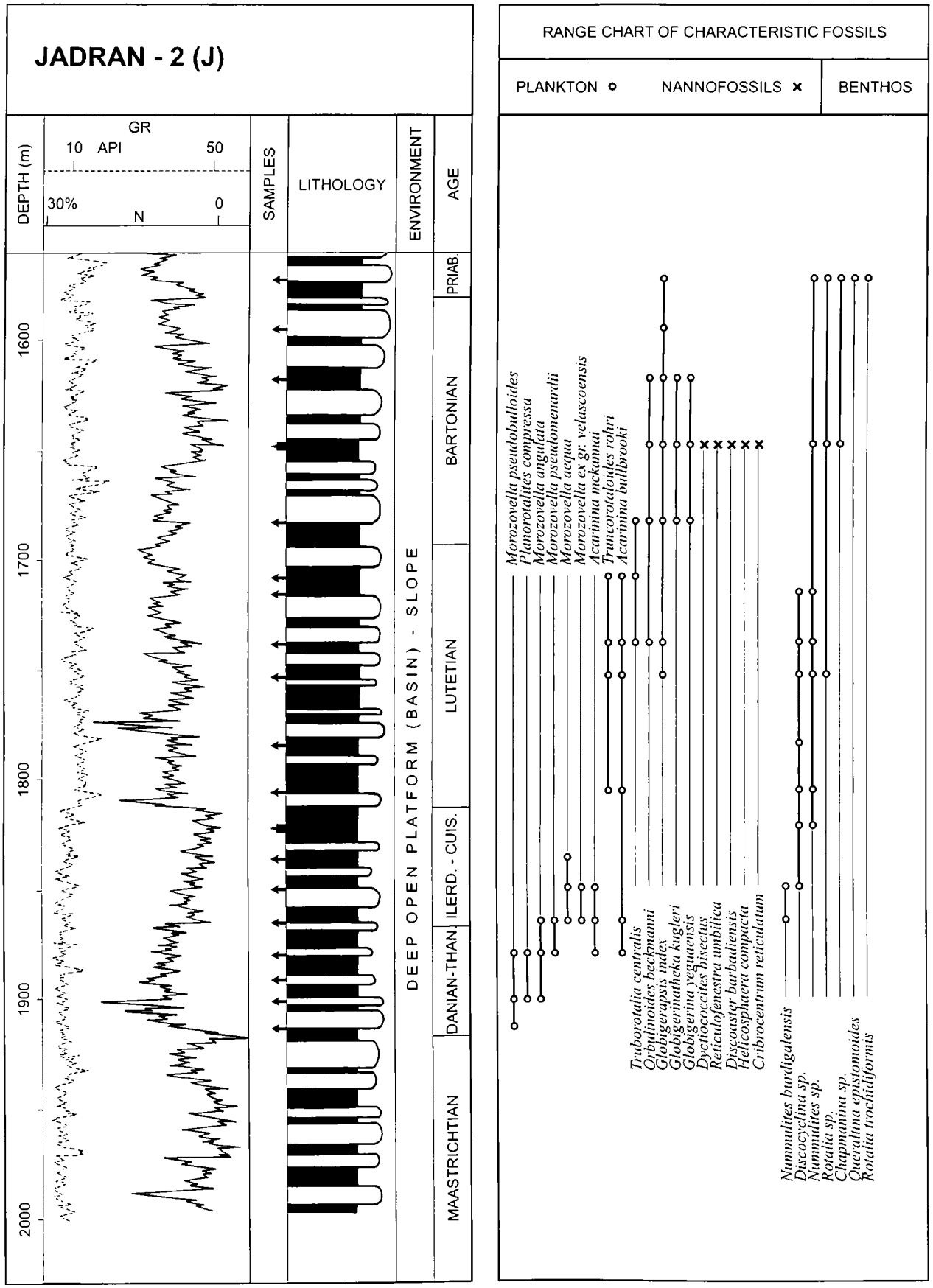


Fig. 4: Sequence of Paleogene strata in the deep well Jadran-2. (Plate 2, figs 3, 4; Plate 4, figs 4, 5, 8, 10; Plate 5, fig. 3; Plate 10, figs 1–4, 6).

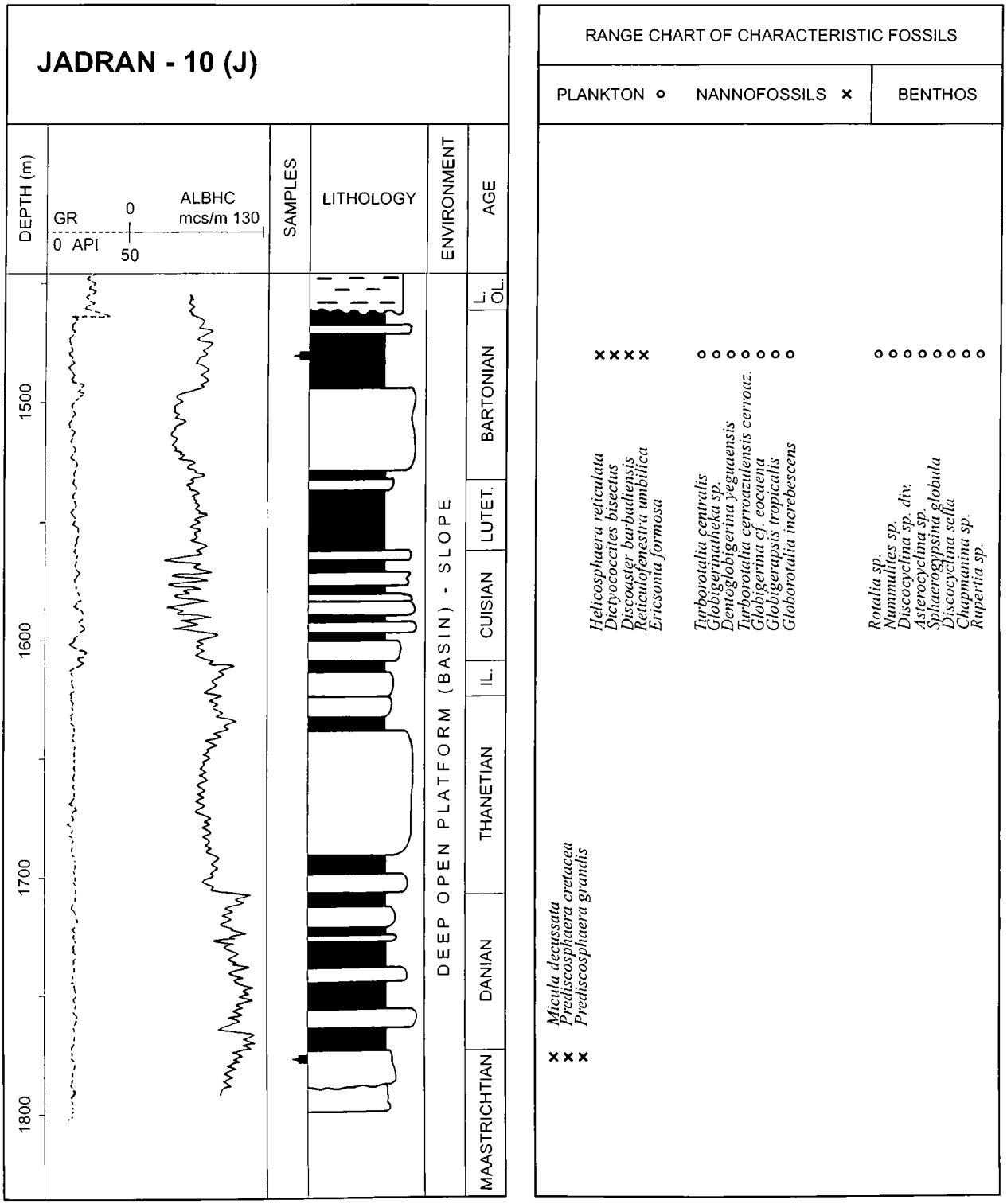


Fig. 5: Sequence of Paleogene strata in the deep well Jadran-10.

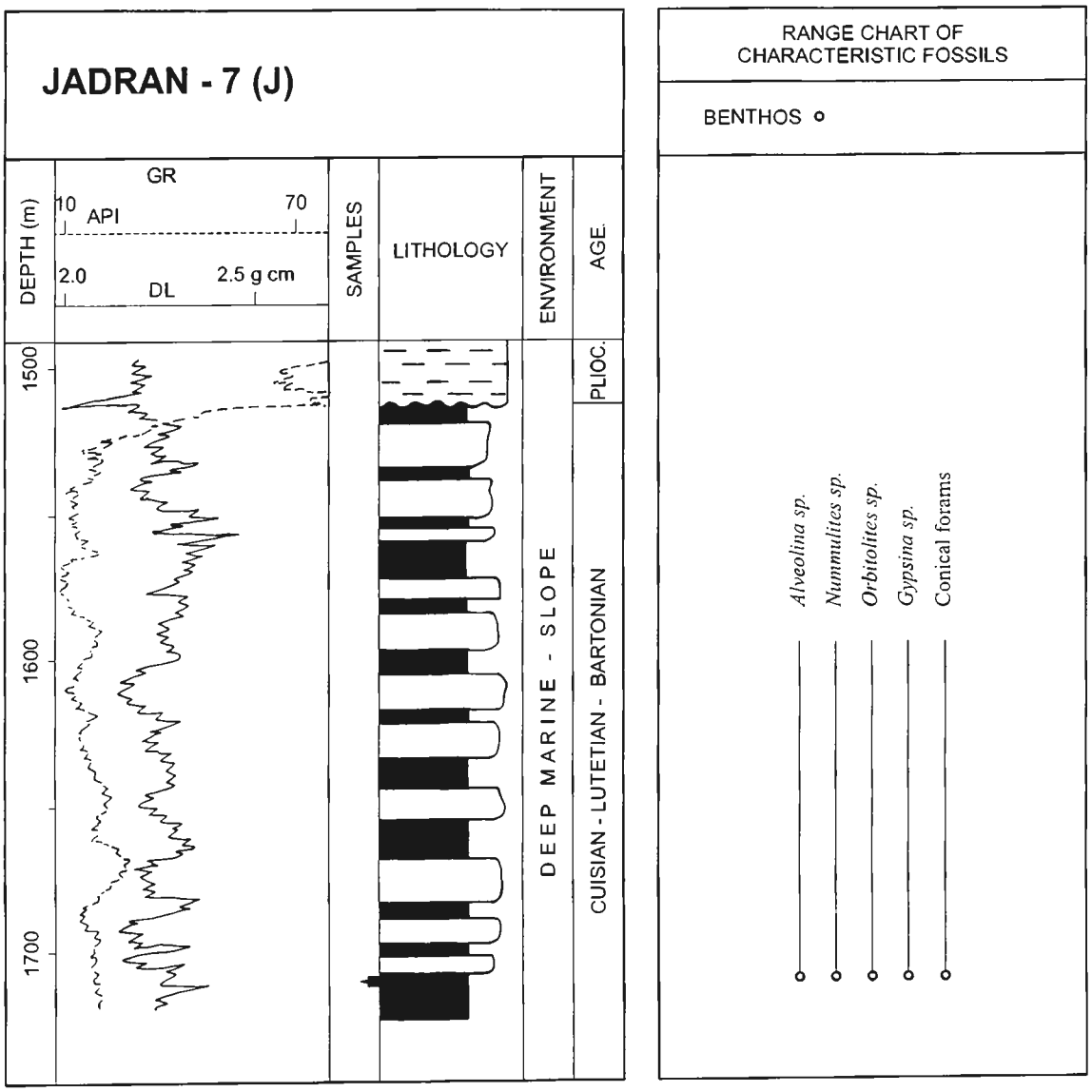


Fig. 6: Sequence of Paleogene strata in the deep well Jadran-7. (Plate 8, fig. 5).

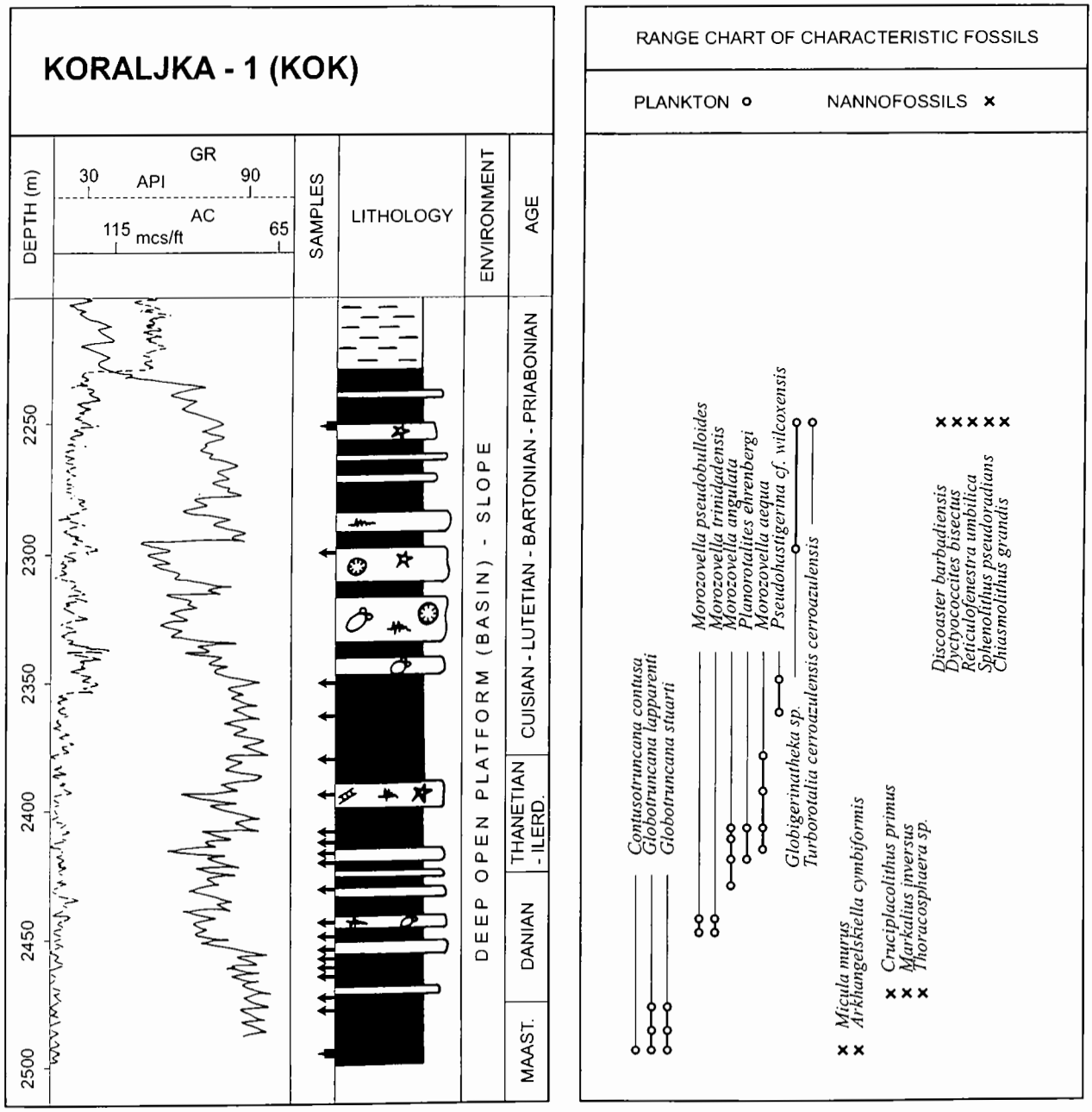


Fig. 7: Sequence of Paleogene strata in the deep well Koraljka-1. (Plate 3, figs 1–6; Plate 4, figs 1, 2, 3, 6, 11; Plate 5, figs 2, 4, 5; Plate 10, fig. 5; Plate 13, figs 1, 3, 5–7; Plate 14, figs 1–20; Plate 15, figs 1–19).

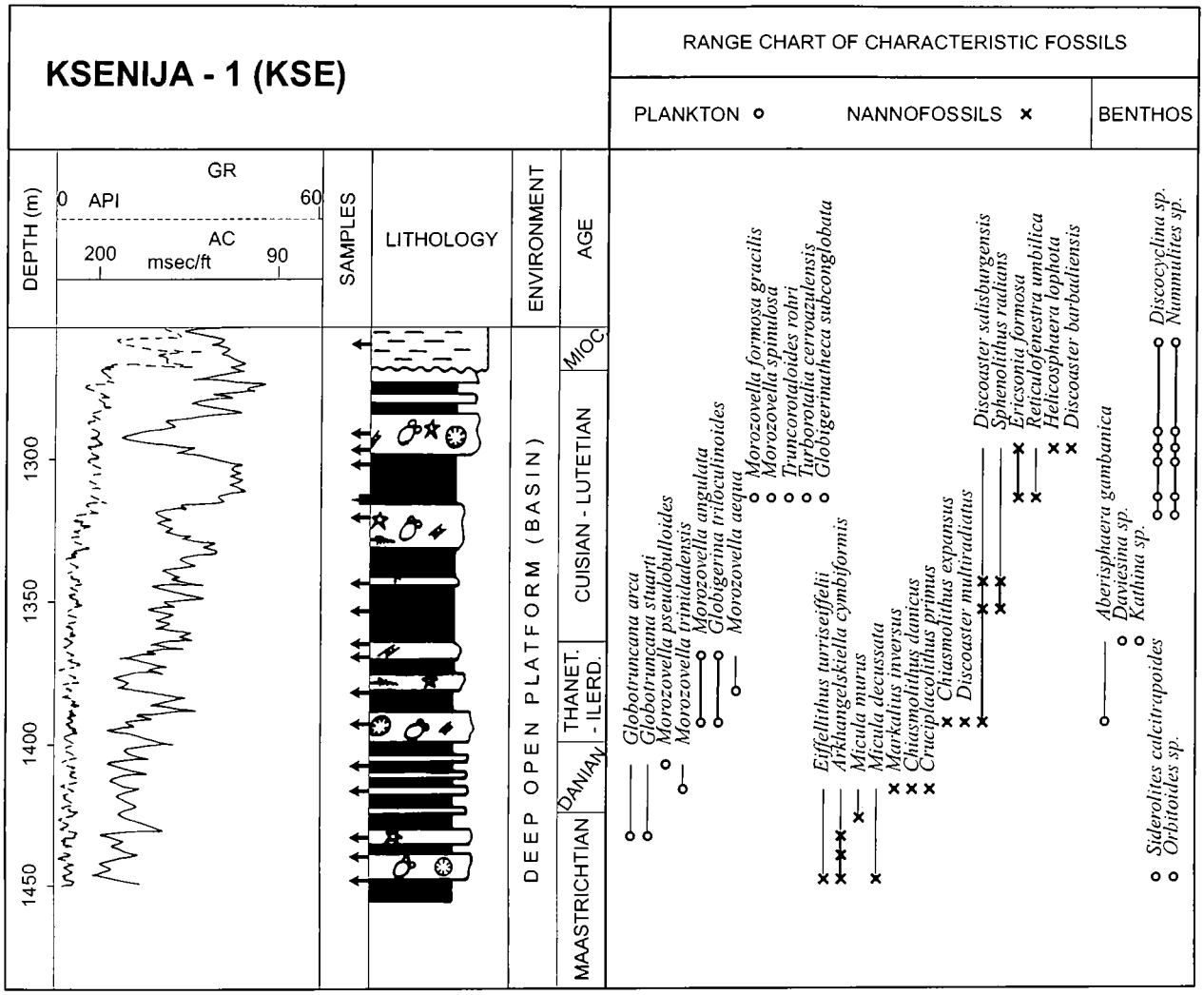


Fig. 8: Sequence of Paleogene strata in the deep well Ksenija-1. (Plate 5, fig. 1).

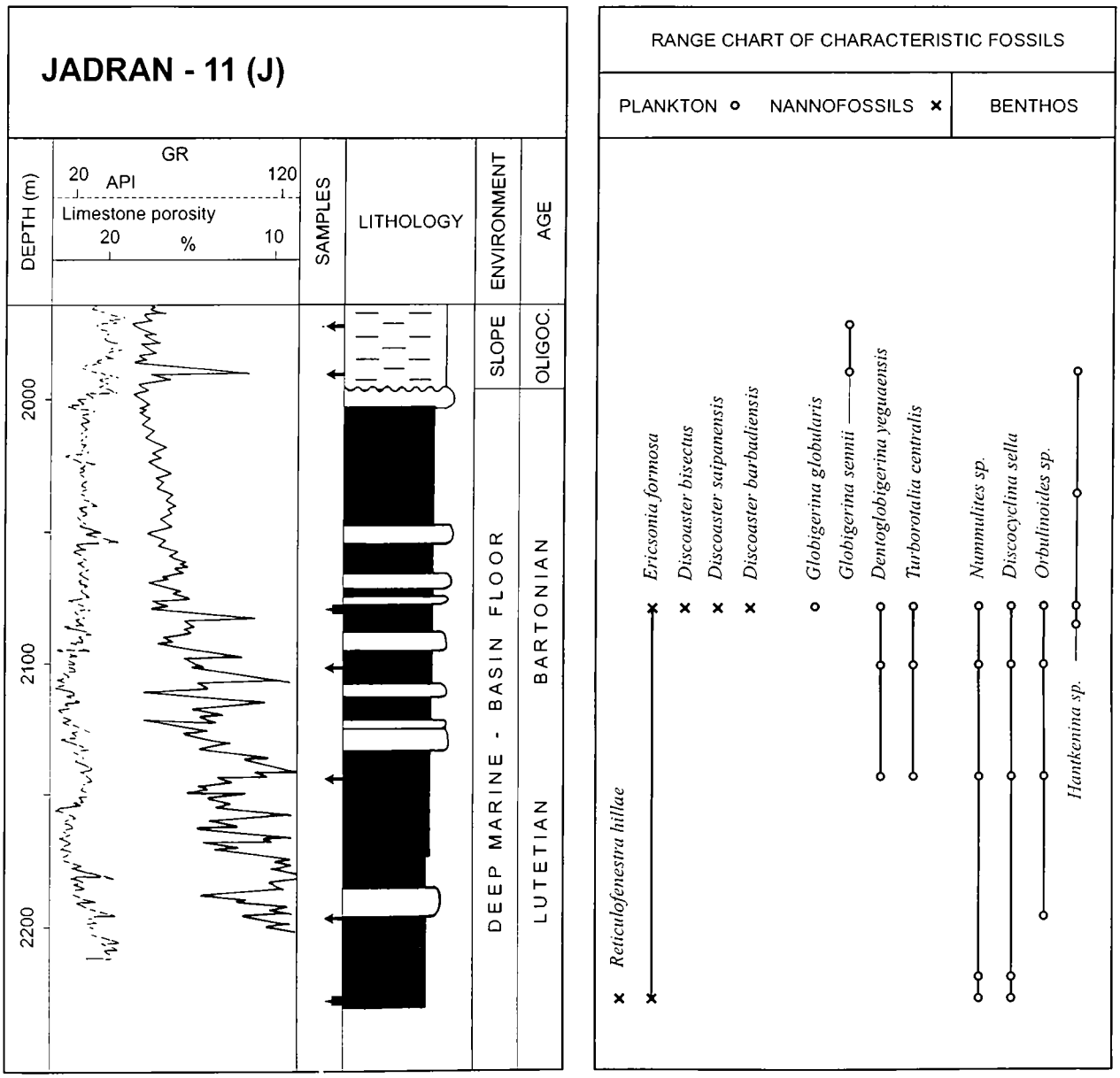


Fig. 9: Sequence of Paleogene strata in the deep well Jadran-11.

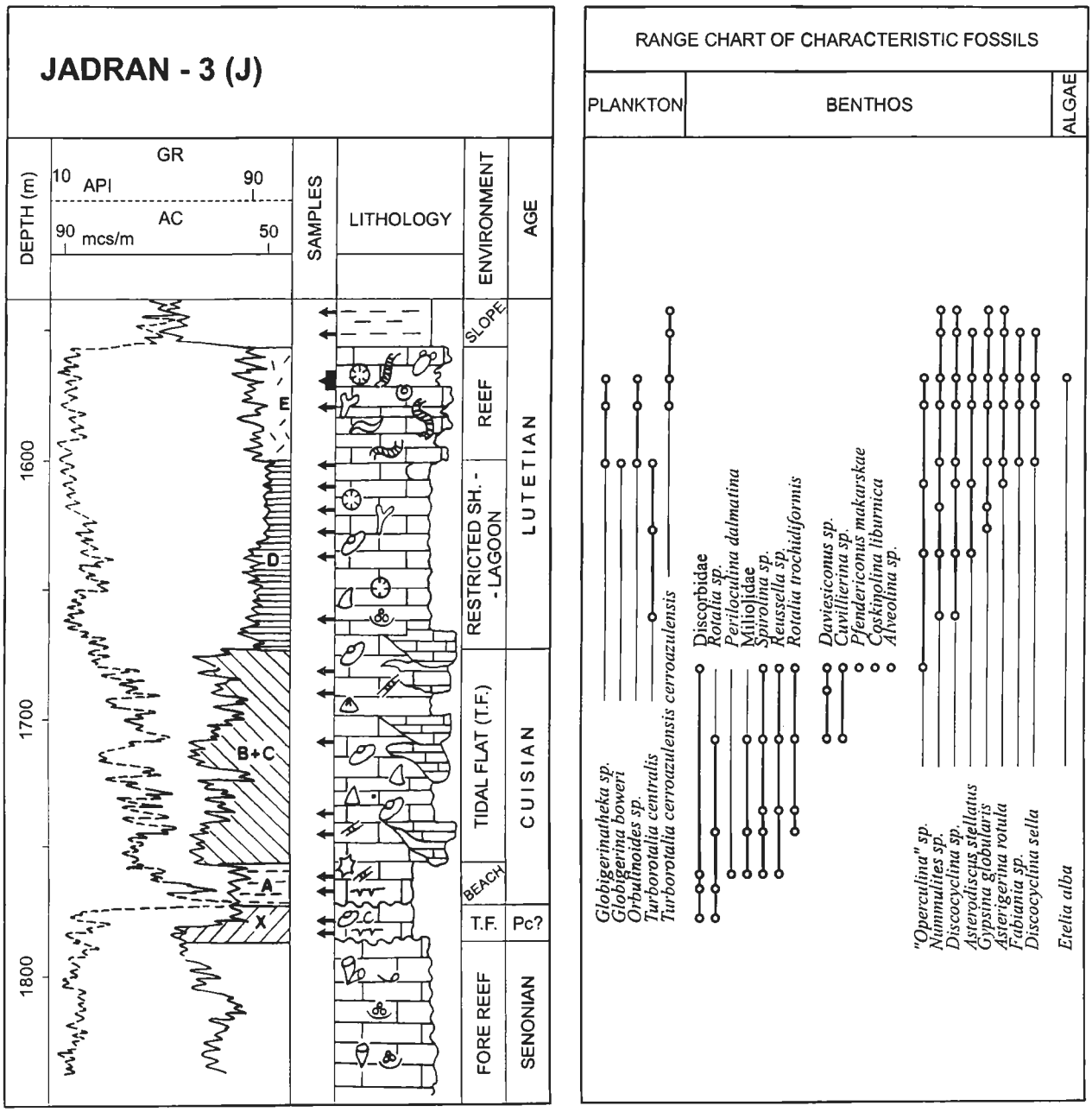


Fig. 10: Sequence of Paleogene strata in the deep well Jadran-3. (Plate 6, figs 3–5; Plate 11, figs 2, 7).

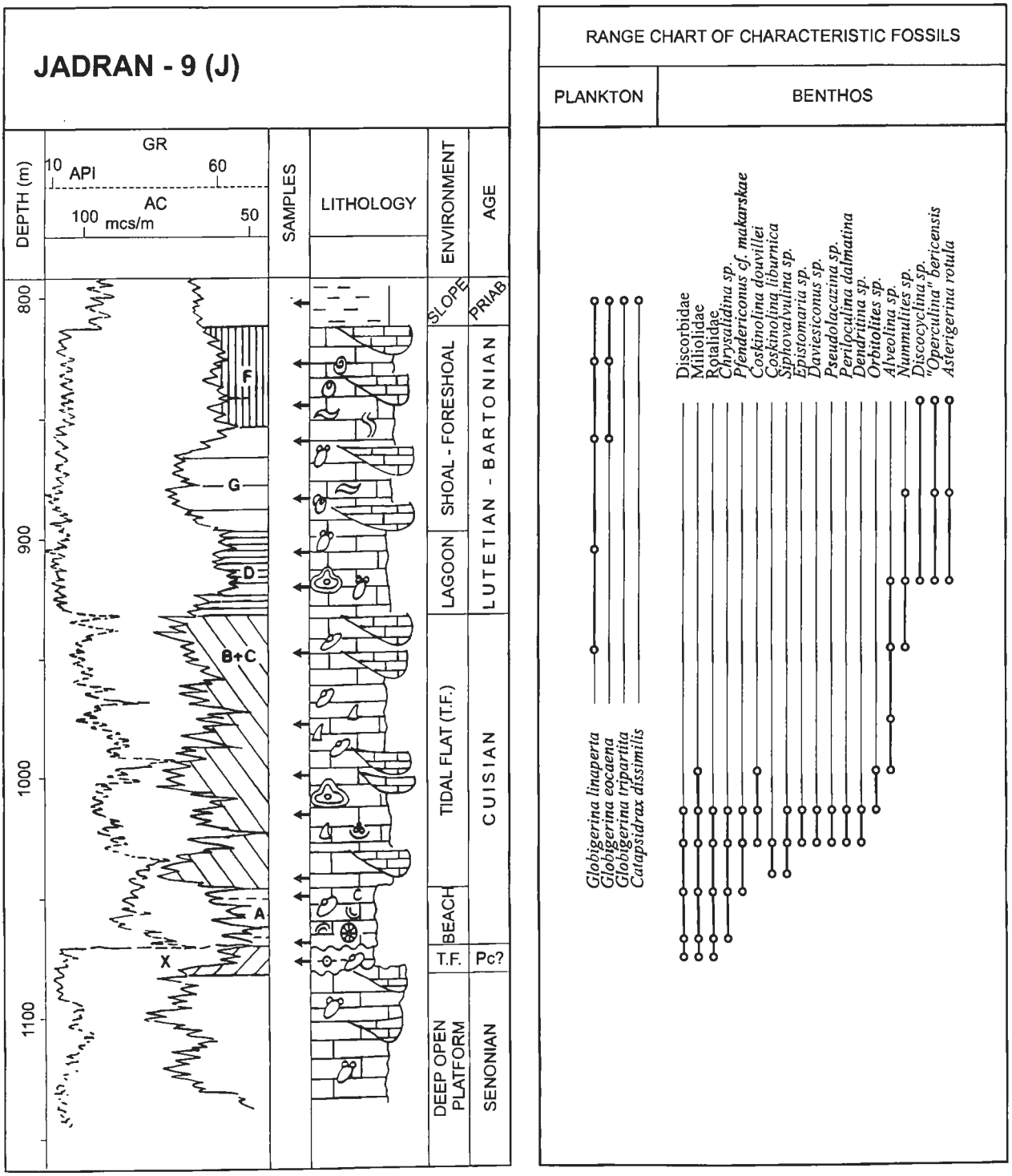


Fig. 11: Sequence of Paleogene strata in the deep well Jadran-9. (Plate 6, figs 6, 8–11; Plate 7, figs 1–6; Plate 8, fig. 1; Plate 11, figs 1, 5).

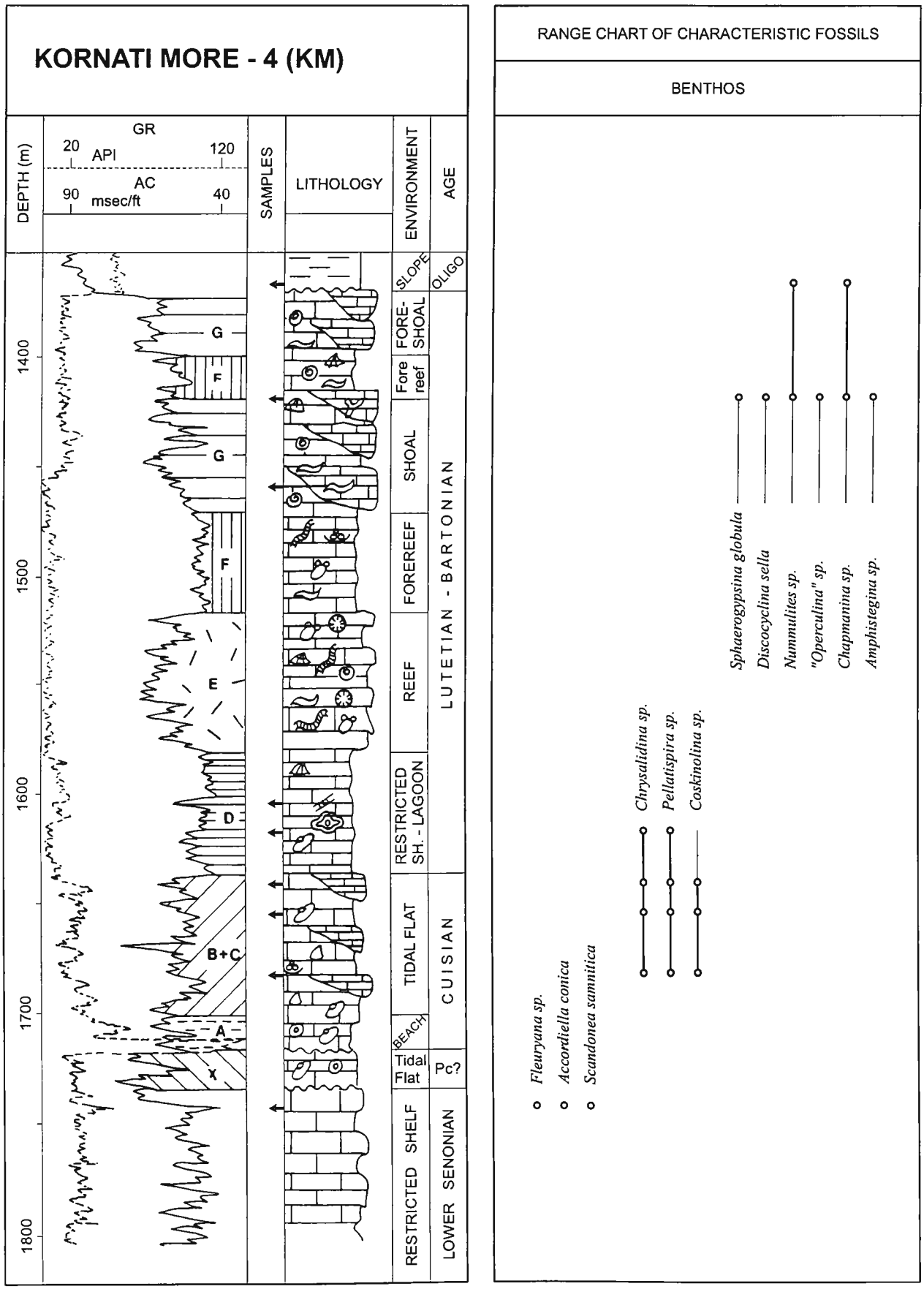


Fig. 12: Sequence of Paleogene strata in the deep well Kornati More-4.

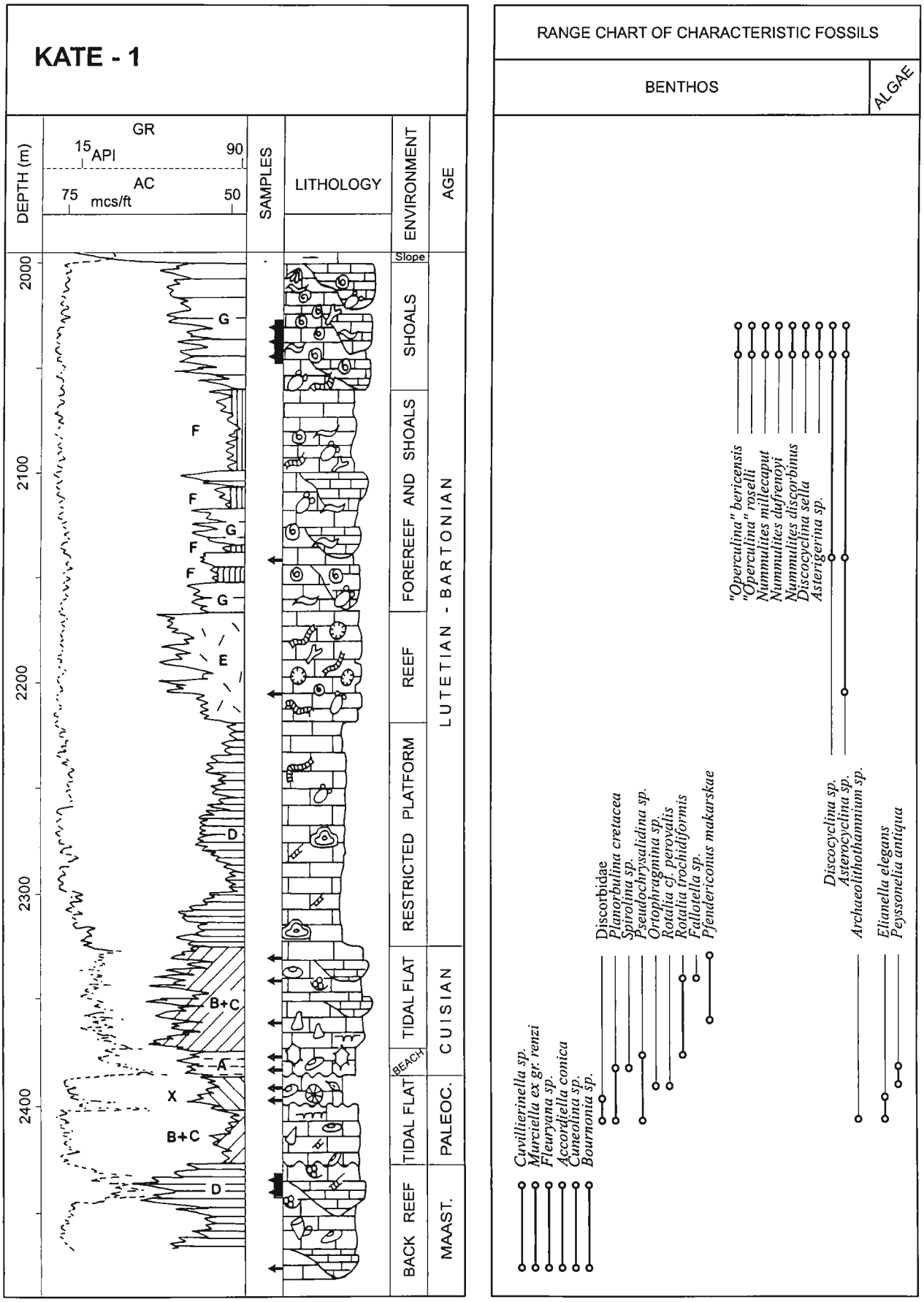


Fig. 13: Sequence of Paleogene strata in the deep well Kate-1. (Plate 1, figs 1–4; Plate 2, figs 1, 2; Plate 6, figs 1, 2, 7).

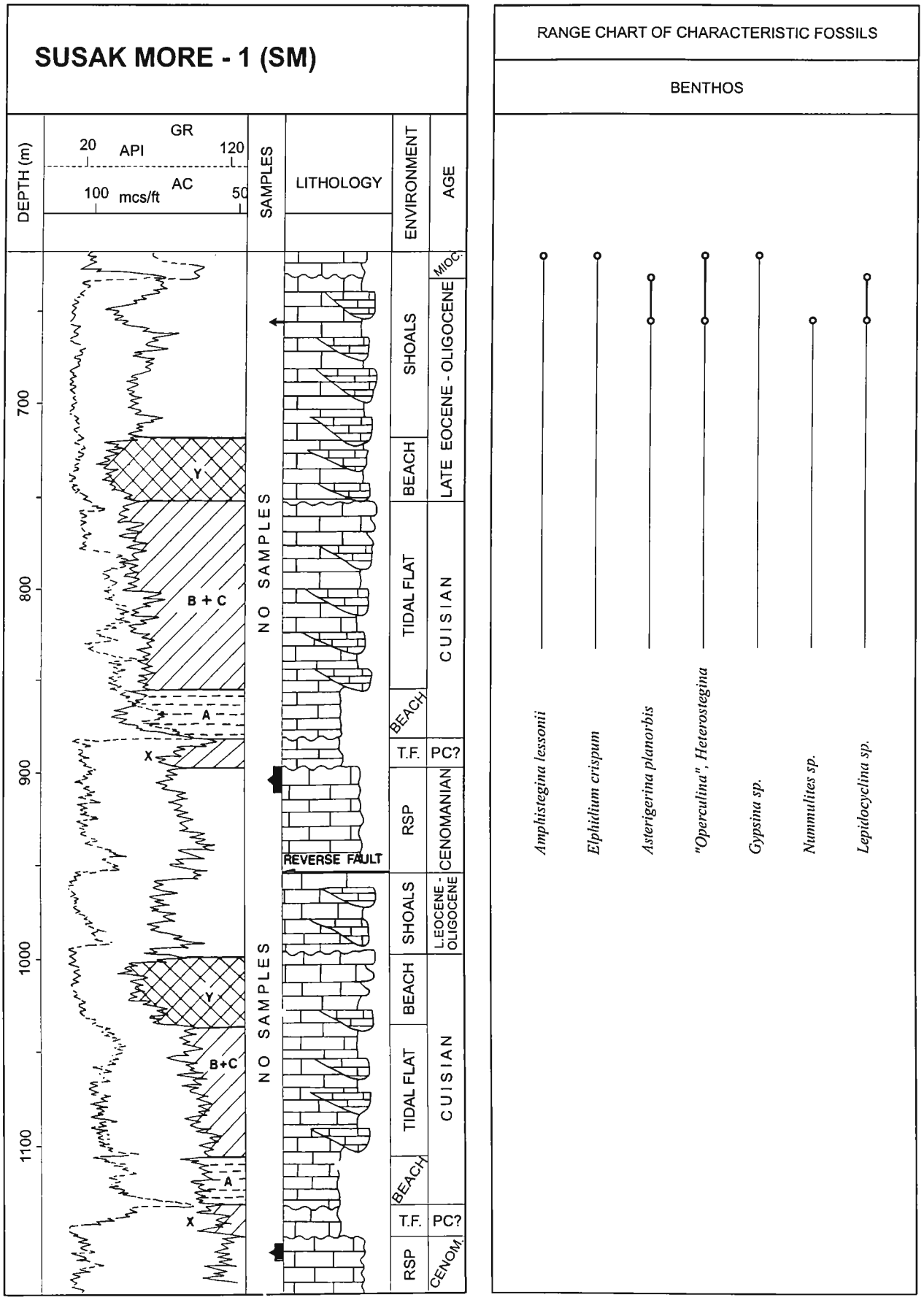


Fig. 14: Sequence of Paleogene strata in the deep well Susak More-1.

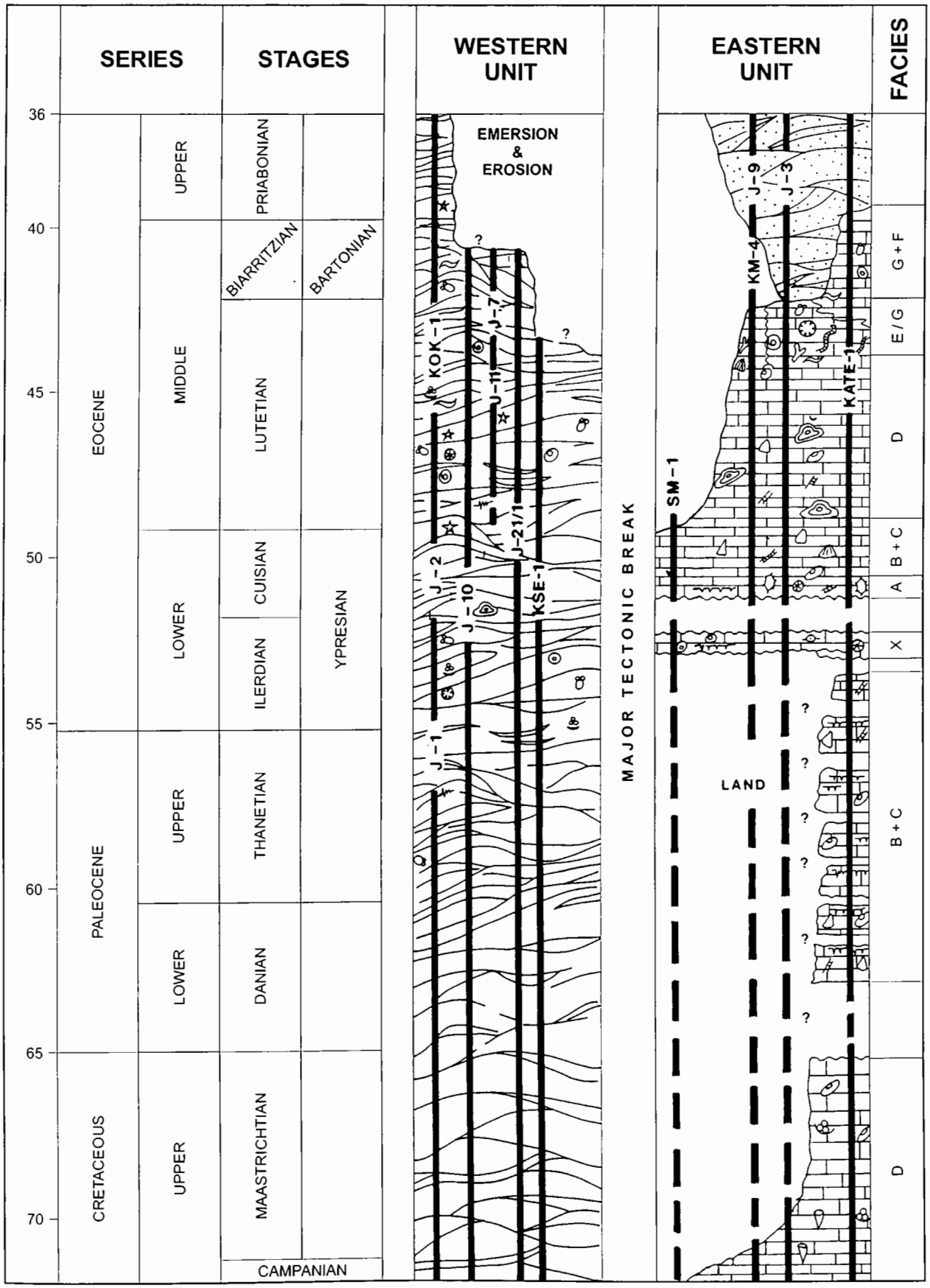


Fig. 15: Stratigraphic position of the drilled section in the Paleogene sequences.

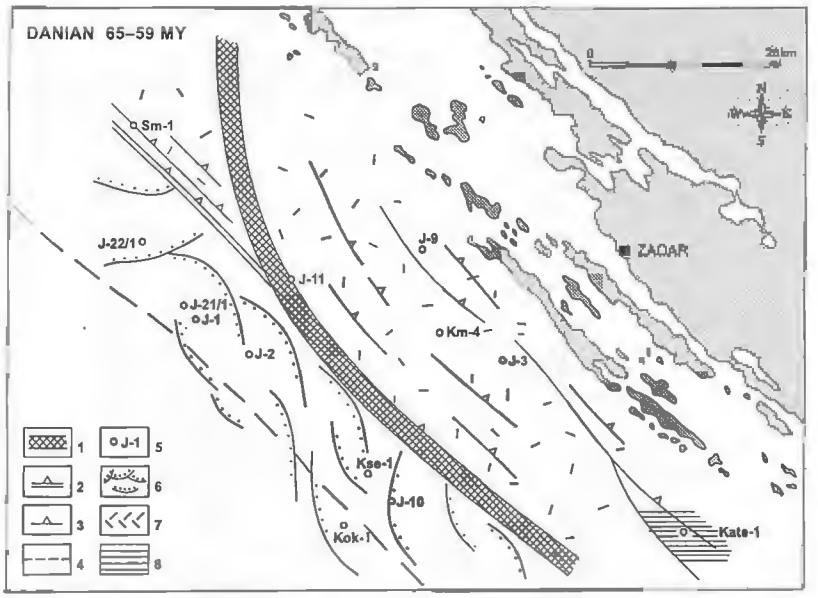


Fig. 16. Paleogeographic map of the Central Adriatic Area in Danian.
1. — Major tectonic break;
2. — Shallow reverse fault;
3. — Deep reverse fault;
4. — Western edge (limb) of The Central Adriatic Uplift;
5. — Well location;
6. — Slope;
7. — Emerged area, land;
8. — Low energy supratidal-tidal flat.

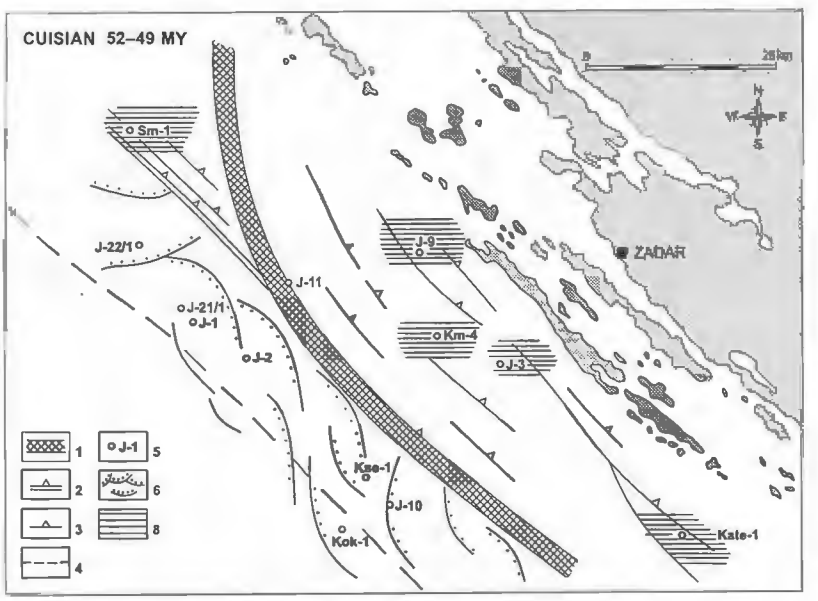


Fig. 17: Paleogeographic map of the Central Adriatic Area in Cuisian.
1. — Major tectonic break;
2. — Shallow reverse fault;
3. — Deep reverse fault;
4. — Western edge (limb) of The Central Adriatic Uplift;
5. — Well location;
6. — Slope;
8. — Low energy supratidal-tidal flat.

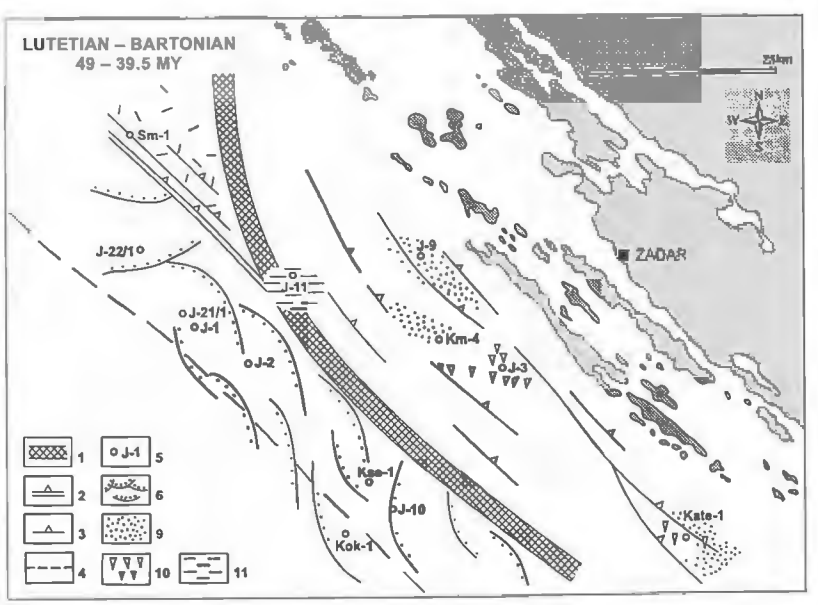


Fig. 18: Paleogeographic map of the Central Adriatic Area in Lutetian and Bartonian.
1. — Major tectonic break;
2. — Shallow reverse fault;
3. — Deep reverse fault;
4. — Western edge (limb) of The Central Adriatic Uplift;
5. — Well location;
6. — Slope;
9. — Shoals;
10. — Reef-fore reef;
11. — Basin floor.

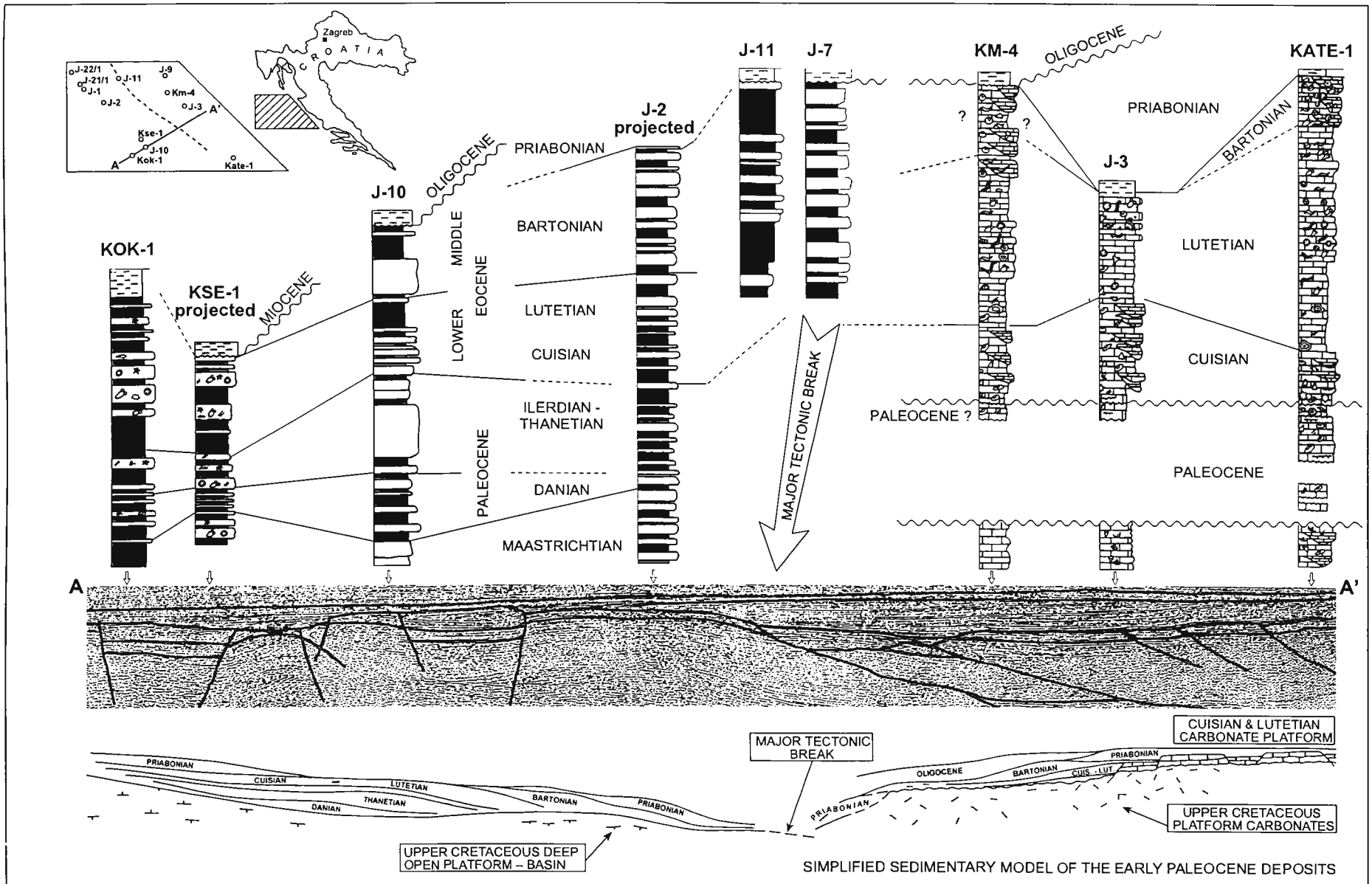
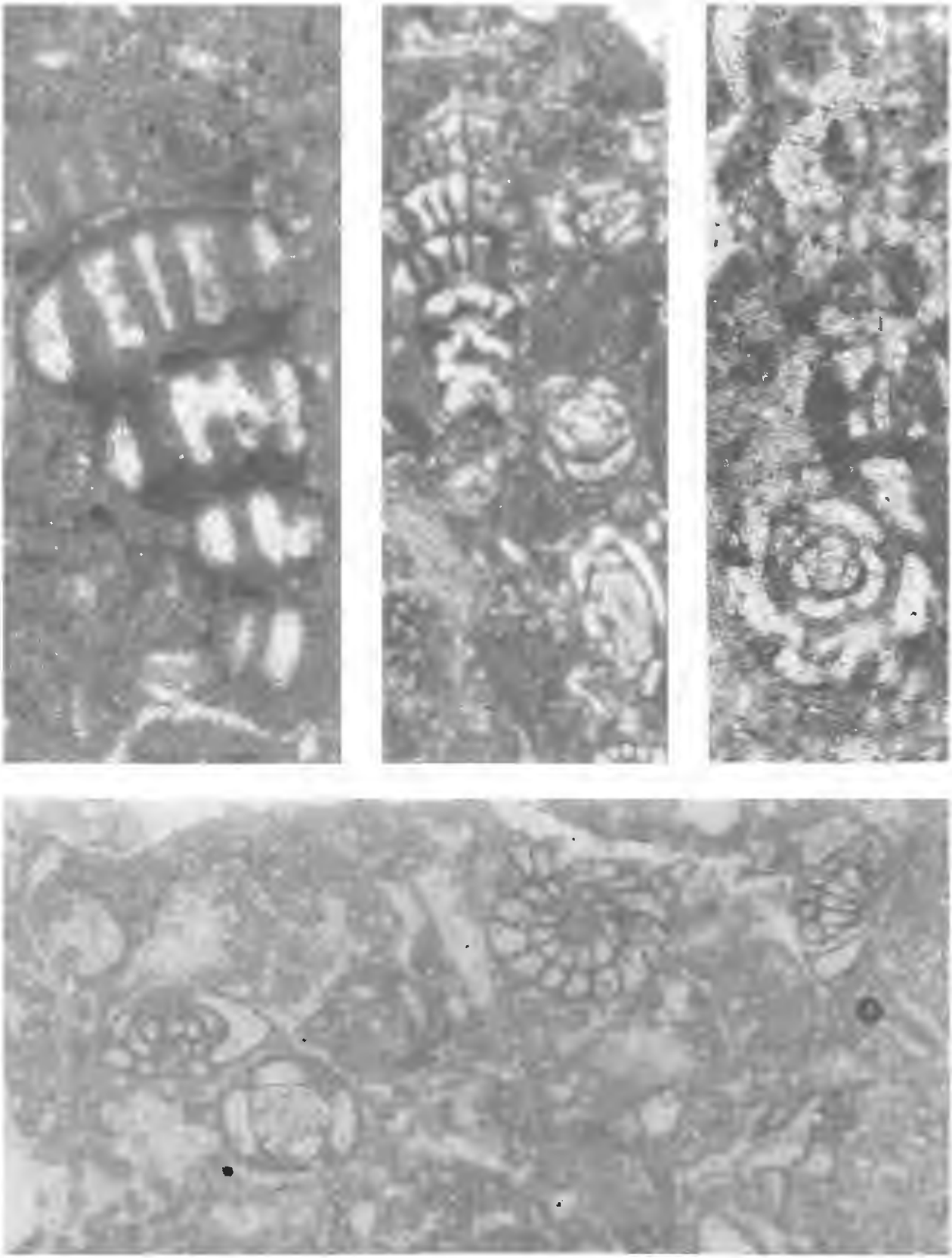
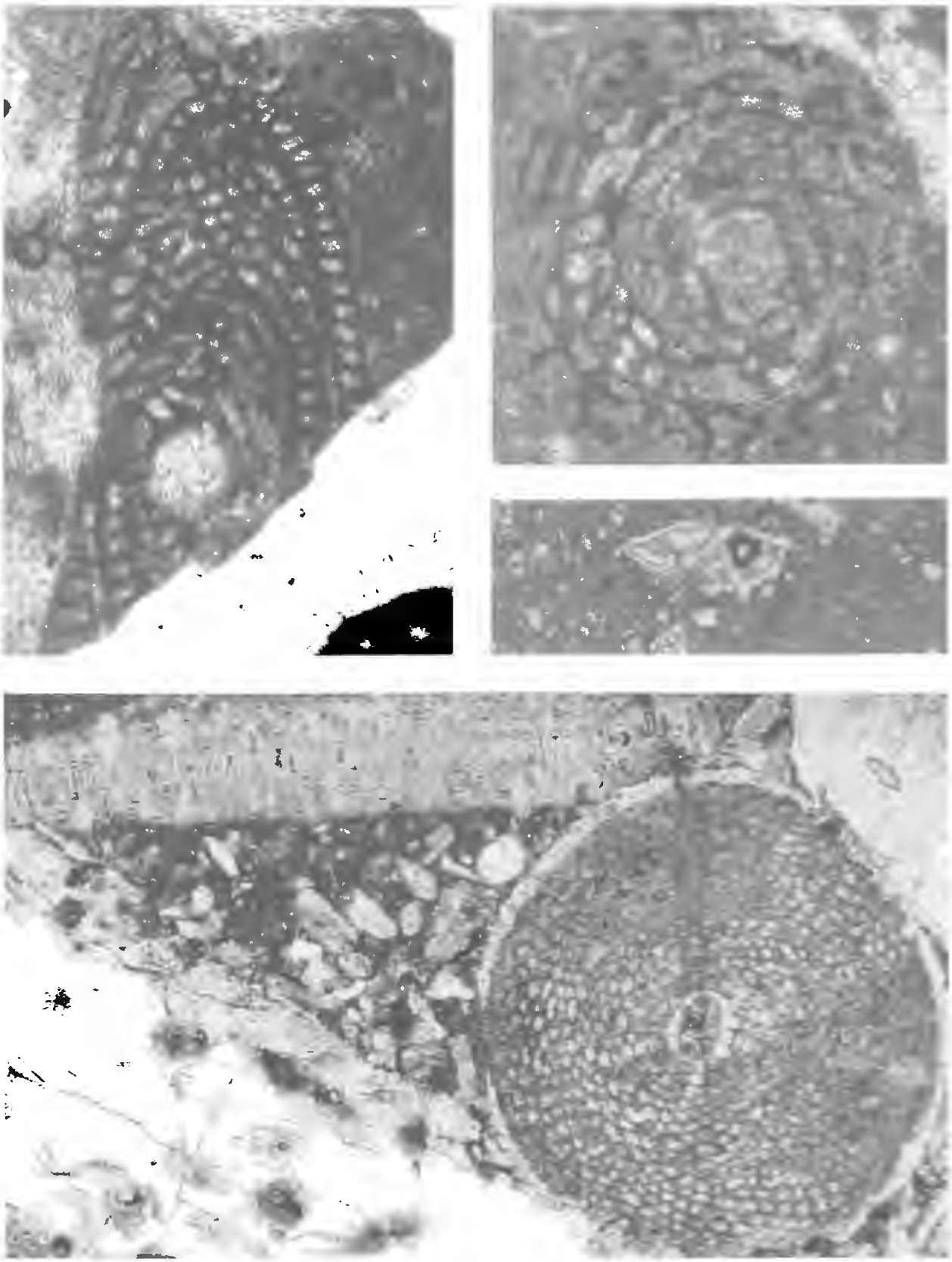


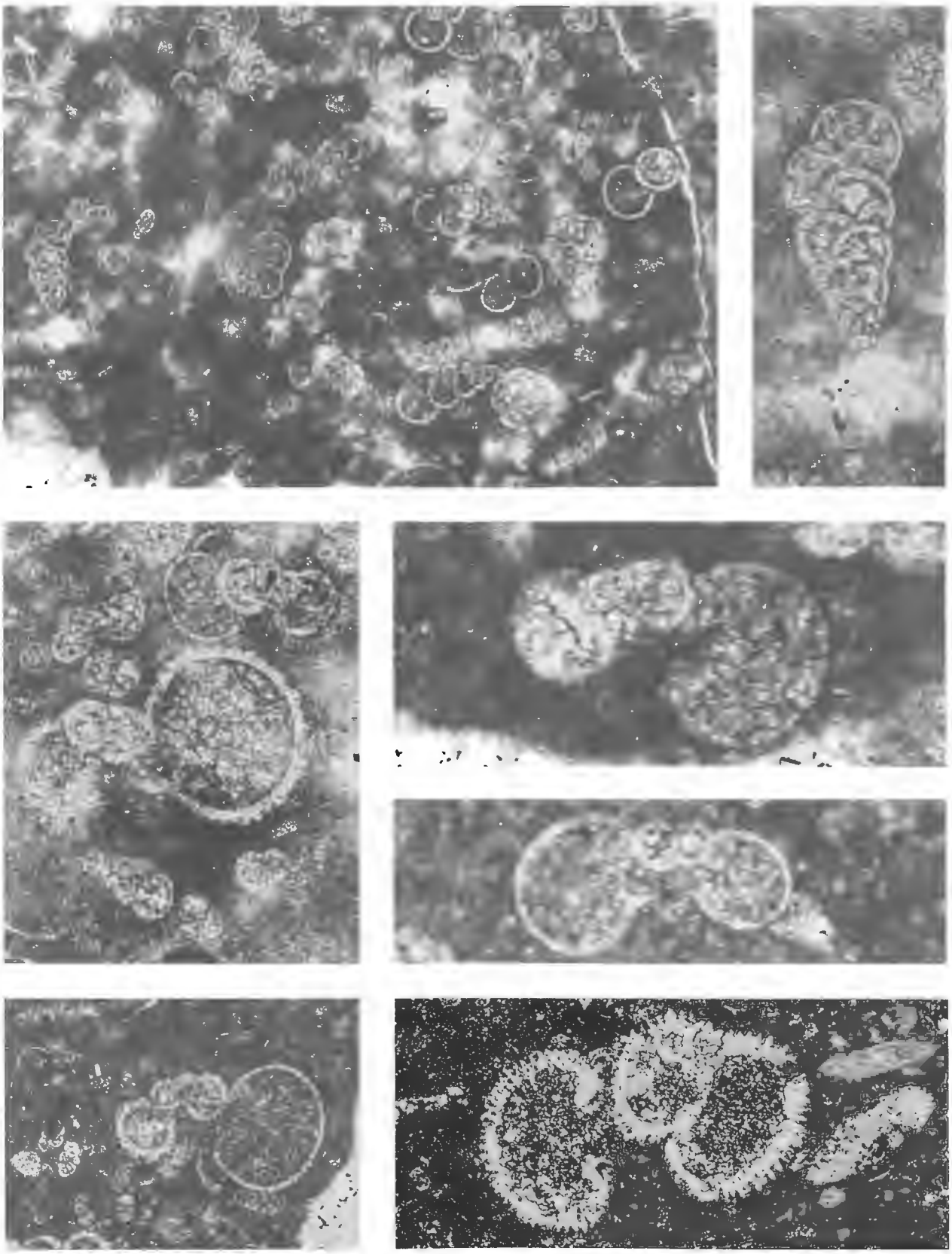
Fig. 19: Facies distribution and tectonic display.



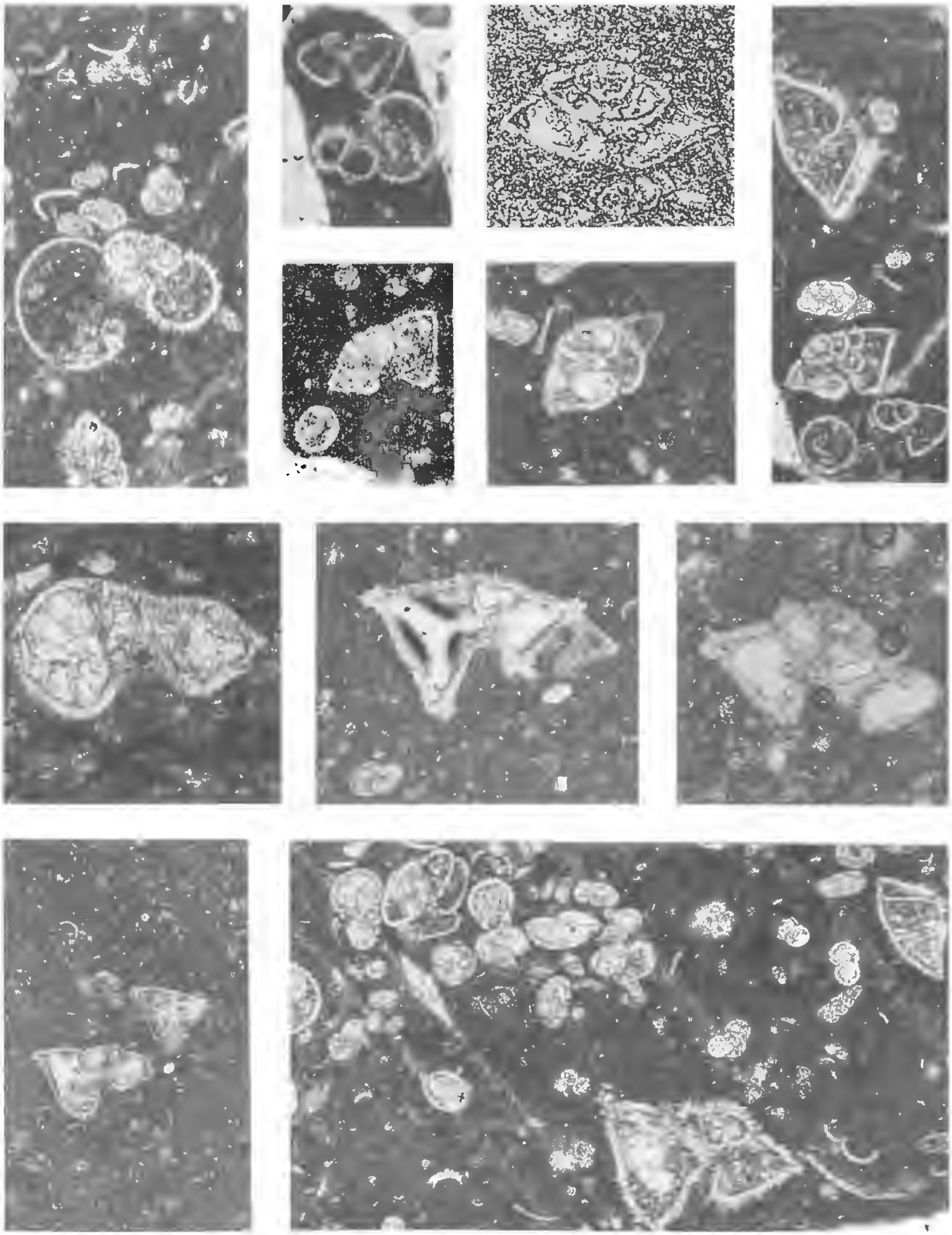
Figs 1–4: 1 *Cuvillierinella* sp., Kate-1, 2438 m, × 100, **2** *Cuvillierinella* sp., Kate-1, 2438 m, × 100, **3** *Cuvillierinella* sp., Kate-1, 2427 m, × 100, 4 *Fleuryana adriatica* De Castro, Drobne, Gušić, Miliolidae, Kate-1, 2438 m, × 30. **Age:** Maastrichtian.



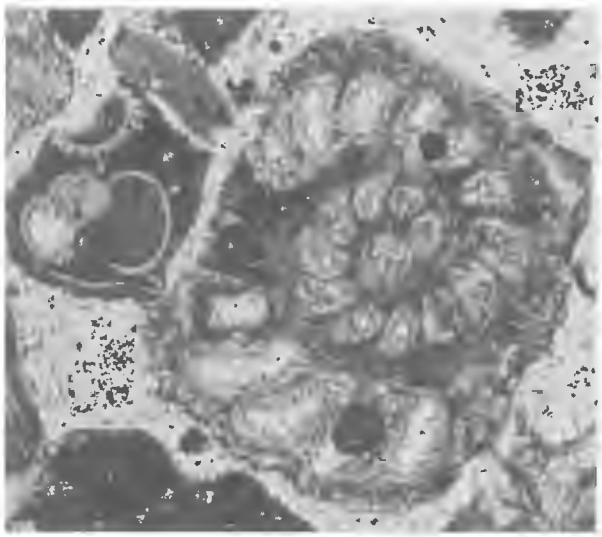
Figs 1–4: 1 *Murciella ex* gr. *renzi,* Fleury, Kate-1, 2421 m, × 100, **2** *Murciella ex* gr. *renzi,* Fleury, Kate-1, 2438 m, × 100, **3** *Globotruncana* sp., Jadran-2, 1950 m, × 100, **4** *Orbitoides media* (D'Archiac) and rudist remains, Jadran-2, 1925-192 m, × 30.
Age: Maastrichtian.

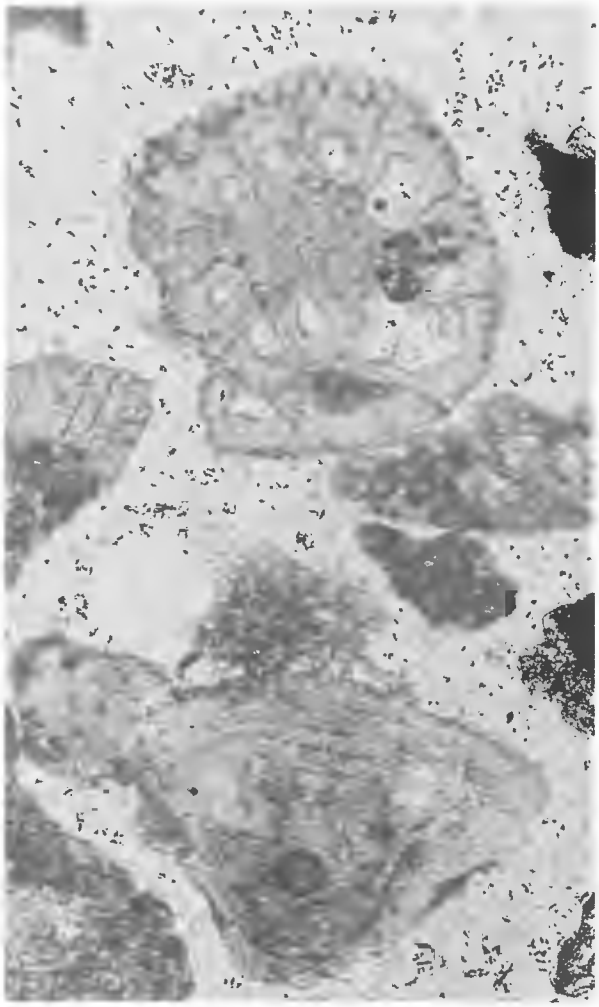


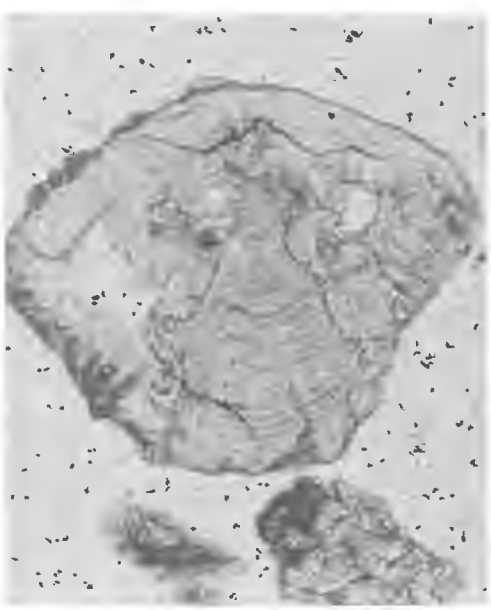
Figs 1–7: **1** microfacies, Koraljka-1, 2450 m, × 100, **2** *Chiloguembelina* sp., Koraljka-1, 2450 m, × 250, **3** *Morozovella ex gr. pseudobulloides* (Plummer), Koraljka-1, 2450 m, × 250, **4** *Planorotalites.* cf. *compressa* (Plummer), Koraljka-1, 2450 m, × 250, **5** P. cf. *compressa* (Plummer), Koraljka-1, 2450 m, × 250, **6** *M.* cf. *pseudobulloides* (Plummer), Koraljka-1, 2400 m, × 100, **7** Planktonic foraminifera, Jadran-1, 1572 m, × 100. **Age:** 1 Lowermost Danian; 2–7 Danian.



Figs 1–11: 1 Globigerinds, Koraljka-1, 2430 m, × 100, **2** *Morozovella angulata* (White) and *Globigerina triloculinoides* Plummer, Koraljka-1, 2430 m, × 100, **3** *M. angulata* (White), Koraljka-1, 2395 m, × 100, **4** *Planorotalites* cf. *pusilla pusilla* (Bolli), Jadran-2, 1900 m, × 250, **5** *P.* cf. *pusilla pusilla* (Bolli), Jadran-2, 1890 m, × 100, **6** *Morozovella* sp. Koraljka-1, 2430 m, × 100, **7** *Planorotalites* cf. *chapmani* (Parr), Jadran-22/1, 2226 m, × 100, **8** *Morozovella* ex gr. *velascoensis* (Cushman), Jadran-2, 1890 m, × 100, **9** *Morozovella* sp., Jadran-1, 1572 m, × 100, **10** *M.* ex gr. *aequa* (Cushman & Renz), Jadran-2, 1890 m, × 100, **11** *M.* ex gr. *velascoensis* (Cushman), Koraljka-1, 2430 m, × 100. **Age**: 1–7, 9–10 Thanetian; 8, 10 Thanetian-Ilerdian.

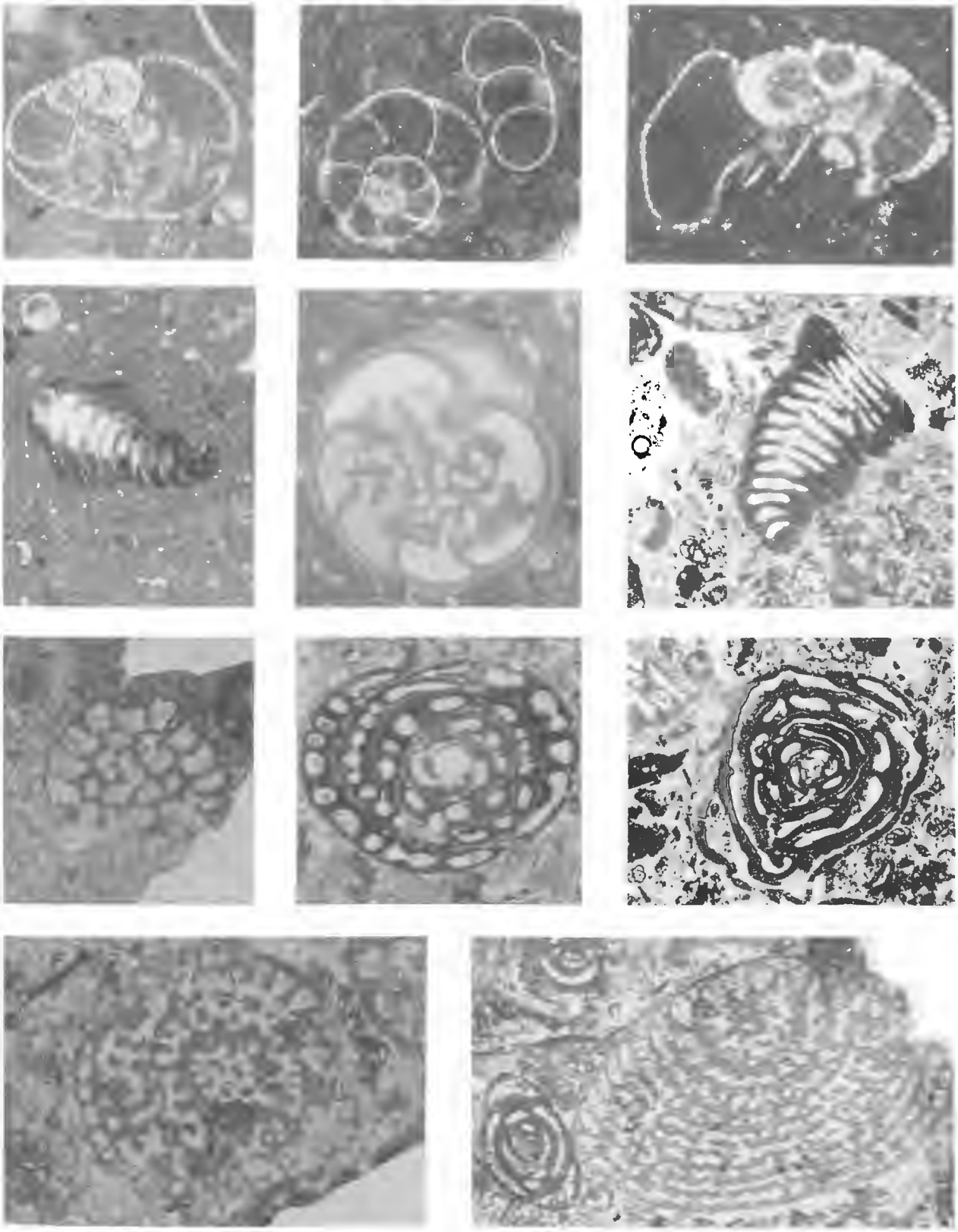




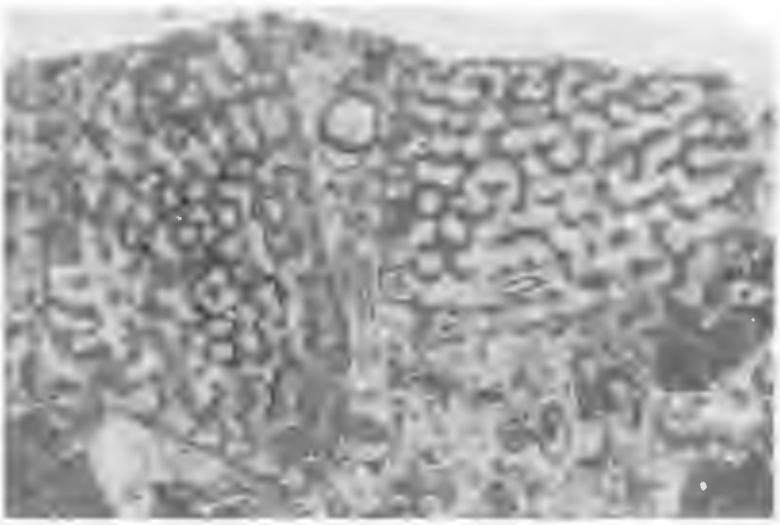


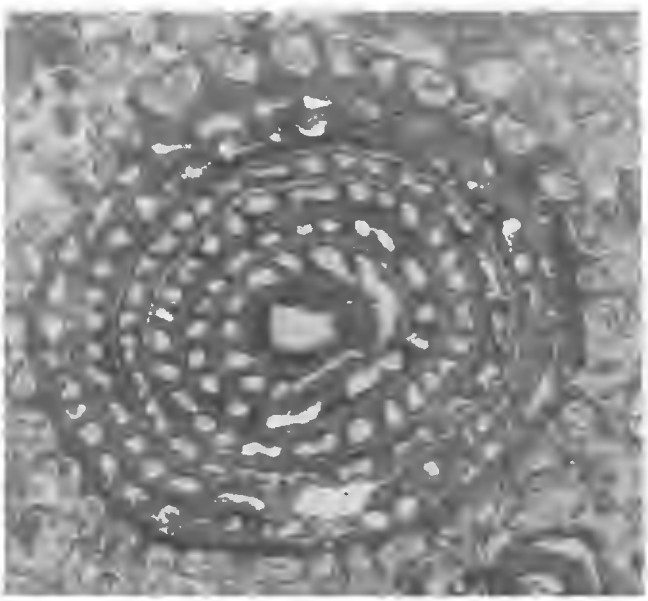
Figs 1–5: **1** *Miscellanea* sp. and *Globignerina triloculinoides* Plummer, Ksenija-1, 1370 m, × 100, **2** *Smoutina* sp., Koraljka-1, 2420 m, × 100, **3** *Kathina* sp., Jadran-2, 1950 m, × 100, **4** *Smoutina* sp., Koraljka-1, 2420 m, × 100, **5** *Smoutina* sp., Koraljka-1, 2445 m, × 100.

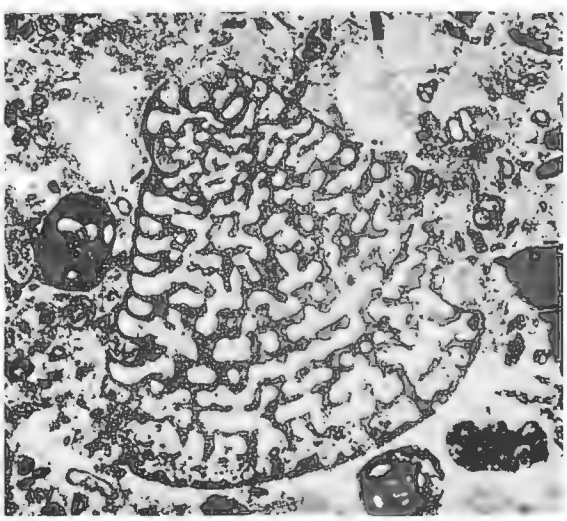
Age: 1–5 Thanetian.

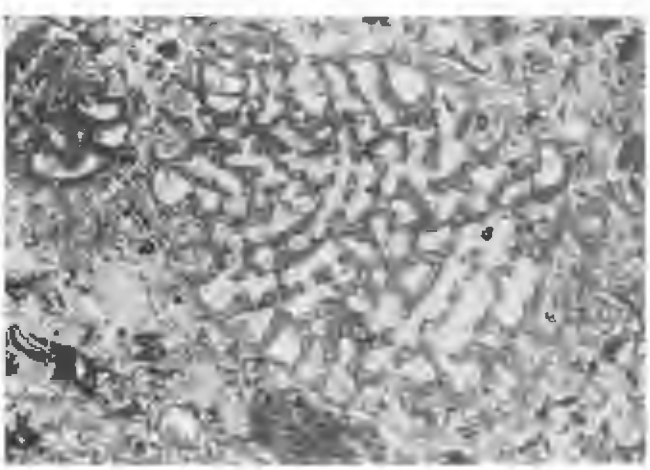


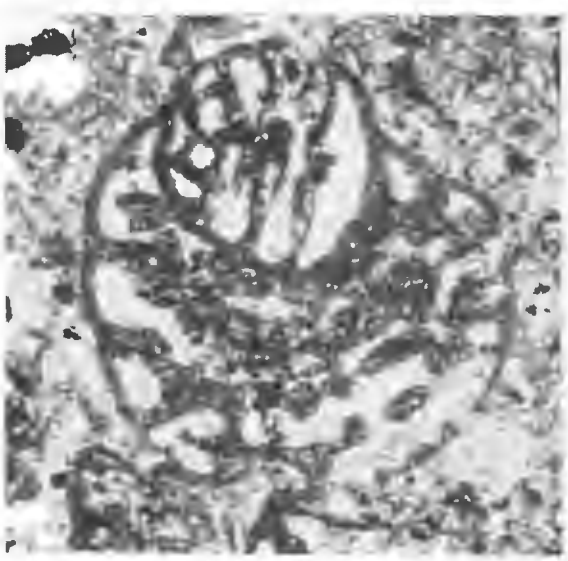
Figs 1–11: 1 Rotalid foramimnifera, Kate-1, 2403 m, Thanetian, × 120, **2** Rotalid foramimnifera, Kate-1, 2373 m, Thanetian, × 120, **3** Rotalid foramimnifera, Jadran-3, 1764–1766 m, Lower Eocene, × 100, **4** *"Spirolina"* sp., Charophyta, Jadran-3, 1764–1766 m, Lower Eocene, × 30, **5** *Chrysalidina* sp., Jadran-3, 1760 m, Cuisian, × 40, **6** *"Spirolina"* sp., Jadran-9, 1029–1032 m, Lower Eocene (Cuisian), × 30, **7** *Daviesiconus* sp., Kate-1, 2346 m, Lower Eocene, × 35, **8** *Pseudolacazina* sp., Jadran-9, 1029–1032 m, Cuisian, × 30, **9** *Periloculina dalmatina* Drobne, Jadran-9, 1029–1032 m, Cuisian, × 25, **10** *Daviesiconus* sp., Jadran-9, 1029–1032 m, Cuisian, × 30, **11** *Daviesiconus* sp., Miliolidae, Jadran-9, 1029–1032, Cuisian, × 20. **Age:** Thanetian-Cuisian





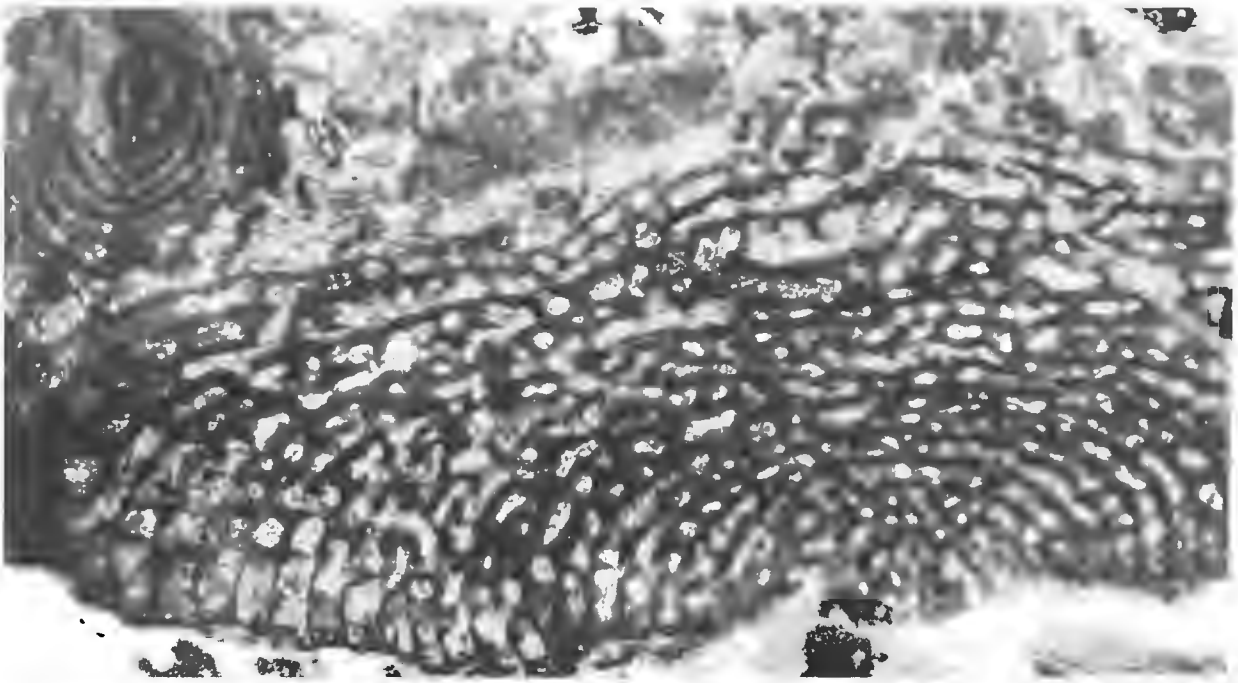


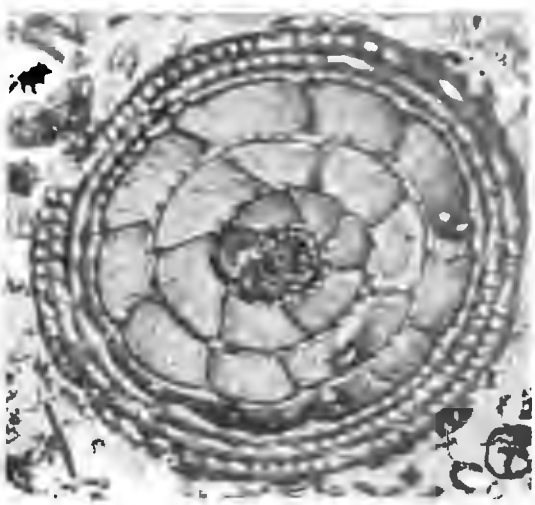


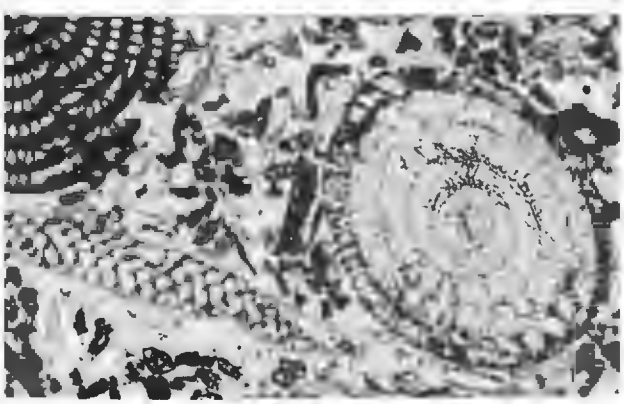


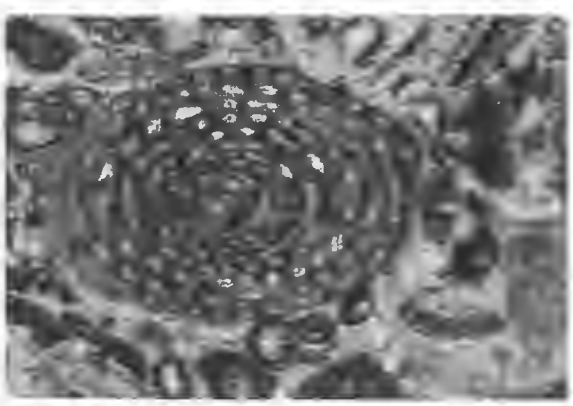
Figs 1–6: **1–2** *Daviesiconus* sp., Jadran-9, 1029–1032 m, × 30, **3** *Pseudolacazina* sp., Jadran-9, 1029–1032 m, × 30, **4–5** *Coskinolina liburnica Stache*, Jadran-9, 1029–1032 m, × 25, **6** *Pfendericonus makarskae* (Van Soest), Jadran-9, 1029–1032 m, × 30.

Age: Cuisian.

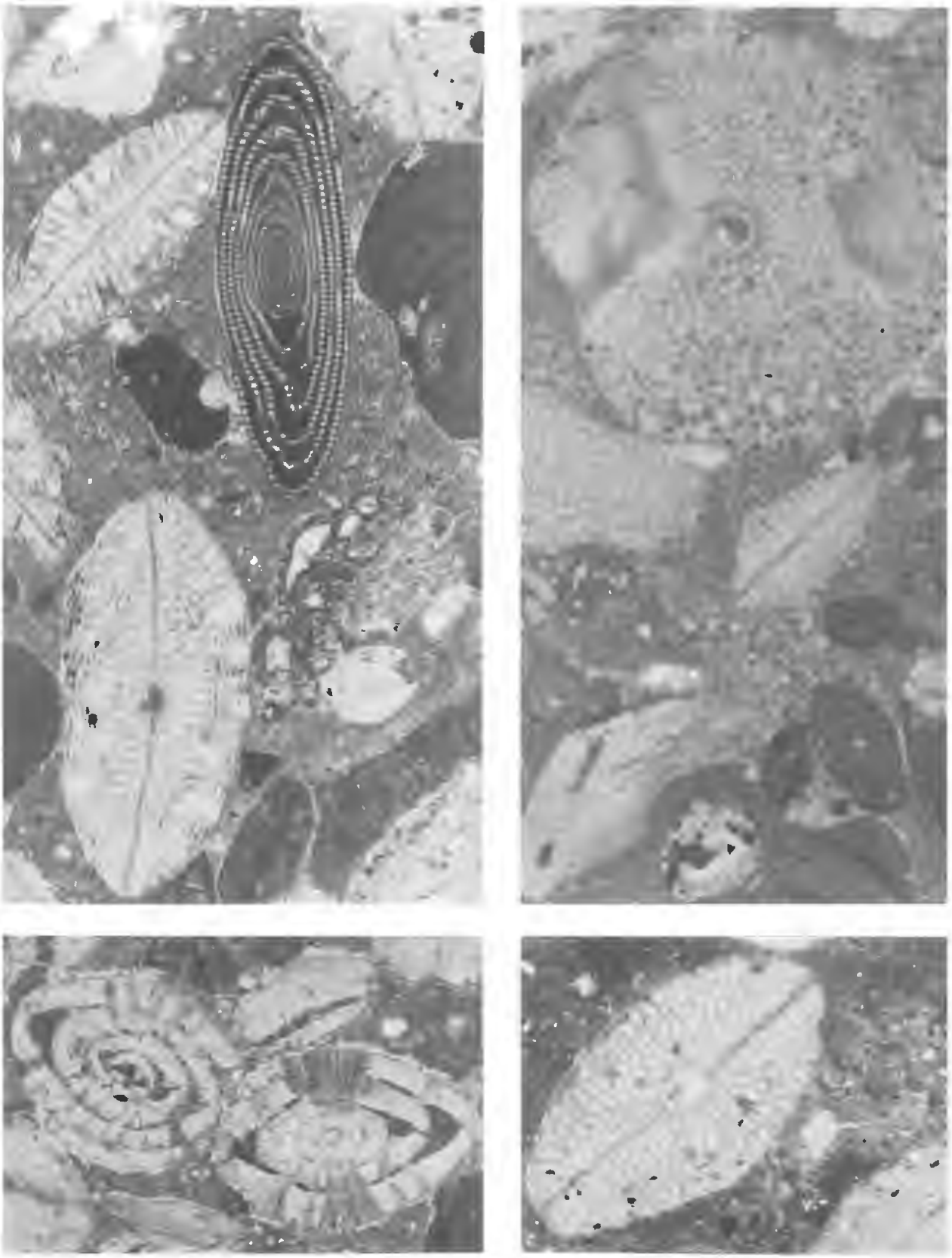




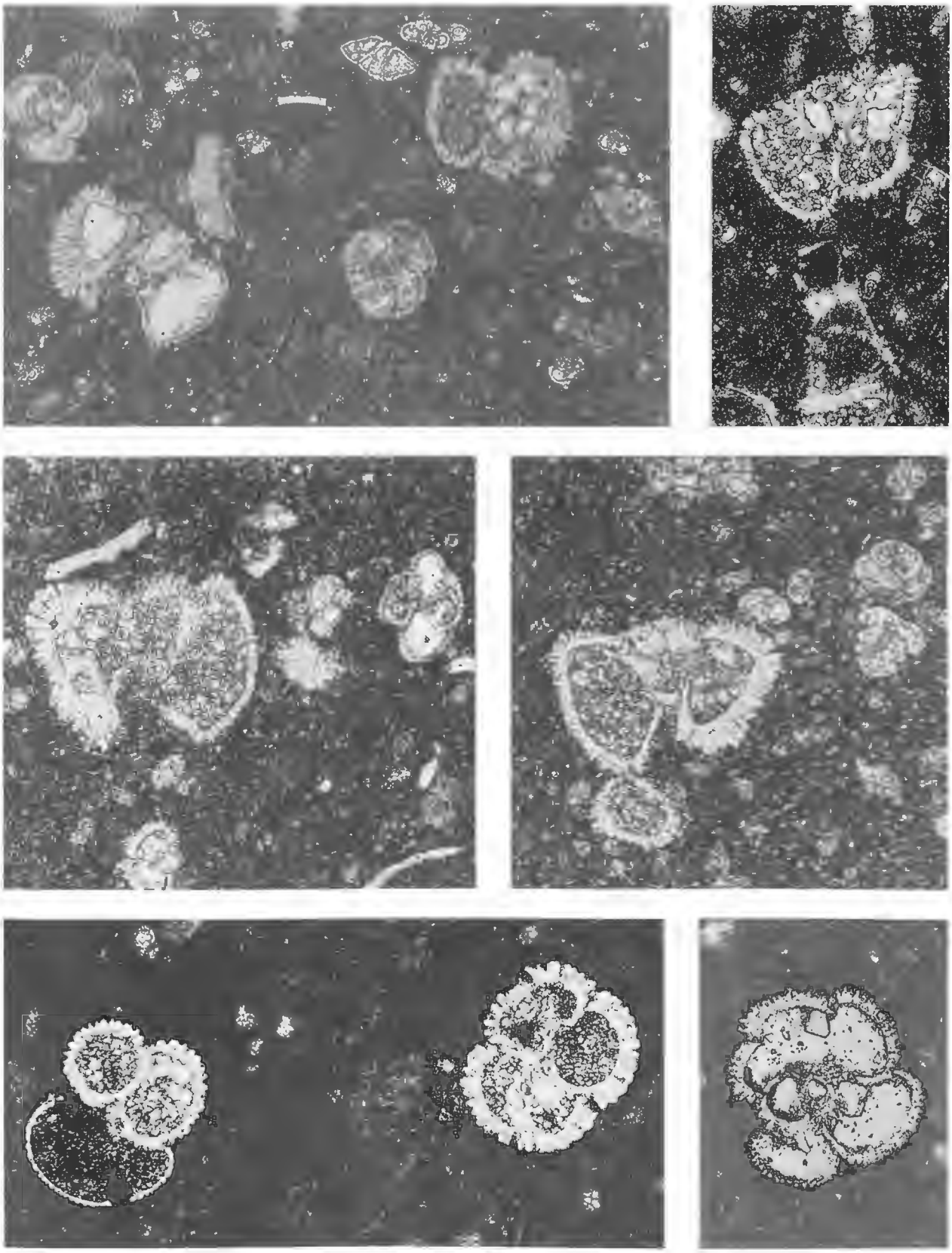




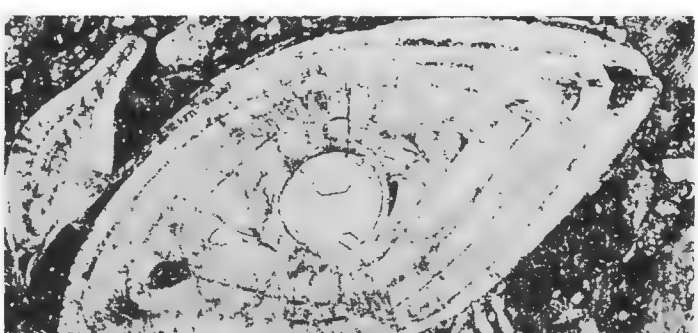
Figs 1–5: 1 *Coskinolina* cf. *douvillei* (Davies), Jadran-9, 1000 m, × 30, 2 *Alveolina* sp., Jadran 22/1, 1916–1918 m, × 25, 3 *Alveolina* cf. a*zzarolii* Drobne, Jadran 22/1, × 20, 4 *Nummulites* sp., *Orbitolites* sp., Jadran 22/1, 1916–1918 m, × 20, 5 *Alveolina* ex gr. *fusiformis,* Jadran-7, 1721 m, × 32. **Age:** Cuisian.

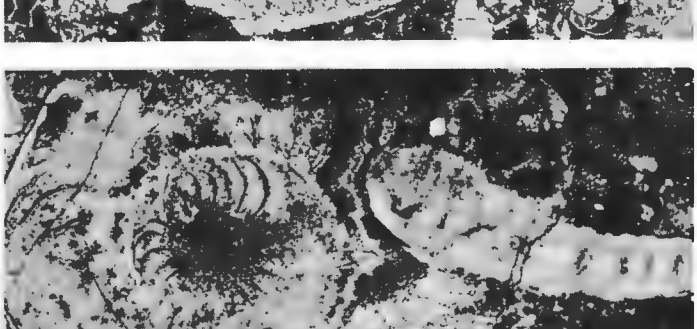


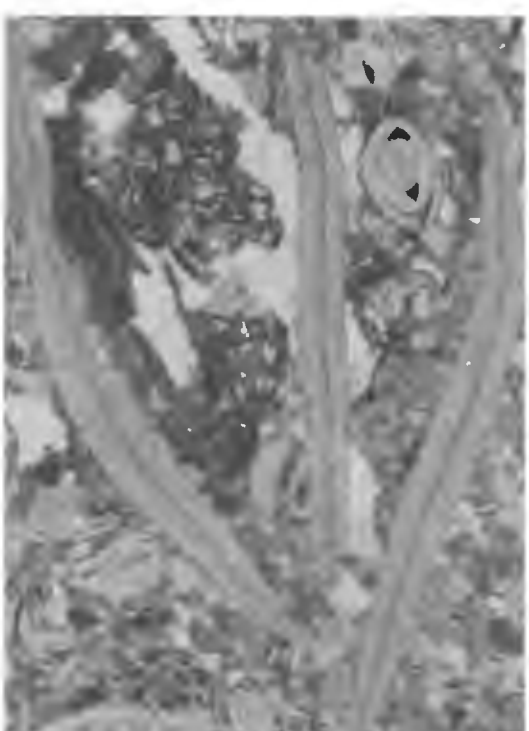
Figs 1–4: **1** *Orbitoclypeus* sp., *Discocyclina* sp., *Alveolina* sp., *Gypsina* sp., **2** *Discocyclina nummulitica* (Guembel), **3** *Nummulites* sp., **4** *Discocyclina* sp. **Age:** Lutetian; all: × 30; all: Jadran-22/1, 1916–1918 m.

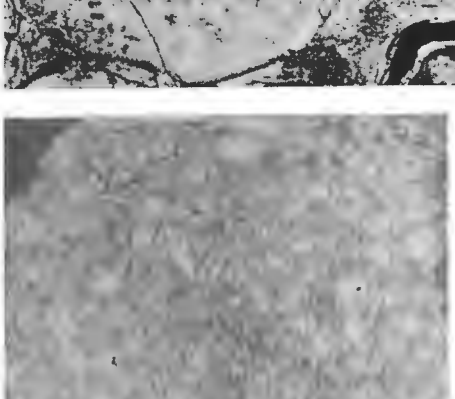


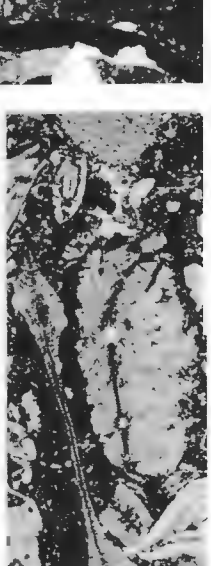
Figs 1–6: **1** *Acarinina* sp., Jadran-2, 1824 m, **2** Truncorotaloides ex gr. *toplilensis* (Cushman), Jadran-2, 1824 m, **3** *A.* ex gr. *bullbrooki* (Bolli), Jadran-2, 1824 m, **4** *A.* ex gr. *bullbrooki* (Bolli), Jadran-2, 1824 m, **5** ?*Globigerinatheka* sp., Koraljka-1, 2254–2258 m, **6** ?*Globigerinatheka* sp., Jadran-2, 1824 m.
Age: Lutetian; all: × 100.

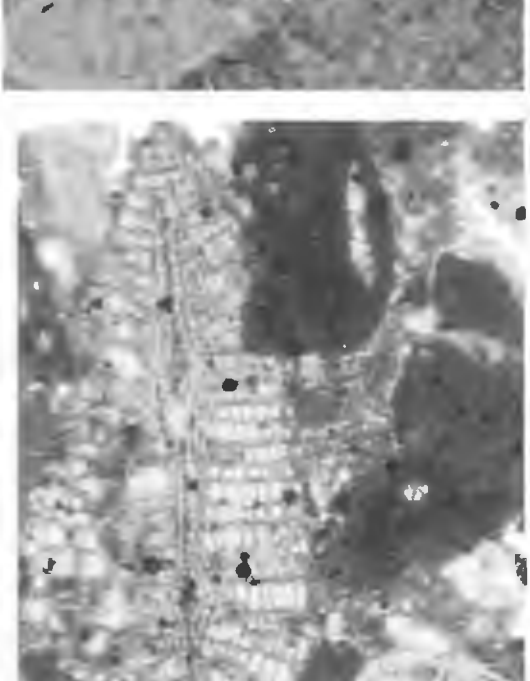


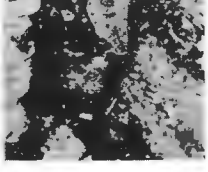




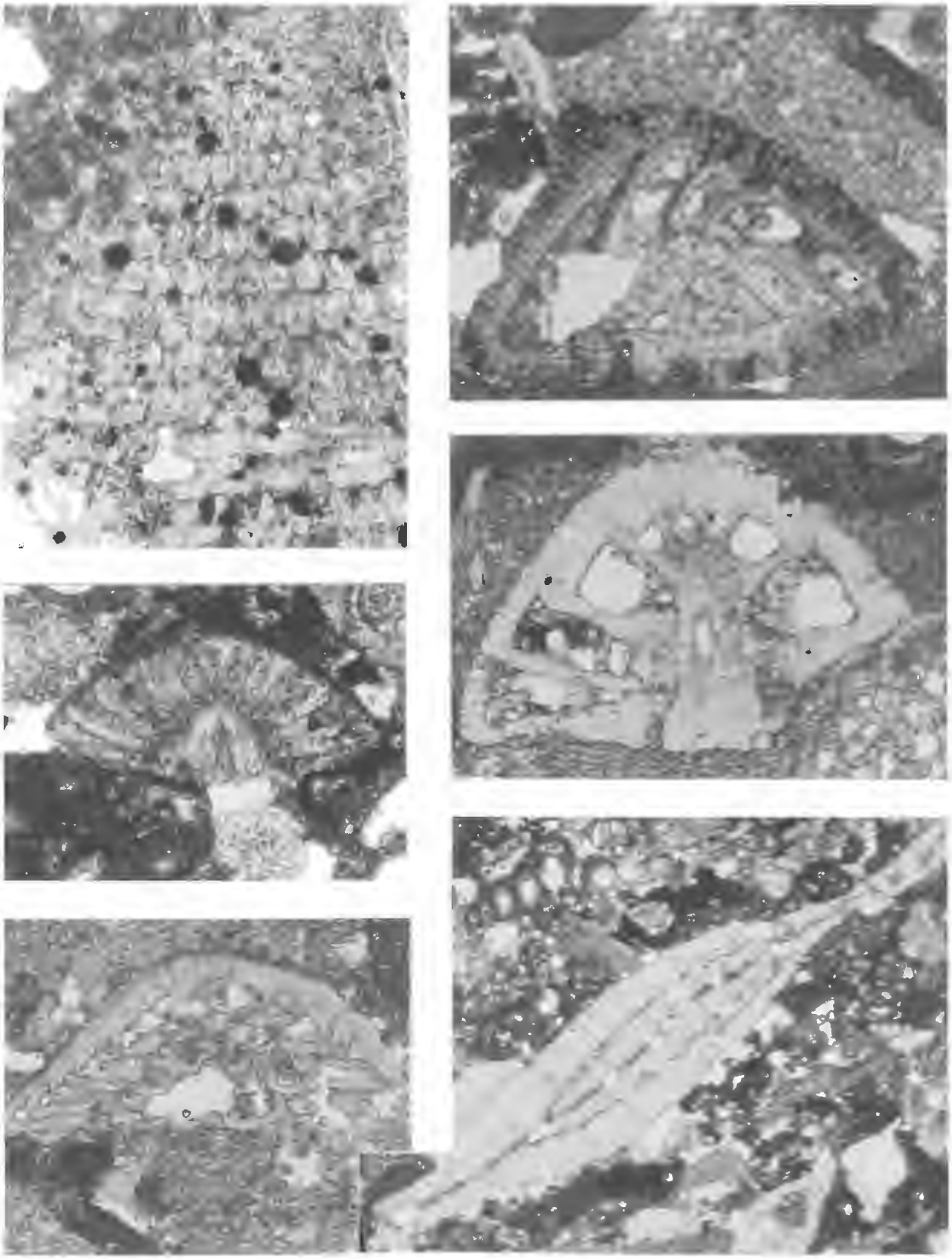




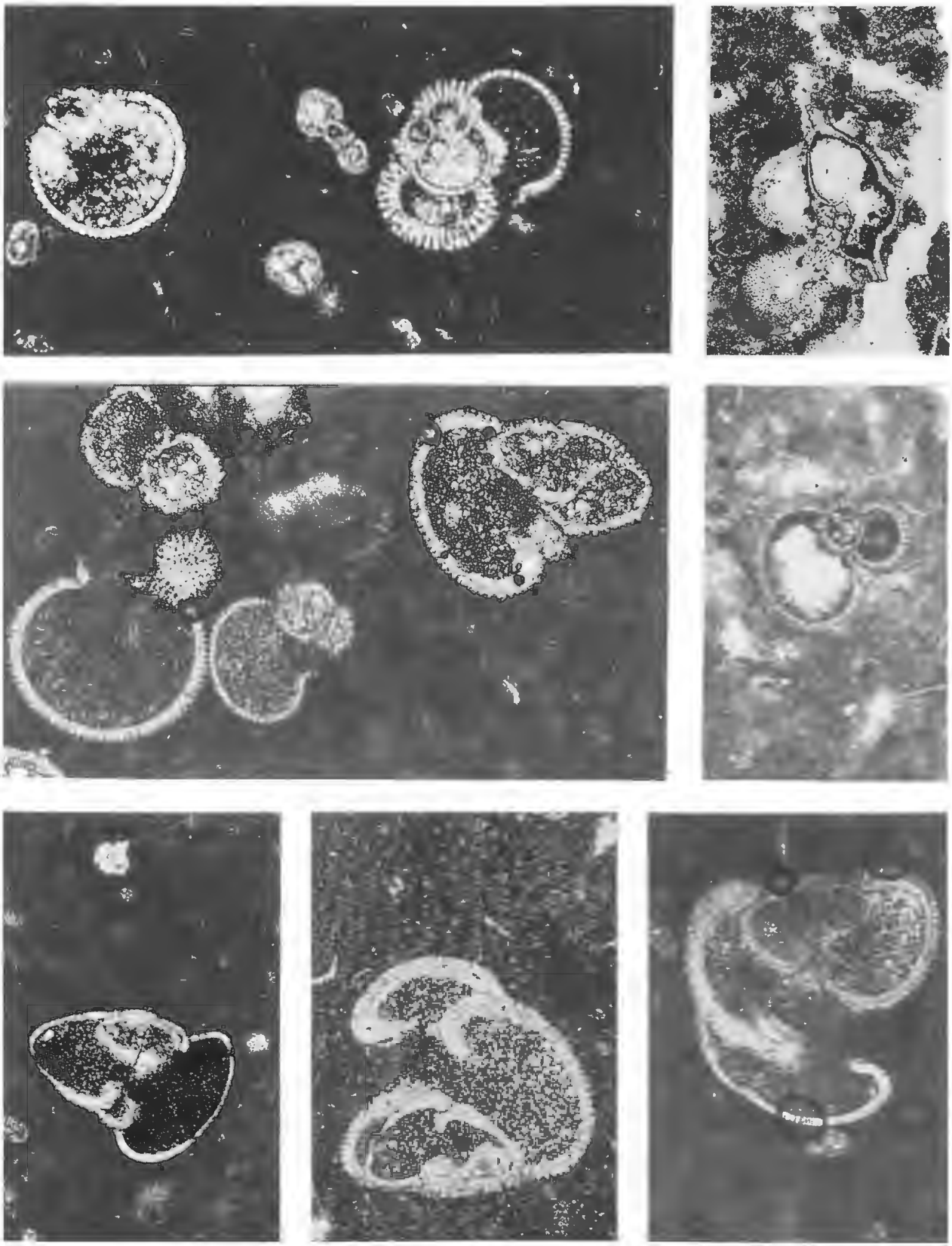




Figs 1–8: **1** *Nummulites* sp., *"Operculina" bericensis* Oppenheim, Jadran-9, 915–929 m, Lutetian, × 25, **2** *"Operculina" bericensis* Oppenheim, Jadran-3, 1580 m, Lutetian, × 25, **3** *Asterocyclina* ex gr. *radians* d'Archiac, *"Operculina"* sp., Jadran-9, 915–929 m, Lutetian, × 25, **4** *Gypsina* sp., Jadran-7, 1728–1731.8 m, Middle Eocene, × 25, **5** *Discocyclina sella* d'Archiac, Jadran-9, 915–929 m, Lutetian, × 15, **6** Conical imperforate foraminifera, Jadran-22/1, 1817–1823 m, Bartonian-Priabonian, × 40, **7** *Sphaerogypsina globula* (Reuss), Jadran-3, 1505–1505.7 m, Lutetian, × 20, **8** *Asterocyclina* sp., *Asterodiscus stellatus* (Guembel), Jadran-22/1, 1817–1823 m, Middle Eocene, × 40. **Age:** Lutetian-Priabonian.

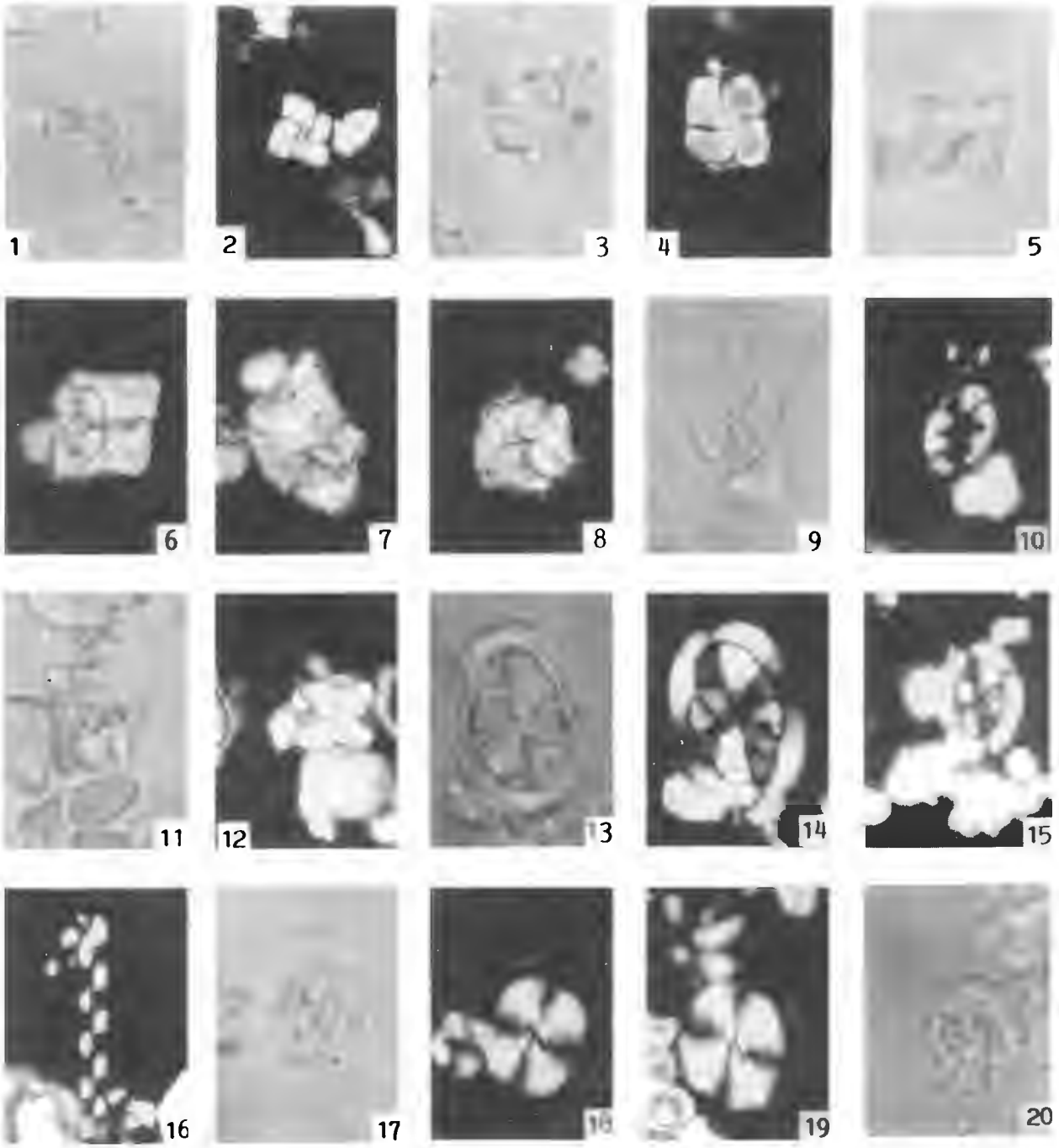


Figs 1–6: **1** *Chapmanina* sp., Jadran 22/1, 1817–1823, × 100, **2** *Halkyardia minima* (Liebus), Jadran-21/1, 1258–1265 m, × 100, **3** Conical imperforate foraminifera, Jadran-21/1, 1258–1265 m, × 100, **4** *Heterolepa* sp., *Gypsina mastelensis* Bursch, Jadran-21/1, 1258–1265 m, × 100, **5** *Rotalia trochidiformis* Lamarck, Jadran 21/1, 1258–1265 m, × 100, **6** *Heterostegina reticulata* Ruetimeyer, Jadran 21/1, 1258–1265 m, × 40. **Age:** Priabonian.



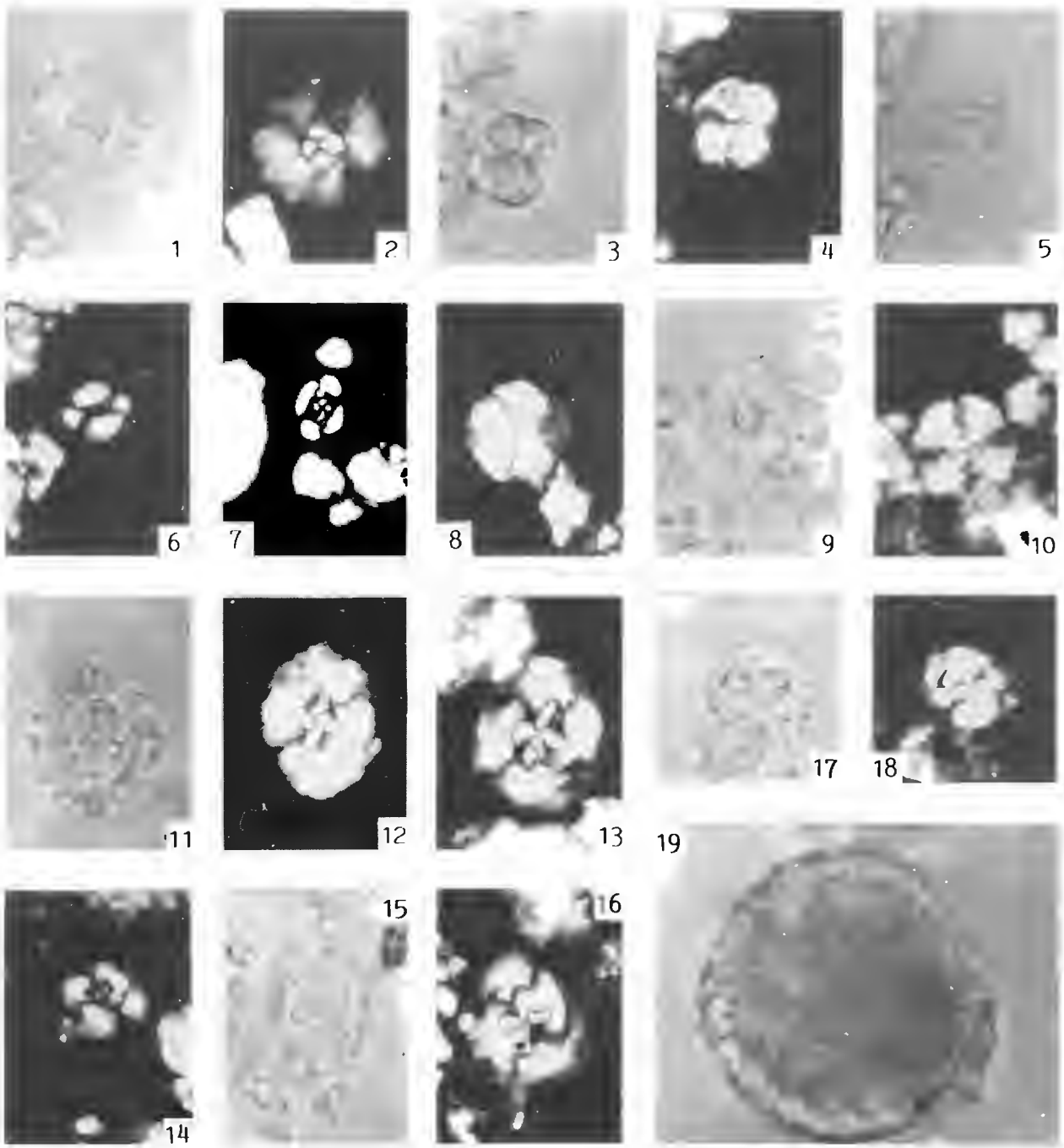
Figs 1–7: 1 *Globigerina* sp. and *Pseudohastigerina micra* (Cole), Koraljka-1, 2254–2258 m, **2** *Hantkenina* cf. *alabamensis* Cushman, Jadran-2, 1261 m, **3** *Turborotalia* ex gr. *cerroazulensis* (Cole), Koraljka-1, 2254–2258 m, **4** *Globigerina* sp., Jadran-1, 1261.5 m, **5** *Turborotalia* ex gr. *cerroazulensis* (Cole), Koraljka-1, 2254–2258 m, **6–7** *T.* ex gr. *cerroazulensis* (Cole), Koraljka-1, 2254–2258 m, all × 100.6

Age: Priabonian.



Figs 1–20: 1–2 *Micula murus (Martini) Ko*raljka-1, 2470 m, **3–4** *Micula praemurus* (Bukry), Koraljka-1, 2470 m, **5–8** *Micula decussata* Vekshina, Koraljka-1, 2465 m, **9–10** *Eiffellithus turriseiffellii (*Deflandre), Koraljka-1, 2470 m, **11–12** *Quadrum gothicum* (Deflandre), Koraljka-1, 2497–2500 m, **13–15** *Arkhangelskiella cymbiformis* Vekshina, Koraljka-1, 2470 m, **16** *Microhabdulus decoratus* Deflandre, Koraljka-1, 2470 m, **17–19** *Watznaueria barnesae* (Black), Koraljka-1, 2470 m, **20** *Cribrosphaerella ehrenbergii* (Arkhangelsky), Koraljka-1, 2470 m.

Age: Late Maastrichtian.



Figs 1–19: 1–2 *Markalius inversus* (Deflandre), Koraljka-1, 2450 m, **3–4** *Biantholithus sparsus* Bramlette & Martini, Koraljka-1, 2450 m, **5–6** *Ericsonia cava* (Hay & Mohler), Koraljka-1, 2440 m, **7** *Bisuctum? parvulum* Romein, Koraljka-1, 2440 m, **8** *Braarudosphaera bigelowii* (Gran et Braarud), Koraljka-1, 2435 m, **9–10** *Cyclagelosphaera reinhardtii* (Perch-Nielsen), Koraljka-1, 2435 m, **11–13** *Cruciplacolithus tenuis* (Stradner), Koraljka-1, 2435 m, **14, 17–18,** *Cruciplacolithus primus* Perch-Nielsen, Koraljka-1, 2435 m, **15–16** *Cruciplacolithus tenuis* (Stradner), Koraljka-1, 2435 m, **19** *Thoracosphaera* sp., Koraljka-1, 2435 m, all: × 2000. **Age:** Paleocen

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EOCENE CARBONATE SEDIMENTS AND SEA-LEVEL CHANGES ON THE NE PART OF ADRIATIC CARBONATE PLATFORM (ISLAND OF HVAR AND PELJEŠAC PENINSULA, CROATIA)

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Abstract

After the emersion of the Adriatic Platform that lasted since the end of the Senonian and after the local accumulation of bauxite, the sedimentation was reestablished in the Early Eocene. This occurred in more-or-less brackish, protected lagoons and bays, where Kozina-type Limestones have been deposited. These are overlain by the Foraminiferal Limestones of an open marine shelf which has been deposited above a ravinement surface. Deposition of the Eocene carbonates (Kozina-type Limestones in particular) is characterized by numerous breaks of sedimentation (hiati), some of which have lasted for ca. 2–2.5 Ma. These were caused by emersions in response to relative sea-level falls, and are documented by leached bedding planes, karstification and occurrences of bauxite. Progressive deepening of the depositional environment is responsible for formation of the so-called Transitional Beds, again aborted by a sea-level fall which caused emersion and created a hiatus. Finally, a thick Flysch Formation was deposited in a deeper-marine basin which was created by tectonical disintegration of the Adriatic carbonate platform accompanied by a sea-level rise. The oldest part of the so-called Flysch Formation (predominantly marls) was deposited during a highstand, whereas the youngest part characterized by turbidites was deposited during the sea-level lowstand.

The reduced thickness of the sediments in the Hvar section is caused by comparatively slow subsidence, whereas thicker sediments in the Orebić section indicate higher subsidence of a more labile structural block.

Key words: Stratigraphy, Eocene, paleoecology, sequence stratigraphy, inshore sections Hvar, Pelješac, Croatia.

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Errata:

V. Tari-Kovačič et al.: Startigraphic Analysis of Paleogene Beds in some off-shore Wells (Central Adriatic Area, Croatia), pp. 228 to 240 (Plate 1-13)

Plate 1 (p. 228)

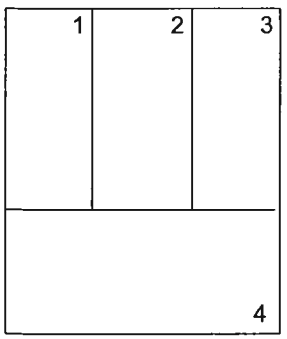


Plate 2 (p. 229)

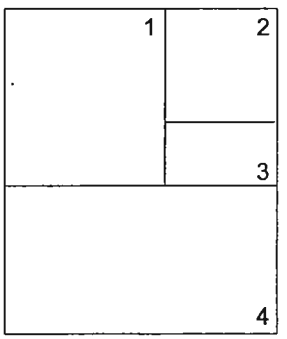


Plate 3 (p. 230)

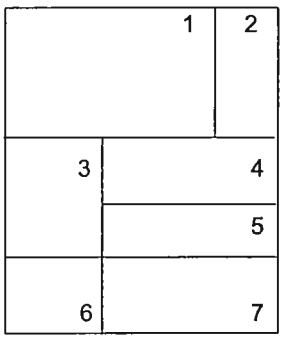


Plate 4 (p. 231)

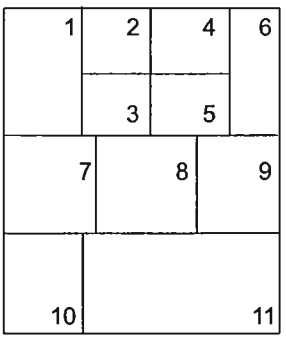


Plate 5 (p. 232)

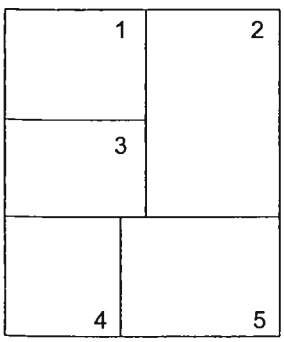


Plate 6 (p. 233)

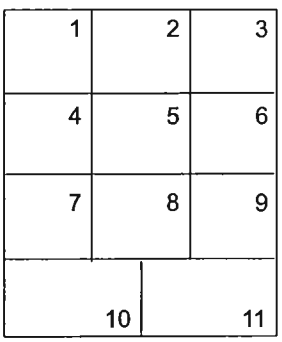


Plate 7 (p. 234)

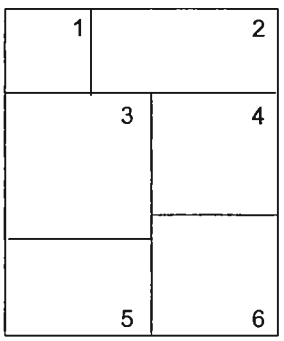


Plate 8 (p. 235)

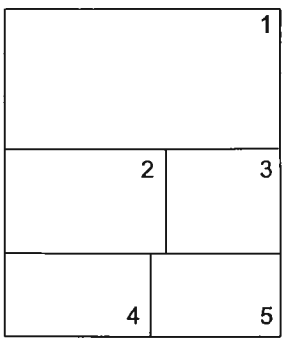


Plate 9 (p. 236)

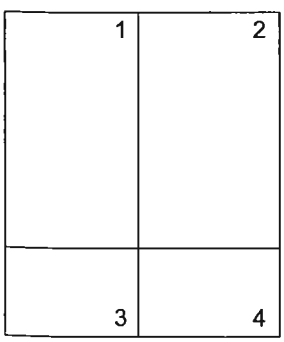


Plate 10 (p. 237)

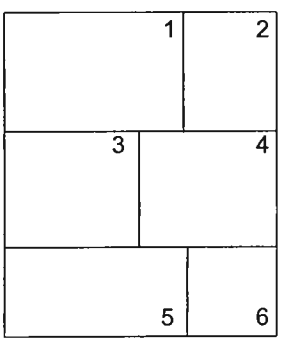


Plate 11 (p. 238)

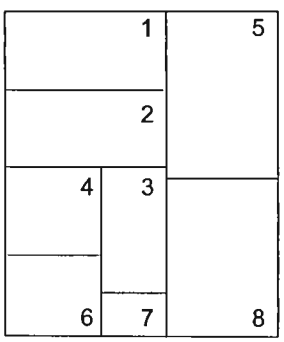


Plate 12 (p. 239)

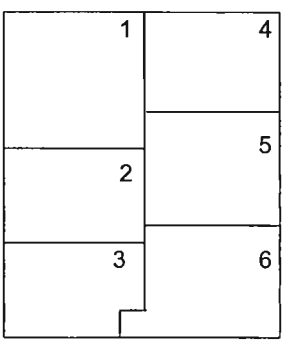
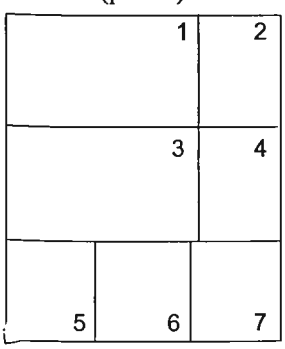


Plate 13 (p. 240)



INTRODUCTION

The northeastern part of the Eocene Adriatic carbonate platform discussed in this paper, is located in Middle Dalmatia on the Island of Hvar, and the Pelješac Peninsula (Fig. 1). Previous explorations of the area comprise regional mapping (Borović *et al.*, 1976, 1977; Herak *et al.*, 1976; Korolija *et al.*, 1976, 1977), complex studies on stratigraphy and tectonics of the region (Blanchet 1972, 1974; Chorowicz 1969, 1975, 1977; Salopek, 1928, 1931; Šikić, 1965), sedimentology of flysch, as well as on stratigraphy of the Palaeogene deposits (Benić, 1983; Drobne *et al.*, 1988; Puškarić, 1987).

The outcrops explored at both localities are only slightly tectonized with a moderate dip of the beds. On the Island of Hvar and the Pelješac Peninsula, the Palaeogene deposits are cropping out along the southern coasts and occur in tectonic contact with the Mesozoic carbonates (Fig. 1). Biostratigraphic control in the carbonates is based on larger foraminifera (alveolinids, numulitids, etc.), and on nannoplankton in the clastic sequence.

FACIES AND FACIES ASSOCIATIONS

The sedimentary succession explored consists of several distinct facies and facies associations:

1. Kozina-type Limestones,
2. Foraminiferal Limestones,
3. Transitional Beds and
4. Flysch which has an informal status as lithologic unit at the formation rank.

Kozina-type Limestones (A in Figs 2 and 3)

The equivalent facies association (but without stromatolites) in Istria was identified as the "Kozina-beds" and attributed to the proposed Liburnian stage by Stache (1889). The usage of formation and stage names is different; thus Blanchet (1974), Salopek (1928, 1931) and Schubert (1909) used them in Stache's original sense, but Chorowicz (1977), Magaš & Marinčić (1973), Muldini-Mamužić (1971), Pavlovec (1968) and Šikić (1965) understood the Liburnian as a facies or group of facies, while

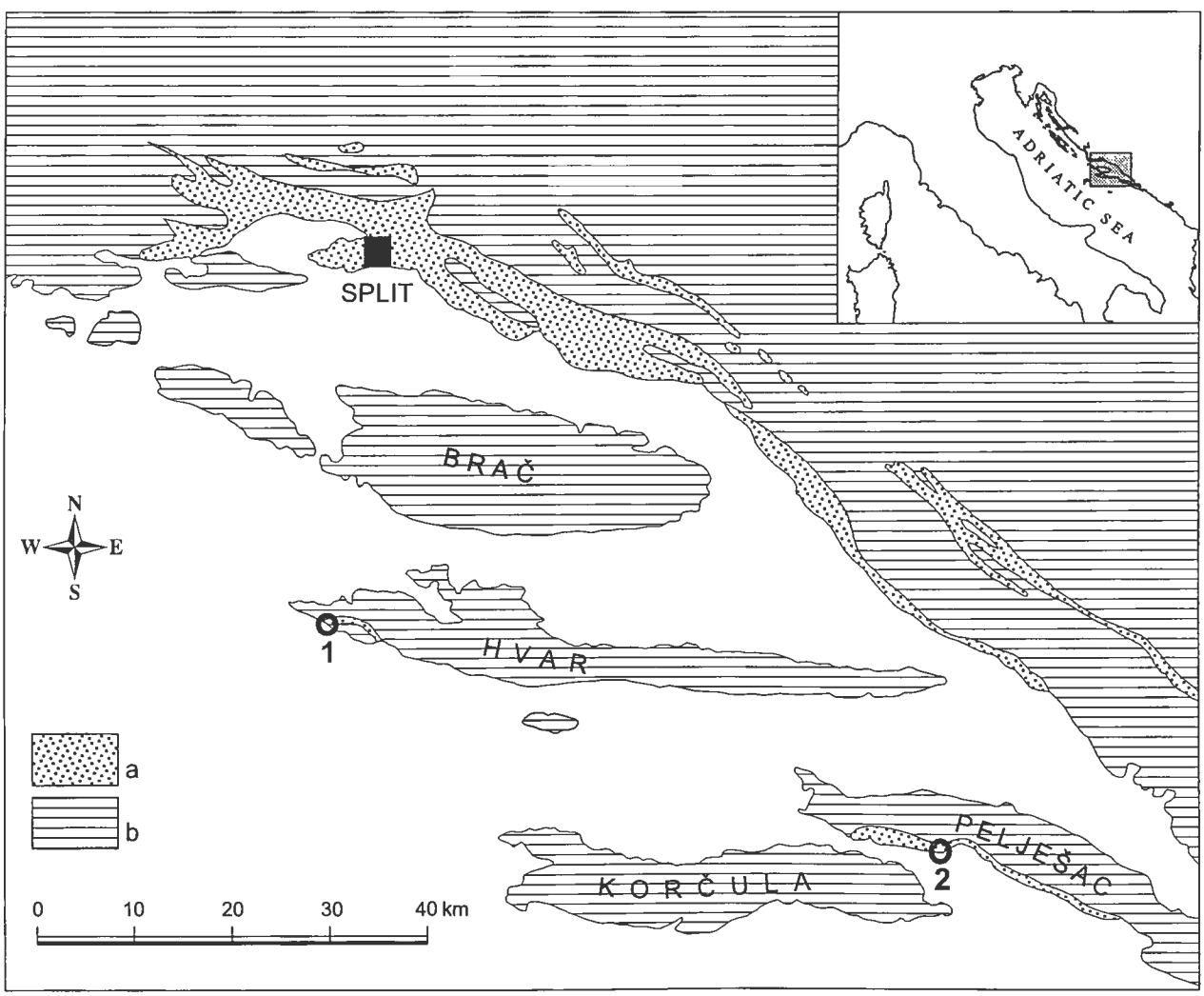


Fig. 1: General geology of central Middle Dalmatia and position of the sections studied. (1. Hvar section, 2. Orebić section). Location of the area studied is shown in the map inset. Key: a) Eocene (predominantly Flysch clastics, carbonates are subordinate), b) Mesozoic carbonates. Map simplified after Geological Map of SFR Yugoslavia 1 : 500.000.

Gušić & Jelaska (1990) and Pavlovec & Pleničar (1981) recognized the Liburnian Formation. Drobne (1979) accepted "Kozina" and "Liburnian" as similar facies but of different ages (Paleocene and 'Cuisian', respectively).

Kozina-type Limestones are 15.5 m and 96 m thick at the Hvar and Orebić sections, respectively. They comprise the following facies:

1. Discorbida Limestones,
2. Miliolida Limestones,
3. Stromatolites, and
4. Breccias.

Although some researchers hold Miliolida Limestones as the earliest facies of the Foraminiferal Limestones (see Muldini-Mamužić 1971 and Šikić 1965), they are treated here as a member of the Kozina-type Limestones due to alternation with the Discorbida Limestones.

The facies boundaries are locally transitional, or locally sharp, the latter characterized by leached sediments as well as by erosion and karstification. The respective share of individual facies types also differ; in the Hvar section Discorbida Limestones and Stromatolites predominate, while in the Orebić section the Miliolida Limestones attain much greater thickness than other lithofacies. The intensity of karstification is also different at various stratigraphic levels, so it locally reaches a depth of several meters. It is sometimes difficult to determine the real karstification depth, because some cavities occur superimposed and cross-cutting the older ones.

The description of the facies studied, as well as their interpretation is summarized in the following tables.

Some upper bedding planes of Discocyclina Limestones are leached, and 9 such surfaces were recognized in the Hvar section. The colour of leached sediment is yellowish at the base and somewhat paler above. The contact with the underlying unaltered rock is transitional and diffuse. The overlying sediments are in a sharp contact with the leached sediment, but sometimes it is possible to see leaching products penetrating upwards along microfissures.

Some of the upper bedding planes are karstified with very irregular relief and smaller and bigger voids created in a range from larger fenestrae to narrow caverns. In most cases, caverns and fenestrae are vertical, sometimes branching and enlarged along some bedding planes. Caverns have penetrated step-wise to a depth of at least 3 m. Moreover, some vertical caverns are cross-cutting several older weathered and karstified surfaces. The width of these paleocaverns is to our knowledge of the order of a few centimetres up to a few decimeters. The cavern-fill is mostly bauxitic with lithic debris formed by corrosion of the host rocks.

	Discorbida Limestones
Description	Thin bedded, light-coloured, massive, locally faintly parallel-laminated. Bedding planes gently undulating, sometimes flat, frequently karstified with relief of 5–10 cm, or sometimes leached. ***Structure:*** biomicrites/wackestones. Biota usually floats in matrix but gastropode lumachellas, and thin ostracode skeletal laminae occur locally. Molds of ostracods and dissolved gastropods are infilled with mosaic sparry calcite. Geopetally infilled corrosion fenestrae are abundant locally. Bioturbation is generally rare. ***Biota:*** numerous small discorbids, compacted ostracods, scattered characean gyrogonites, gastropods and rare lamellibranch debris.
Interpretation	Deposited in a low-energy, oxygenated brackish environment. Periodic bottom currents (probably storm-induced) accumulated skeletal grains that form faint laminae and lumachellas.
Environment	Isolated brackish lagoon(s) or protected bay(s).

	Miliolida Limestone
Description	Found only in Orebić section. Thin bedded, brownish-coloured. Contacts with the underlying facies are transitional. ***Structure:*** biomicrites and bio-intra-pelmicrites/wackestones, locally poorly-washed sparites. Random distribution of allochems, and variable number of micrite intraclasts. Syntaxial calcite overgrowths on echinoderm plates. Numerous spherical pelletal grains. Matrix micritic, locally recrystallized. Neomorphic spar rich in micritic residuals. ***Biota:*** Miliolids predominate, spirolinas are locally abundant, less frequent are agglutinated foraminifers, ostracods and ? *Tubyphites*. Characeans and perforate foraminifers are poorly preserved. Lammelibranch debris is rare. Different degree of skeletal preservation; most skeletal grains are affected by extensive micritization and sometimes by severe bioerosion. Rare dissolved dasycladacean fragments and rare gastropods are preserved as sparite-filled molds.
Interpretation	Skeletal fragmentation due to bioerosion? Micrite intraclasts are produced by desiccation of temporally exposed muds. Resedimentation of debris was caused by storm-induced currents.
Environment	Saline open lagoons with periodic influence of storms in subtidal depth range.

	Stromatolites
Description	Frequent in Hvar (12), but only 1 level in the Orebić section. 10–30 cm thick, reddish to pink and white-coloured. Commonly overlie karstified lms. with ostracods, and their growth compensated relief of substrate. Well laminated (LLH), disturbed locally by synsedimentary faulting and small-scale folding. ***Structure:*** thin irregular pel-micro-sparite laminae alternate with fossiliferous micrite. Small horizontal fenestrae frequent. Thin lensoid lithoclast accumulations are locally interlayered with stromatolites. Bundles of cyanobacterial filaments are poorly preserved in some microsparite laminae. Alveolar in upper part with oval to spherical voids -mm to 1 cm in diameter marking distinct levels. Some laminae comprise undefinable, tiny skeletal debris. ***Biota:*** poorly preserved; ostracods, miliolids and rare discorbids. In Hvar section, stromatolites have colonized karstified limestones, but near Orebić they are developed above unkarstified Miliolida Limestones.
Interpretation	Formed by accretion of micrite, pellets and skeletal debris on cyano-bacterial mats. Unsteady growth formed laminae of different thickness. Alveolar structure most probably originated from gas bubbles formed by decay of organic matter. Disturbances in growth probably caused by intensive storms as well as desiccation.
Environment	Supratidal in Hvar section, indicated by karstified substrate and lack of marine fauna. Intertidal in Orebić section, indicated by lack of subaerial exposure in their base, and alternation with poorly fossiliferous micrite, as well as abundant skeletal debris accreted.

	Breccias
Description	In Hvar section only. Few cm to 30 cm thick lenses and interbeds along bedding planes, frequently overlie karstified surfaces. Composed of unsorted, angular debris (Discorbida Limestones, etc.) of a wide size range (mm–dm), with only thin normal grading locally developed. Matrix is bauxite and fills karst caverns locally, some more than 3 m deep.
Interpretation	Produced by weathering of lithified sediments. Negligible transport distance indicated by a wide range of clast sizes and their angular shapes.
Environment	Supratidal indicated by bauxite matrix deposited during prolonged emersions.

Stratigraphy: The Hvar section is stratigraphically incomplete (Figs 2 and 3); the base of 'Cuisian' is missing due to emersion at the K/Tc boundary (hiatus I in Figs 2 and 3), so the oldest sediments belong to the Middle 'Cuisian'. The total stratigraphic span of the Kozina-type Limestones is of the Middle to the Upper 'Cuisian' age. Within this time-span, 18 levels marked by subaerial exposure are recognized, causing a significant reduction of overall sediment thickness. The final emersion created a hiatus with a duration extending over the whole Early Lutetian (ca. 3 Ma) (II in Figs 2 and 3), since the deposition of the overlying Foraminiferal Limestones started in the Middle Lutetian.

The Orebić section is stratigraphically almost complete (Figs 2 and 3). The base of the section is of probable Early 'Cuisian' age. The stratigraphic range of the Kozina-type Limestones is ?Early 'Cuisian'-Early/Middle Lutetian, as constrained by age of the overlying Foraminiferal Limestones. It this section, 16 levels characterized by subaerial exposures were recognized.

Discussion: The depositional environment of stromatolites is usually interpreted as higher intertidal and supratidal (James, 1984; Laporte, 1967; Shinn, 1983; Shinn *et al.*, 1969), although their occurrence was reported from a wide range of environments (eg. Flügel, 1982; Massari, 1975; Williams, 1984). The karstified substrate overgrown by stromatolites and the absence of a marine fauna including gastropods in the stromatolites of the Hvar section indicate a supratidal environment. The lack of evidence of subaerial exposure at the base of the stromatolites in the Orebić section, as well as their alternation with poorly fossiliferous micrite, and accreted numerous fine-grained skeletal debris, indicate an intertidal setting.

Frequent surfaces of subaerial exposures in the Hvar section indicate emersions and intensive weathering. Deep bauxite- and breccia-filled caverns were formed during considerably long exposures, unlike shallow karstified surfaces, fenestrae, and leached bedding planes that might have formed during much shorter exposures. An unknown amount of sediments was dissolved and removed, so the stratigraphic record is very incomplete. Alternation of restricted subtidal with supratidal sediments indicate frequent changes of the sea-level.

Small thicknesses of stromatolites are probably a result of a low subsidence rate and (possibly) short-lasting intervals of favourable conditions (intertidal to supratidal) that were followed by rapid floodings. Greater thicknesses of individual facies in the Orebić-, compared to the Hvar section indicates a higher subsidence rate which kept pace with the rate of deposition.

The transitions from the Discocyclina-Limestones to the Miliolida Limestones in the Orebić section indicate reestablishment of communication with the open sea after temporary isolation.

Foraminiferal Limestones (B in Figs 2 and 3)

The foraminiferal Limestones can be subdivided into the Alveolina Limestones, Nummulite Limestones and Discocyclina Limestones (in relative stratigraphic order), according to the predominant occurrence of specific microfossils. However, individual representatives of the type genera sporadically occur already in older sediments as a subordinate skeletal constituent. Foraminiferal Limestones are transgressive over the Kozina-type Limestones in the Hvar section, but their base is unexposed in the Orebić section.

Foraminiferal Limestones are 22.5 m and 76.5 m thick in the Hvar- and Orebić sections, respectively. Alveolina Limestones are not represented in the Hvar section due to its stratigraphic incompleteness, but in the Orebić section they alternate with limestones of the upper part of the Kozina-type Limestones.

	Foraminiferal Limestones
Description	Light-coloured, usually massive, thick-bedded in Hvar- and thin-bedded in Orebić section. Thin-bedded Alveolina Limestones in Orebić section. ***Structure:*** biomicrites/wackestones to packstones with large fossil debris. On Hvar- locally cross-bedded with imbricated nummulitids, but parallel-laminated and cross-bedded in Orebić section. ***Biota:*** benthic and pelagic foraminifers, echinoderms, corallinaceans, bryozoans. Echinoderms occur in the lower part of Foraminiferal Lms. Faunal composition changes upward: from Alveolina to Nummulite, and Discocyclina Lms. In Hvar section transgressive, with thin pebble lag above karstified Kozina-type Lms. In Orebić section 'transitional' base due to interbedding with Miliolida Lms. Above Transitional Beds, in Orebić section occur 'upper' Foraminiferal Lms. with large foraminifers scattered in packstone 'matrix' composed of tiny foraminiferal debris.
Interpretation	Cross-bedding in Orebić section produced by currents probably initiated by major storms. Skeletal debris probably produced by severe bioerosion.
Environment	Low-energy, well aerated, open shelf below fair-weather wave base.

Stratigraphy: The stratigraphic completeness of the Hvar and Orebić sections is different, so the stratigraphic range of the Foraminiferal Limestones is also different. In the Hvar section, Foraminiferal Limestones were deposited in the span from the early Middle Lutetian to the early Late Lutetian according to the nummulite fauna, and from the Early Lutetian to the late Middle Lutetian in the Orebić section.

The 'upper' Foraminiferal Limestones which overlie the Transitional Beds in the Orebić section have the Late Lutetian age as indicated by the stratigraphic range of *Nummulites maximus* (Schaub, 1981).

Discussion: The base of Foraminiferal Limestones in the Hvar section is transgressive, exhibiting an erosional unconformity (paraconformity) observable at the outcrop scale paved by a discontinuous pebble lag. The transgressive sediments are open-shelf biogenic sands, indicating rapid transgression and flooding of a flat ravinement surface (Swift, 1968), so that no transitional facies are preserved. The sedimentation in the Orebić section was not significantly interrupted after deposition of the Kozina-type Limestones and prior to deposition of the Foraminiferal Limestones, so the relationship of the two facies associations is transitional. These relationships illustrate that at the beginning of deposition of the Foraminiferal Limestones the Hvar section area was emergent, but the Orebić section area was continuously subsiding and no major break in deposition occurred. Consequently, the total thickness of the Foraminiferal Limestones is also different; but in both cases they are much thinner than in other sections in Dalmatia (ca. 200 m, Korolija *et al.*, 1977; Magaš & Marinčić, 1973). In addition to the rate of subsidence, the thickness of sediments is a function of a rate of deposition that is (in this case) governed by the biogenic productivity which is assumed equal for both areas.

The alternation of the Alveolina Limestones with Discorbida Limestones indicates deposition during phases of better communication with the open sea. The depth of deposition was of a subtidal range, below the fair-weather wave-base, and probably near (or within ?) the tidal channels that supplied marine water and allowed stronger bottom circulation capable of accumulation and sorting of the larger foraminifers.

Massive Nummulite-Discocyclina Limestones indicate a regular deposition in a quiet, well-aerated environment with a negligible water energy. The depth of deposition was of a subtidal range, probably in a photic zone as indirectly indicated by symbiosis of recent nummulitids with algae (Lee *et al.*, 1979; Hallock, 1988). The water depth has been frequently estimated 50–70 m (Belazi, 1985; Bosence *et al.*, 1985). Their environment is usually interpreted as specialized monotypic shallow 'sands' from the platform edge (Sellwood, 1986). Cross-bedded skeletal sand as well as imbricated large foraminifers probably originated during a major storm that affected skeletal debris at the bottom, similarly to

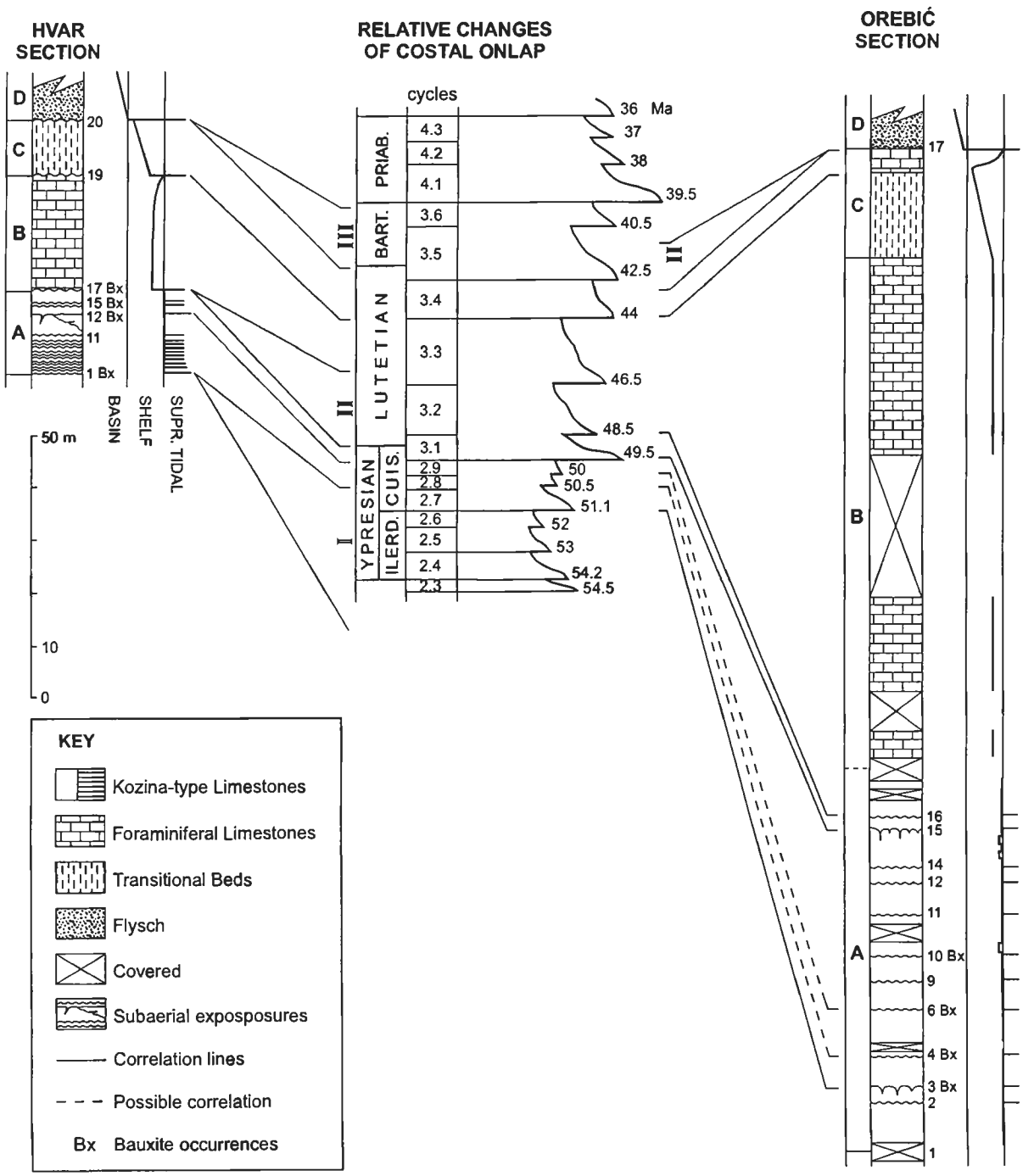


Fig. 2: Correlation of the Hvar and Orebić sections and sea-level changes reconstructed with relative changes of coastal onlap. Chart after Haq et al., (1987), simplified. Bold letters next to the sections correspond to the facies associations described in the text, and numbers indicate subaerial exposures. Roman numerals indicate major hiatuses. Several subaerial exposure surfaces may be correlated with the sea-level falls illustrated on the coastal onlap curve, but the most of them may not, so their effect on the curve is speculative. See text for discussion. Thicknesses of sediments on studied sections is controlled by different rate of subsidence of the two structural blocks.

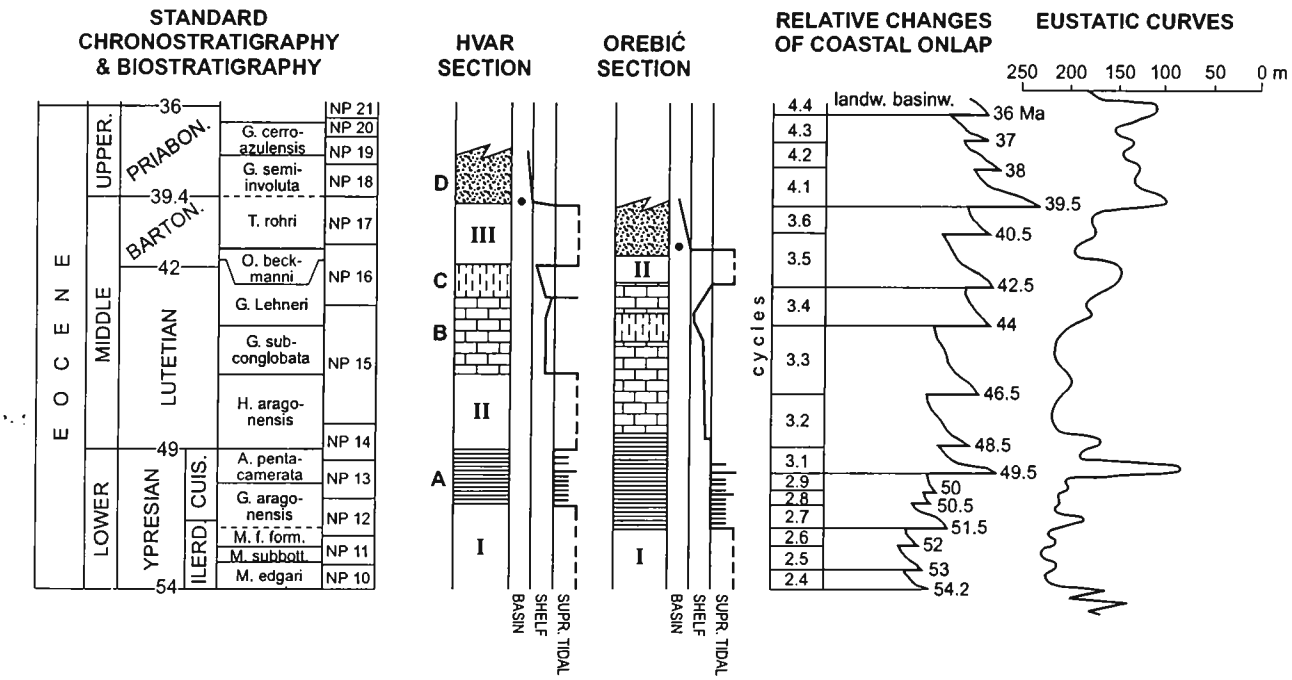


Fig. 3: Simplified logs of the Hvar and Orebić sections in the chronostratigraphic scale, respective curves of the sea-level change, relative changes of the coastal onlap and corresponding eustatic curve of Haq et al., (1987). Bold letters indicate facies associations described in the text, and Roman numerals indicate major hiatuses. Dots indicate events of rapid deepening interpreted as induced by tectonic disintegration of the carbonate platform. Note that boundaries of facies associations (formations) are not synchronous and that all of them are older in the Orebić- than in the Hvar section.

the 'numulitic banks' described by Aigner (1983, 1985). This 'event' interpretation is supported by the small thickness of cross-bedded sediments, and by the restriction to just one bed.

Transitional Beds (C in Figs 2 and 3)

The Foraminiferal Limestones are overlain by the so-called Transitional Beds (Šikić, 1965) consisting of: 1) 'marls with crabs' (Transitional Beds *sensu stricto*, see Juračić, 1980), and 2) Globigerina Marls. Due to a high glauconite content the lower unit is commonly referred to as the Glauconite Limestones (Magdalenić, 1971). Their position between the underlying Foraminiferal Limestones and the overlying Flysch Formation makes them 'transitional'. It is generally accepted that they reflect progressive deepening of the sedimentary environment.

The transitional Beds are about 11 m thick in the Hvar-, and about 15 m thick in the Orebić section. In both sections they are represented only by their lower member, but no fossil crabs have been found.

In the Hvar section, the Transitional Beds have a peculiar contact with the underlying Foraminiferal Limestones. Here occurs a thin synsedimentary breccia as infill of fissures and voids in the Foraminiferal Limestone, as well as in the Transitional Beds. The lithic debris are platy, sharp-edged and normally graded and cemented by sparry calcite. The size of individual fragments locally equals to the width of some cavities and their lithology corresponds to that of the host sediment. Breccia-filled caverns and fissures are crudely bedding-parallel, but vertical and steeply inclined fissures also occur. Their walls are sharp, may cut the fossils and morphologically resemble some karst caverns.

	Transitional Beds
Description	Thin-bedded, bedding irregularities increase upwards in Hvar section. Thick regular beds in Orebić section ***Structure:*** biomicrites/wackestones to packstones with numerous equi-dimensional small skeletal debris. Authigenic glauconite is frequent to numerous. Clay content increases upwards. ***Biota:*** poorly preserved; benthic foraminifers, ostracods, bryozoans, lamellibranchs, corallinaceans, spiculas. Frequent globigerinas and other planktonics, and their number increasing upwards. Rare gastropods and echinoderms. Locally intensively bioturbated.
Interpretation	Skeletal debris most probably produced by severe bioerosion. Most shallow marine biota seems allochtonous, only pelagics deposited by 'pelagic rain'. Gradual increase of planktonics and marl content indicates progressive deepening.
Environment	Deep subtidal with negligible water energy. Progressive deepening.

Stratigraphy: The deposition of the Transitional Beds in the Hvar section started in the Late Lutetian and the first overlying clastics were deposited by the end of the Bartonian — at the end of the NP 17 nannozone. The stratigraphic range of Transitional Beds in the Orebić section extends from the late Middle Lutetian to the Late Lutetian.

Discussion: The breccia-filled fissures from the base of the Transitional Beds in the Hvar section may have formed during the tensional fracturing of the early lithified sediments, and these may have been widened to some extent by karstification. Normal grading in breccia indicates that debris were transported and did not form by the *in situ* brecciation. However, the debris are never rounded, so distance and duration of the transport must have been short.

The depositional depth range of the Transitional Beds must have been wide because of the position above the typical platform shallow-marine deposits and below typical deep-marine deposits of the Flysch Formation. The accurate depth is hard to estimate, but their deposition must have started in rather shallow sea (deep shelf below the fair-weather wave base) as indicated by the benthic fauna, and ended (in general) at rather great depths with no autochthonous benthic fauna.

Irregular bedding and lenticularity at the upper part of the Hvar section may have been caused by compaction solution as well as carbonate dissolution and migration. Glauconite grains are traditionally considered as indicators of deepening, but their formation is controlled by moderate temperatures (15–20° C), low sedimentation rate, low alkalinity (pH 7–8) (Mc Rae, 1972) and it occurs in a wide depth range (30–250 m Mc Rae, 1972; 60–1000 m Odin & Fullgar, 1988; 30–700 m Porrenga, 1967). According to the planktonics/benthics ratio Juračić (1980) interpreted the depositional depth of the Transitional Beds from the Istrian Eocene as a 60–100 m deep shelf at the beginning, and about 1000 m, or deeper by the end of their deposition. It is possible to conclude that this facies originated in a very wide depth range, and documents progressive deepening and subsidence of the carbonate platform.

Since the Globigerina Marls (known from most of the Adriatic Eocene basins, Juračić, 1980; Šikić, 1965) are not preserved, it is possible to speculate about another shallowing episode that resulted in emersion and severe erosion. The indirect evidence of shallowing and emersion is the hiatus III (Figs 2 and 3) representing a timespan corresponding to almost the whole of Bartonian (approx. 3 Ma), as indicated by the age of the overlying Flysch in the Hvar section. The direct evidence for this is the occurrence of the 'upper' Foraminiferal Limestones in the Orebić section where carbonate deposition ceased by emersion of unknown duration (hiatus II in Figs 2 and 3).

Flysch (D in Figs 2 and 3)

Above the Transitional Beds occurs several hundred meters thick flysch. Its relationship with the underlying sediments is locally transgressional as well as transitional (see discussions in Marinčić, 1981 and Šikić, 1965). Some depositional characteristics of the flysch in northern Dalmatia have been recently described by Babić & Zupanič (1983), in the broad Adriatic region by Marinčić (1981), and in the coastal Middle Dalmatia by Marjanac (1986, 1989, 1990, 1991).

Marinčić (1981) stated that Flysch on the Island of Hvar was deposited above a 12 m thick breccia which overlies the Senonian carbonates, but in the section described herein this is not the case. The Flysch in the Hvar section lies in an erosive contact on the underlying Transitional Beds and 1.5 m thick coarse-grained rudite marks its base. The base of the rudite is clearly erosive (concave-upwards lower bedding plane) with ca. 10 cm wide, regularly spaced, shallow grooves, but no angular unconformity was observed. The orientation of the grooves indicates a NE–SW scour. The rudite is composed of mixed lithic and skeletal debris with a crude upcurrent imbrication developed in the lower part of the bed, indicating palaeotransport towards SE. The geometry of the lower bedding plane suggests that the sediment represents a shallow channel-fill.

Above the 'basal' rudite, 30 m of thick marls with a small number of rudite-arenaceous interbeds were deposited, as well as several hemipelagite/pelagite layers of highly carbonate marls that reaching 80 cm in thickness.

Above the karstified 'upper' Foraminiferal Limestones, in the Orebić section 20–50 m thick (prevailingly covered) silty marls were deposited. The lower part of the Flysch is unexposed, and the clastic sequence was not studied in detail. However, in the lower part of the sequence several meters thick calcareous turbidites with clear evidence of flow reflections were recognized.

Stratigraphy: Deposition of the Flysch started first in Istria and is getting younger towards SE (Benić, 1983, Drobne, 1979, Drobne & Pavlovec, 1991, Drobne & Pavšič, 1991, Proto-Decima & Piccoli, 1969). Its deposition in Middle Dalmatia started during the Bartonian (in the NP 17 nannozone) (Benić, 1983, Puškarić, 1987).

Herak *et al.* (1976) and Krašeninnikov *et al.* (1968) dated the Hvar flysch by assemblages of the planktonic foraminifers, and recognized the Late Eocene (Priabonian) *Globigerina corpulenta* biozone (equivalent of Bolli's *G. semiinvoluta* biozone). Marinčić (1981) held that deposition started during the NP 18 nannozone (and quoted its Late Eocene to the Early Oligocene age), but Puškarić (1987) documented its start already during the NP 17 nannozone (Bartonian). However, the recent exploration of one of the authors (J.B.) showed that clastic deposition on the Hvar section was initiated at the end of NP 17 nannozone and continued into the NP 18 nannozone. The latter is represented only in a thin lithologic in-

terval, and deposition continued through the NP 19 nannozone.

In the Orebić section, deposition of the Flysch started earlier namely during the NP 17 nannozone, similarly as in the Split region (Benić, 1983).

Discussion: The deposition of the Flysch in both sections started after a significant deepening, most probably caused by a tectonical disintegration of the carbonate platform (Marinčić, 1981; and for the neighbouring Split region, Marjanac, 1991). A tectonical cause is favoured over a eustatic one due to lack of synchronism of the base of the Flysch even in a small area as this.

Deposition must have been well below the storm wave base because the preceding Transitional Beds already lack any evidence of the wave action. Depositional environment was topographically restricted as suggested by great thicknesses of the marls interpreted as deposits of the ponded turbidity current tails (eg. Blanpied & Stanley, 1981, Kuenen, 1968, Stanley & Maldonado, 1981) and some turbidites originated from the reflected flows.

Sporadic occurrence of the resedimented older nannoplankton (eg. of the Early Eocene and Palaeocene ages) indicates on Paleogene uplift and erosion in a neighbouring area.

RECONSTRUCTION OF SEA-LEVEL CHANGES

The base of the Eocene at both sections is characterized by a major hiatus (I) that comprises the whole Palaeocene and the main part of the Early Eocene in the Hvar section. The time-span in the Orebić section is similar (Fig. 3). This time-span correlates with the third-order cycles (TA) 1.1 to 2.7 on the chart of Haq *et al.* (1987). However, it is not possible to assign the break in sedimentation to one distinct sea-level fall.

Deposition started in response to sea-level rise that first created brackish lagoons, marshes and flooded bays (incised valleys?) where Kozina-type Limestones were formed. The reduced thickness of carbonates in the Hvar section indicates deposition during a period when the sea was near its lowest level and subsidence created very restricted accommodation space. During this period even a minor sea-level fall could lead to exposure which eventually caused leaching or karstification. The favourable conditions were met during regional lowstand, while minor oscillations were probably fourth-order cycles. The difference in thickness of the preserved sediments in the Hvar- and Orebić sections reflects variations in a subsidence rate.

The Kozina-type Limestones were deposited through Haq's cycles TA 2.8 to the lower part of the TA 3.1 (Fig. 3). Their deposition was affected by 17 emersions in the Hvar- and 16 emersions in the Orebić section (Fig. 2). This karstification locally created rather complex micro-cavernous systems with depth of several meters, what gives a crude estimate of the fall in the water table. Stromatolite-forming cyanobacteria colonized the karstified substrate in the Hvar section area most probably at the end of a subaerial phase, when the ground-waters rose in response to sea-level rise, as indicated by lack of any marine fauna between laminae. Stromatolites were eventually drowned and lagoonal sediments deposited above. It is not possible to assign recognized subaerial exposures to known sea-level falls. The contact of Kozina-type Limestones below and Foraminiferal Limestones above is characterized by a major hiatus (in the Hvar section) which comprises the Lower Lutetian (TA 3.1 and 3.2 cycles of Haq *et al.* 1987) and was probably caused by sea-level fall at 48.5 Ma.

The transgression of the Foraminiferal Limestones correlates with the TA 3.3 cycle, (possibly TA 3.2 cycle in the Orebić section) (Fig. 2) and resulted from a renewed sea-level rise. Difference in thickness of the Foraminiferal Limestones in the sections studied, is again attributed to difference in creation of the new accommodation space assuming the biogenic productivity remained the same. Since transgressive sediments are missing (except a pebble lag), most of the deposition of the Foraminiferal Limestones occurred during a highstand, that is also a period of maximal biogenic productivity (Mullins, 1983). New shallowing occurred near the end of the deposition of the Foraminiferal Limestones in the Hvar section, as indicated by an increase in energy and by the occurrence of cross-bedding. This shallowing was caused by a sea-level fall (possibly at 44 Ma) which locally lead to subaerial exposures, such as observed in the Hvar section, and it initiated deposition of the 'upper' Foraminiferal Limestones in the Orebić section. This subaerial exposure was presumably short-lasting, because no significant hiatus could be documented at this level.

The overlying Transitional Beds indicate progressive deepening, and their deposition in the Orebić section correlates with the Haq's cycle TA 3.3, and TA 3.4 in the Hvar section (Fig. 3). Thus, their deposition occurred during a period of sea-level rise which was accompanied by a stronger subsidence. Shallowing that caused deposition of the 'upper' Foraminiferal Limestones in the Orebić section culminated in emersion and karstification (possibly caused by a fall of the sea-level at 40.5 Ma (Bartonian)) which created a major hiatus comprising TA 3.5 and the main part of the TA 3.6 cycle on the Hvar section, and TA 3.5 cycle in the Orebiæ section.

The deposition of the Flysch in the Hvar section started 1.4 Ma later than on the Orebić section, indicating a wider time-span of the hiatus at its base. The base of the Flysch in the Hvar section is characterized by a 'basal' breccia preserved in a shallow channel, that was probably formed during transgression, the grooves being similar to those described by Cheel & Middleton (1993).

The abundance of lithical debris indicates an activation of terrigenous sources, and that is probably related with a sea-level fall at the base. The deposition of clastics started with thick marls with a pervasive pelagic fauna. The lack of any terrigenous debris indicates good isolation most probably caused by deepening during rapid sea-level rise. The reduced thickness of the NP 18 sediments suggests condensed sedimentation probably related to a sea-level highstand. Hemipelagic/pelagic limy marls were deposited during maximal flooding (periods when the rate of sea-level rise was highest).

DISCUSSION

The Miliolida Limestones are very thin and do not represent a mappable unit, and therefore were not treated as individual lithostratigraphic unit.

Since the lowest part of the Flysch succession on the Orebić section comprises thick marls, it is obvious that deposition took place in a restricted 'ponded' part of the basin, without terrigenous influence during the early stage of its evolution. The deposition of Flysch in the Hvar section started with a thick 'basal' bed containing lithoclasts and large quantity of resedimented skeletal debris, that contrasts with 'ponded' marls observed in many other localities (Marjanac, 1991) as well as on the Orebić section. I assume that this sediment represents an erosional remnant of a lowstand wedge eroded by ravinement processes, and may be related to much thicker breccias reported by Marinčić (1981).

The hiati within the Eocene sediments lead previous researchers to introduce several intra-Eocene orogenic phases, such as the Istrian-Dalmatian phase at the boundary between the 'Marls with crabs' and the Globigerina Marls of the Transitional Beds (that broadly corresponds to the hiatus III), and Khun's Ilirian phase at the boundary between the Flysch and the Promina Formation (Šikić, 1965, 1968, 1969). Šikić stated that the Istrian-Dalmatian phase caused folding and uplift followed by deposition of continental sediments and resedimentation, and that the overlying flysch was deposited as a transgressive unit; but that Khun's Ilirian phase has caused only uplift without folding. Although these phases were considered as tectonic, and considerable effort was made to illustrate tectonical features produced by the Istrian-Dalmatian phase (Šikić, 1965) it is possible to assign these hiati to sea-level falls.

CONCLUSIONS

The succession of the Eocene sediments studied in the Hvar- and Pelješac sections reflects sea-level oscillations and numerous breaks of sedimentation. Each of the formations studied has been deposited under the influence of oscillating sea-level. Biostratigraphy documented high stratigraphic incompleteness of the succession explored, in spite of apparently continuous sedimentation during the Eocene suggested by the 'classical' stratigraphic succession.

Most of the sea-level oscillations which resulted in the subaerial exposures affected the deposition of the Kozina-type Limestones, that were interpreted as of brackish lagoonal and intertidal to supratidal origin. Some hiatuses are correlated over 65 km of the present-day section distance and attributed to some of the sea-level falls recognized by Haq *et al.* (1987). However, most of the subaerial exposures cannot be attributed to known sea-level falls due to the poor biostratigraphic control. The Foraminiferal Limestones were deposited transgressively over a ravinement surface on top of the Kozina-type Limestones. Most of the Foraminiferal Limestones were deposited during a highstand on a low-energy open shelf, but near the end of their deposition a new sea-level fall occurred. The transitional Beds of deep subtidal origin were deposited above, and mark progressive deepening, but their deposition was aborted by a sea-level fall which caused one of the major hiati in the Hvar section, and induced the deposition of the 'upper' Foraminiferal Limestones in the Orebić section. The latter deposition ceased due to new sea-level fall and subaerial exposure. Flysch was transgressively deposited after rather rapid deepening which was primarily caused by tectonic disintegration of the carbonate platform. The generation of limy marls is attributed to periods of maximal flooding (or fastest sea-level rise).

The small thicknesses of the facies units, the discontinuous sedimentation and the numerous subaerial exposures in the Eocene succession of the Hvar section indicate deposition on a slowly subsiding structural block. The subaerial exposures, at least most of them, were primarily caused by eustatic sea-level changes, probably of the III and IV order as indicated by the small thicknesses of sediments and by the lack of evidence of synsedimentary tectonics. Larger thicknesses of the Eocene sediments on the Orebić section indicate higher subsidence and possibly a more labile tectonic setting. Tectonics played a significant role in deepening before and during deposition of the Transitional Beds, and at the beginning of flysch deposition. The final disintegration of the carbonate platform was diachronous in the explored sections, so in the Orebić section it occurred ca. 1.4 Ma earlier than in the Hvar section.

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PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE MIDDLE TO UPPER EOCENE SUCCESSION IN THE NORTH ADRIATIC SEA

Vlasta Premec Fuček[1], Ljubomir Babić[2], Zlatan Bajraktarević[2] and Ivan Gušić[2]

Abstract

Three deep exploration wells in the northern part of the Adriatic Sea were drilled through the Middle and Upper Eocene deposits. Drill cuttings and cores were rich in well preserved planktonic foraminifera. Standard planktonic foraminiferal zones P 10 to P 17 have been identified. A zonal scheme which emphasizes levels of extinction (Last Appearance Datum) was used. Beside zonal markers, the evolutionary lineage of the *Turborotalia cerroazulensis* group as well as the species succession of the genus *Globigerinatheka* were useful for biostratigraphic analyses. Lateral difference in species diversity might be explained by different habitats, i.e. different environmental conditions. The test morphology and diversity level of the foraminiferal assemblages correspond to the Mediterranean bioprovince with a subtropical to warm-temperate climate.

Key words: Biostratigraphy, Planktonic foraminifera, Middle to Late Eocene, Offshore wells, Northern Adriatic, Venetian Basin.

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INTRODUCTION

The northernmost portion of the Adriatic consists of two large-scale units (Fig. 1; Jenko & Bistričić, 1978; Đurasek *et al.*, 1981; Cati *et al.*, 1987). The Istrian Platform to the east shows a thick succession of the Jurassic, Cretaceous, and Paleocene to Middle Eocene carbonates, which were predominantly deposited on a shallow platform (Polšak & Šikić, 1973; Tišljar *et al.*, 1983; Kalac & Tari-Kovačić, 1986). The carbonates are overlain by Middle to Late Eocene basinal clastics. In contrast, the Venetian Basin situated to the west shows basinal Jurassic and Cretaceous deposits (Cati *et al.*, 1987; Veseli *et al.*, 1995). The Paleogene sediments have not been documented for the Venetian Basin, although the existence of the Lower Paleogene Scaglia deposits and Middle-Upper Eocene clastics have been recorded in a log of the Amanda 1 bis well published by Cati *et al.* (1987). The present work is based on the study of three wells located in this area (Fig. 1). Facies analysis of the Paleogene sediments penetrated by these wells suggested that the relevant area represented an eastern portion of

the Venetian Basin and was situated close to the margin of the Istrian Platform (Premec-Fuček *et al.*, 1995). The purpose of this work is to document planktonic foraminiferal biostratigraphy of the Middle to Late Eocene succession encountered in these wells. Besides, compositions of foraminiferal assemblages, diversity level and the variability of foraminiferal test morphologies are used in order to improve the understanding of paleoecological, i.e. paleoenvironmental, conditions.

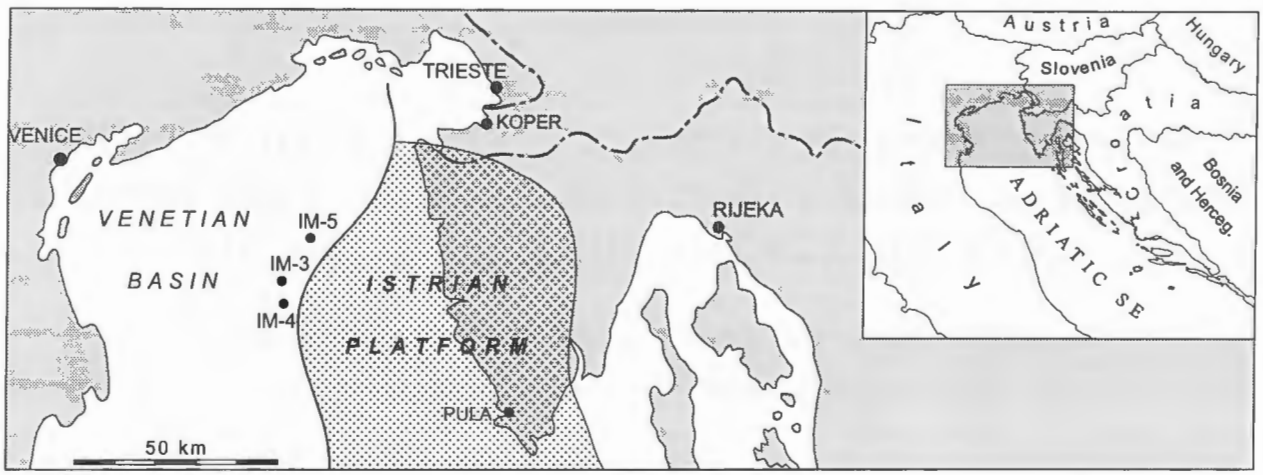

Fig. 1: Situation of three wells studied and the boundary between the Istrian Platform and Venetian Basin according to Jenko & Bistričić (1978). IM-3, IM-4, and IM-5 position of wells Istra more-3, Istra more-4, and Istra more-5.

The samples studied included 700 washed samples of drill cuttings and five cored intervals (Fig. 2).

PALEOGENE SEDIMENTARY SUCCESSION

The Paleogene succession in the three wells studied has been subdivided into three units ranging in age from Paleocene to Early Oligocene (Fig. 2). These three units are described below, and more data are found in Premec Fuček *et al.* (1995) and Premec Fuček (1995).

(A) Pelagic limestones and marls with bioclastic intercalations

Based on planktonic foraminifera, this unit corresponds to the Paleocene and Early Eocene, i.e. to the standard biostratigraphic zones P 10, P 11, and the lower part of the zone P 12 (early Middle Eocene), respectively (Berggren & Miller, 1988). The unit mostly consists of lime wackestones and mudstones in the lower part, which pass into limy marls going upwards. The sediments are rich in planktonic foraminifera and represent a pelagic deposition. Bioclastic intercalations consist of larger and smaller benthic foraminifera, planktonic foraminifera, fragments of corallinaceans, bryozoans, and echinoderms, and clasts of platform carbonates. These intercalations originated by gravity flows, which brought carbonate shelf and slope material. The deposition of the unit probably took place on a slope or at the base of a slope flanking the Istrian Platform. Thus, the beginning of the Paleogene reflects a continuation of the deeper-water conditions, which had governed the deposition of the underlying Late Cretaceous sediments in the same area (Veseli *et al.*, 1995).

(B) Marls with intercalations of mixed and bioclastic composition

This unit corresponds to the upper part of the zone P 12, then P 13, P 14, P 15, and P 16 zones, i.e. to the late Middle Eocene and a larger part of the Late Eocene (Berggren & Miller, 1988). The sediments are dominantly hemipelagic marls rich in planktonic foraminifera. They contain thin intercalations of siltstones and sandstones of mixed carbonate-siliciclastic composition, and intercalations of bioclastic beds. The mixed-type intercalations must have derived from northerly situated deformed regions. The bioclastic inrecalations are similar to those in the unit (A), and derived from the Istrian Platform. Soft-sediment deformations and floating marl clasts in the upper part of the unit (Fig. 2, IM-5) have been produced by slope failure, which resulted in mud flows, and indicate a sloping topography. Associated extraclast pebbles, including a coal pebble, reflect the advance of the coast. This is also indicated by an increase of the proportion of smaller benthic foraminifera in washed samples around the boundary between units (B) and (C).

(C) Marls

Planktonic foraminifera indicate the zones P 17, P 18, P 19, and P 20 corresponding to the uppermost Late Eocene and Early Oligocene (Berggren & Miller, 1988). The unit is represented by monotonous silty marls with rare and thin siltstone beds. In contrast to the lower units, which were characterized by more than 80 and 90 % of planktonic foraminifera in washed samples, their proportion in this unit dropped to some 50 %. The unit was

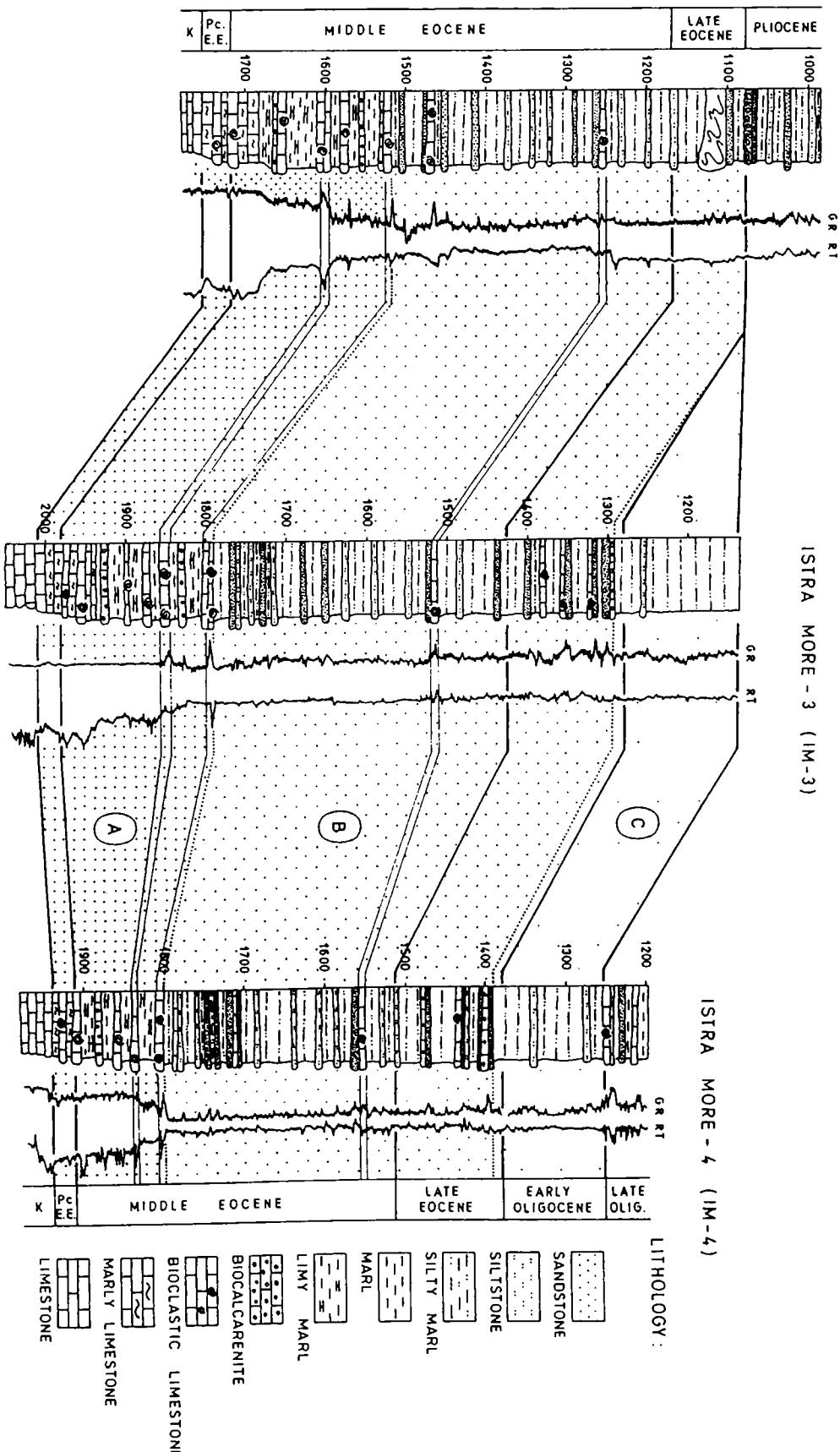

Fig. 2: Paleogene successions in three deep wells in the Northern Adriatic with simplified lithology. Symbols A, B, and C refer to three Paleogene units. Important bioclastic intercalations/horizons used as markers are outlined. After Premec Fuček & al. (1995). The present work is dealing with Middle and Late Eocene portion of these successions.

probably deposited in an upper slope or outer shelf environment at a time when the supply from the Istrian Platform was not available anymore.

PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY OF THE MIDDLE TO UPPER EOCENE SUCCESSION

The frequency of planktonic foraminifera in the samples enabled a successful application of the standard planktonic foraminiferal zonation (Bolli, 1957; Stainforth *et al.*, 1975; Toumarkine & Luterbacher, 1985 and Berggren & Miller, 1988). All planktonic foraminiferal zones of the Middle and Late Eocene times have been identified (Zones P 10 to P 17). Besides zonal markers, evolutionary lineages of the *Turborotalia cerroazulensis* group as well as the species succession of the genus *Globigerinatheka,* were useful for biostratigraphic study.

Hantkenina nuttalli Zone — P 10

The base of the Middle Eocene is not clearly marked by planktonic foraminiferal assemblages. Although the genus *Hantkenina* is not present, the transition from Early to the Middle Eocene could be recognized by the appearance of common and typical *Acarinina bullbrooki*

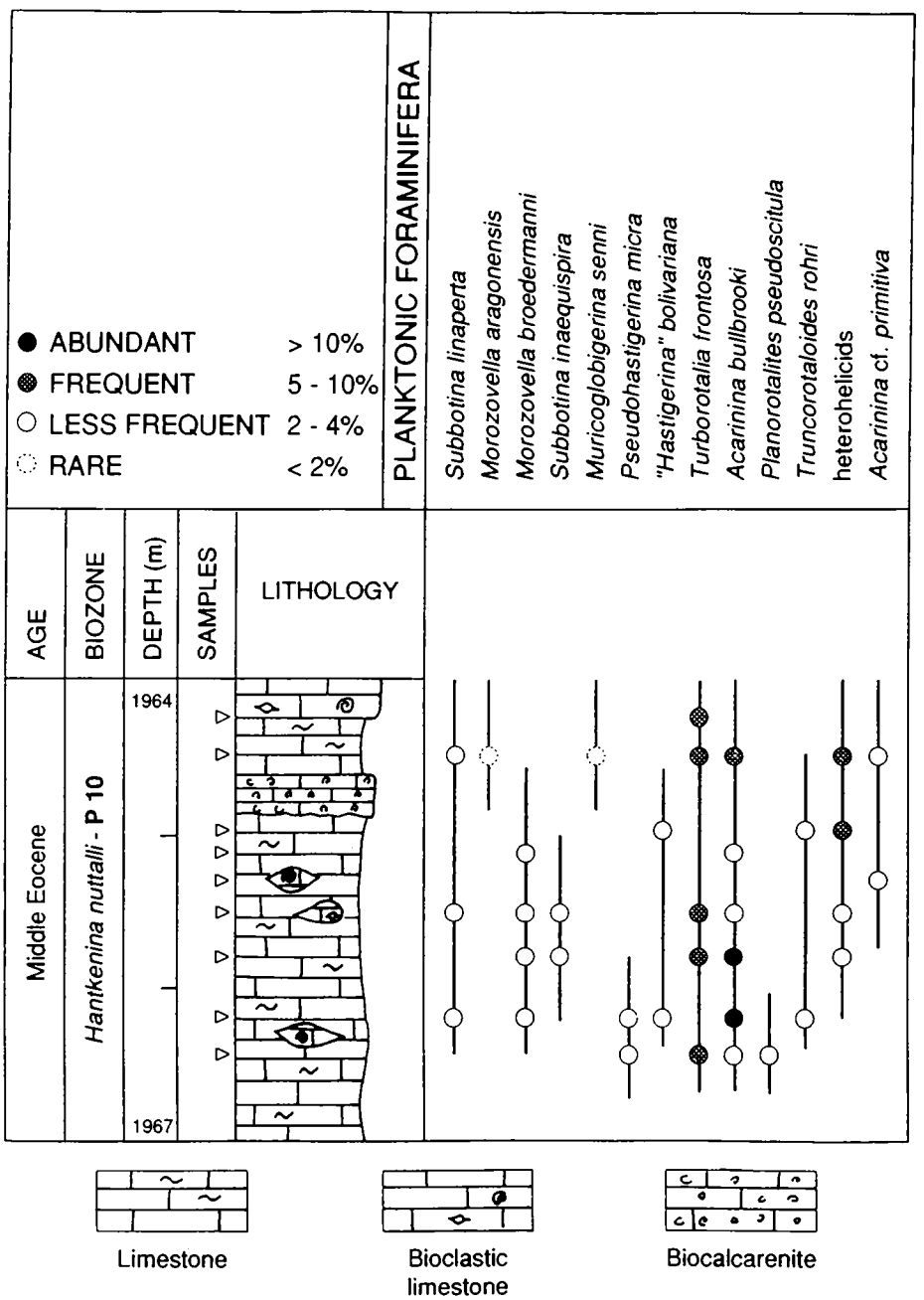

Fig. 3: Lithostratigraphic column and planktonic foraminiferal distribution of the cored interval in Istra more-3 (IM-3) well, (1967–1964 m).

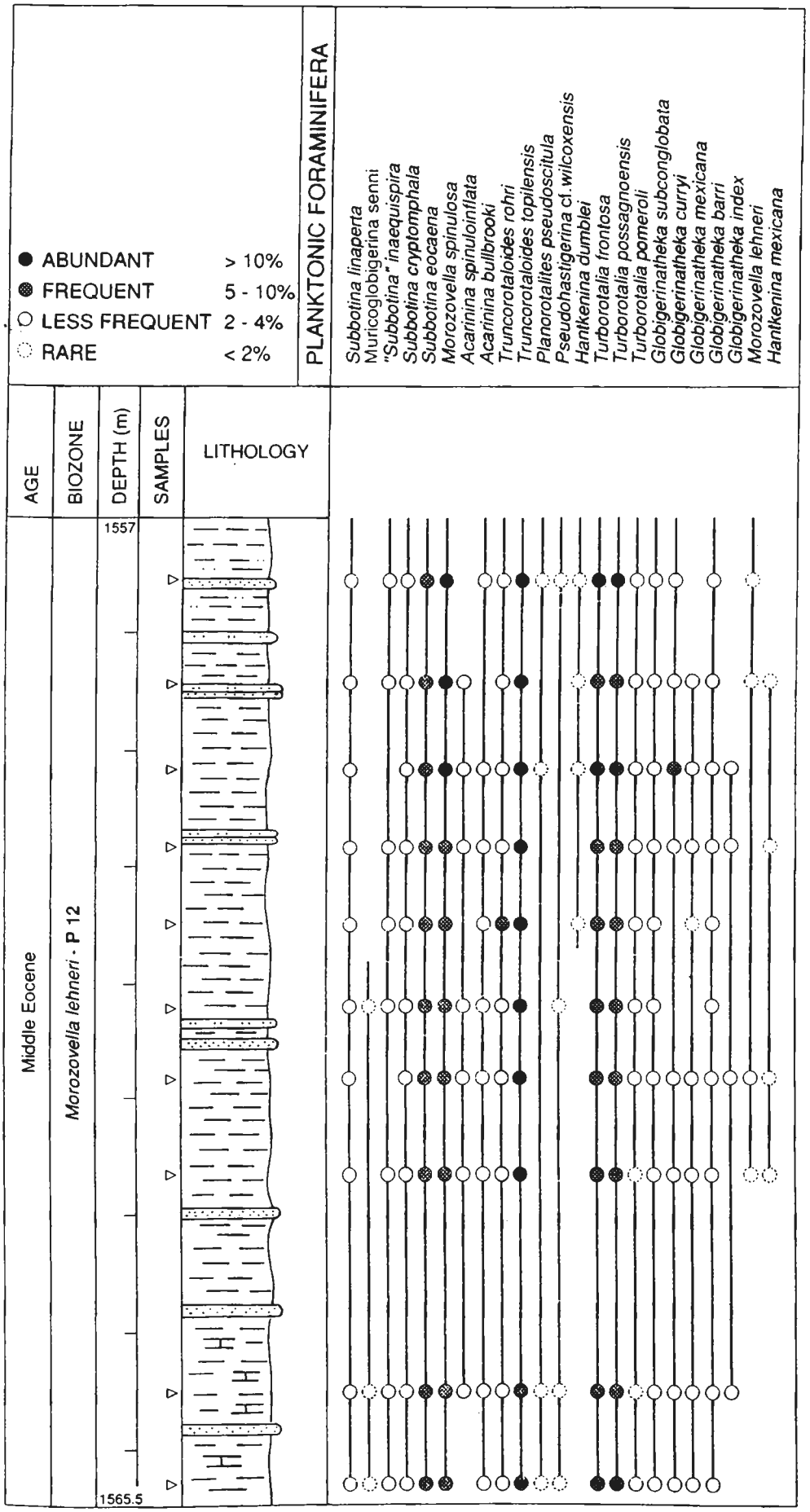

Fig. 4: Lithostratigraphic column and planktonic foraminiferal distribution of the cored interval in Istra more-5 (IM-5) well, 1557.0– 1565.5 m.

(Bolli) and *"Hastigerina" bolivariana* Petters. In addition, *Turborotalia frontosa* (Subbotina) and *Morozovella broedermanni* (Cushmann & Bermudez), which also occur below this zone, become frequent above the Middle-Late Eocene boundary. Biserial heterohelicids are abundant in this zone, while *Subbotina inaequispira* (Subbotina), *Pseudohastigerina micra* (Cole), *Truncorotaloides rohri* Brönnimann & Bermudez and *Morozovella aragonensis* (Nuttall) are represented by only a few specimens. The top of the zone is placed below the frequent occurrences of *Globigerinatheka mexicana* (Cushman).

All features described above are best observed in the samples of the cored interval from IM-3 well (1967–1564 m), Fig. 3.

Globigerinatheka subconglobata Zone — P 11

The assemblages of this zone are typically characterized by frequent occurrence of *Globigerinatheka subconglobata* (Shutskaya), *Acarinina bullbrooki* (Bolli), *Morozovella broedermanni* (Cushman & Bermudez), *M. spinulosa* (Cushman), *Truncorotaloides topilensis* (Cushman), *Planorotalites pseudoscitula* (Glaesner) and *Subbotina inaequispira* (Subbotina). Just one specimen of *Hantkenina dumblei* (Weinzierl & Applin) was found. The only representatives of the *Turborotalia cerroazulensis* lineages are *T. frontosa* (Subbotina) and *T. possagnoensis* (Toumarkine & Bolli). *Globigerinatheka curryi* (Proto Decima & Bolli) is typically frequent in the upper part of the zone.

The top of the zone is marked by the last appearance of the *Morozovella aragonensis,* which precedes the abundant appearance of the forms of the *Globigerinatheka mexicana* group.

Morozovella lehneri Zone — P 12

The main feature of the relevant foraminferal assemblage is the coexistence of *Turborotalia frontosa* (Subbotina) and *T. possagnoensis* (Toumarkine & Bolli), together with the first representatives of *T. pomeroli* (Toumarkine & Bolli). Muricocarinate species *Morozovella spinulosa* (Cushman) and other muricate forms are common: *Truncorotaloides topilensis* (Cushman), *T. rohri* (Brönnimann & Bermudez), *Acarinina spinuloinflata* (Bandy) and *A. bullbrooki* (Bolli). The genus *Globigerinatheka* is represented by *G. subconglobata* (Shutskaya), *G. curryi* Proto Decima & Bolli, *G. mexicana* (Cushman), *G. barri* Brönnimann and *G. index* (Finlay). *Hantkenina dumblei* Weinzierl & Applin and *H. mexicana* Cushman are present with few specimens. *Subbotina eocaena* Guembel and *S. cryptomphala* (Glaessner) are common. All features described above are best observed in the samples of the cored interval from IM-5 well (1557.0–1565.5 m) which contains an abundant and well-preserved planktonic foraminiferal assemblage (Fig. 4).

Orbulinoides beckmanni Zone — P 13

The characteristic assemblage of this zone consists of *Turborotalia pomeroli* (Toumarkine & Bolli), *Globigerinatheka mexicana* (Cushman), *G. barri* Brönnimann, *G. index* (Finlay) and *Subbotina* spp. The older species, *Globigerinatheka curryi,* is replaced by *G. euganea* Proto Decima & Bolli. The zonal marker was not found here, which is in accordance with its rarity in the Alpine-Mediterranean realm, but it is interesting to mention that it has been identified in the Middle Eocene deposits of the Istrian area (Šikić, oral communication, 1995). Muricate species are present with *Morozovella spinulosa, Acarinina spinuloinflata, Truncorotaloides* spp. etc.

In the absence of the zonal marker, the top of the zone can be placed approximately before the frequent appearance of *Turborotalia cerroazulensis.*

Truncorotaloides rohri Zone — P 14

Foraminiferal association of this zone is best documented in samples of the IM-5 well. The cored interval 1170–1176 m in this well contains rich associations of planktonic foraminifera which show the highest diversity in comparison to other Middle-Late Eocene zones encountered in the three wells studied (Fig. 5). The lower part of this interval shows the dominance of the muricate forms: *T. topilensis, T. rohri, Acarinina spinuloinflata, A. triplex* and rarely *Morozovella spinulosa.* In the middle part of this core (3rd meter), muricate forms become very rare and eventually disappear. These forms were replaced by an increasing number of large globigerinids and subbotinids: *Globigerina tripartita* (Koch), *G. officinalis* Subbotina, *Subbotina angiporoides* (Hornibrook), *S. gortanii* (Borsetti). Premoli Silva (oral communication, 1994) considers that the extinction of the muricate species in the Alpine-Mediterranean area took place below the top of the Middle Eocene.

Globigerinatheka semiinvoluta Zone — P 15 and lower P 16

In the material studied, the typical assemblage of this zone is well represented in the cored interval of the IM-5 well (1109.5–1115.0 m), Fig. 6). The zonal marker, *Globigerinatheka semiinvoluta* (Keijzer), is characterized by smaller tests and smaller number of secondary apertures than in the specimens characterizing tropical regions (Toumarkine & Luterbacher, 1985). The *Turborotalia cerroazulensis* lineage is represented by frequent *T. cerroazulensis* and *T. cocoaensis*, and a few specimens of *T. pomeroli.* Very small forms of *Globigerina medizzai* Toumarkine & Bolli, the only muricate species, persisted across the Middle/Late Eocene boundary in the Mediterranean (Premoli Silva & Boersma, 1988). Other small forms in the samples of this zone are *Pseudohastigerina micra* (Cole), *P.* cf. *naguewichiensis* (Myatliuk) and *Globorotaloides car-*

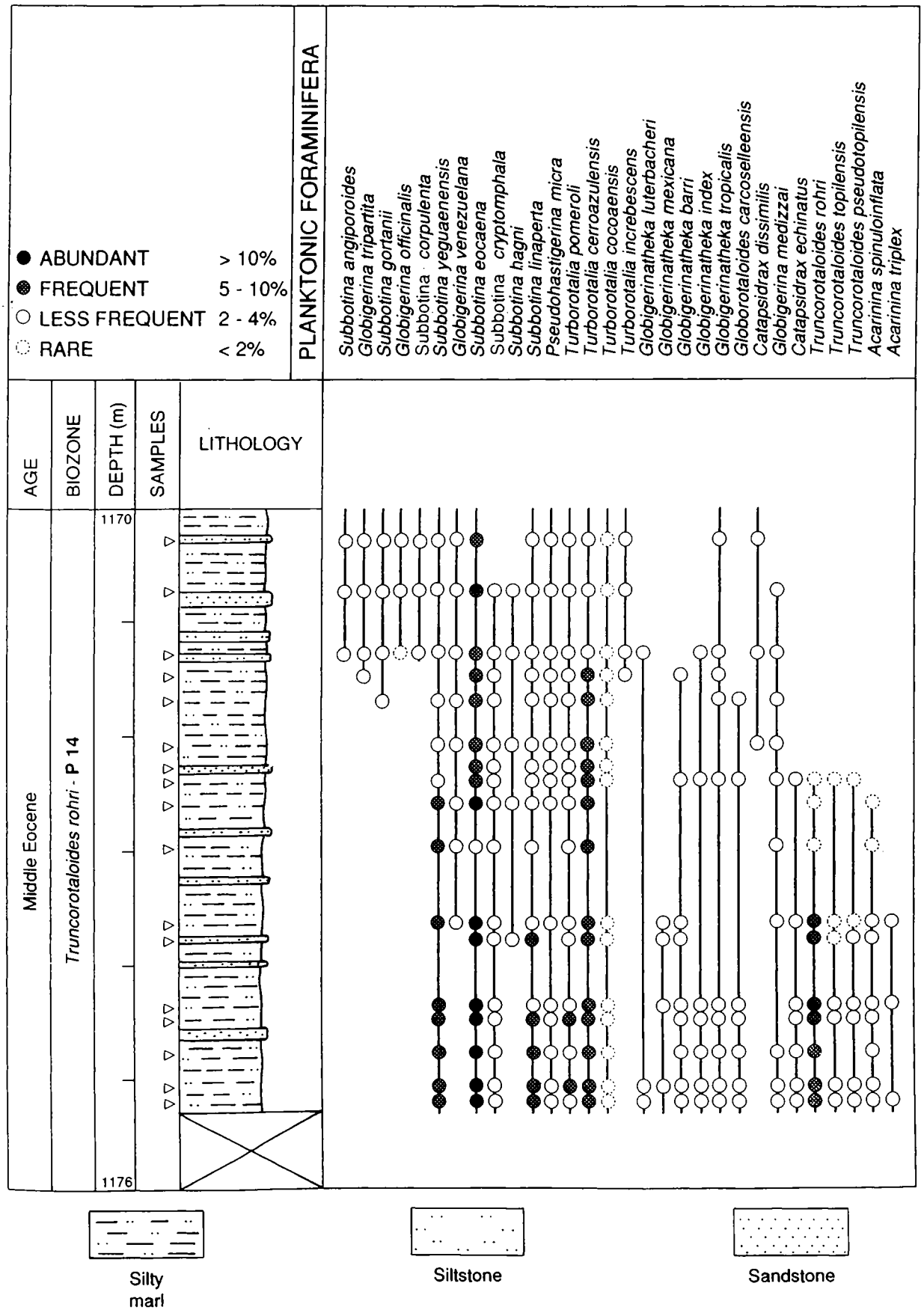

Fig. 5: Lithostratigraphic column and planktonic foraminiferal distribution of the cored interval in Istra more-5 (IM-5) well, (1170–1176 m)

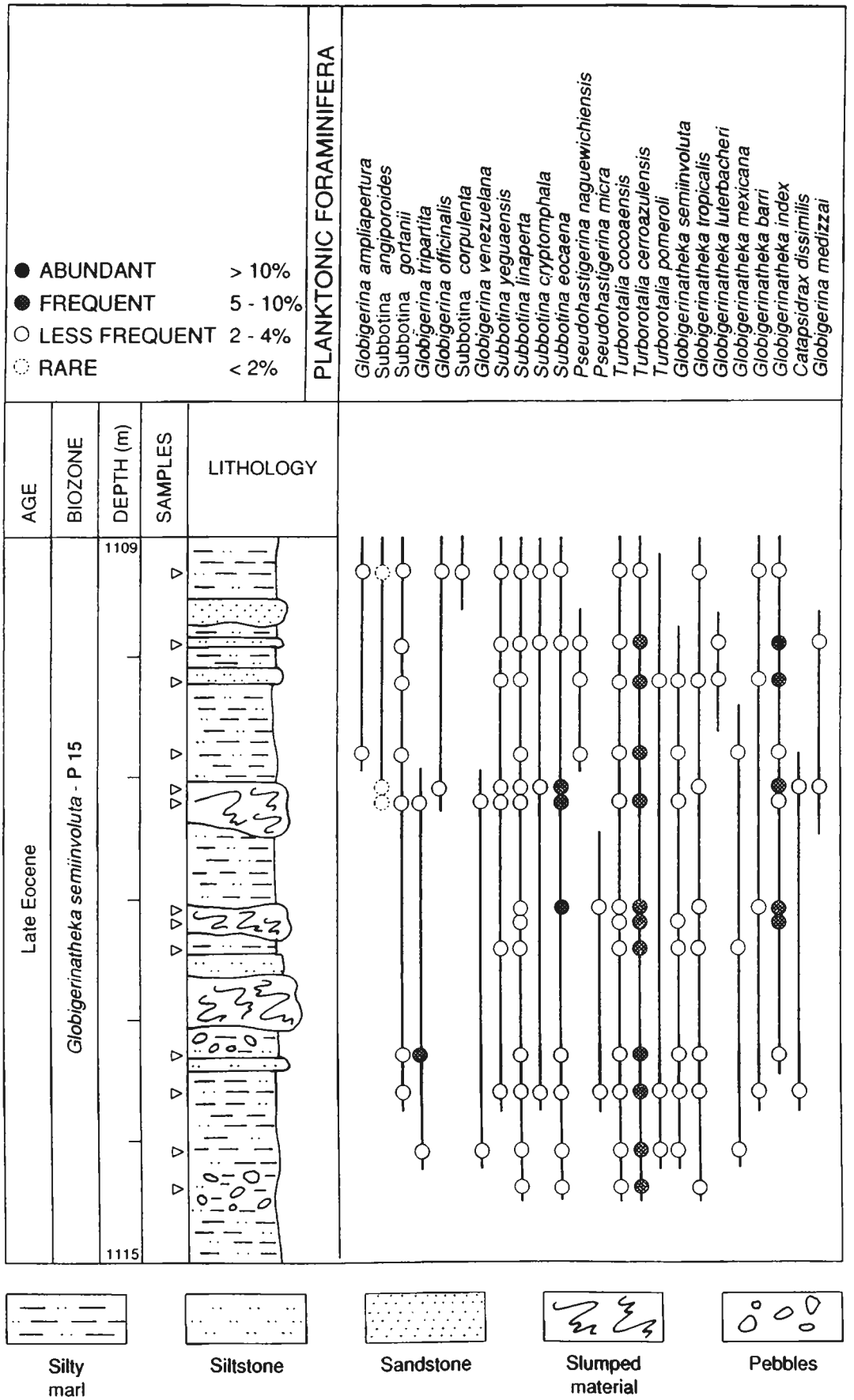

Fig. 6: Lithostratigraphic column and planktonic foraminiferal distribution of the cored interval in Istra more-5 (IM-5) well, (1109.5–1115.0 m)

cosellensis Toumarkine & Bolli. *Globigerinatheka* ex gr. *mexicana* disappears in the upper part of zone, while large *Globigerina* species become more and more frequent going upwards. The top of the zone is marked by the last occurence of the zonal marker and of *Globigerinatheka luterbacheri* Bolli.

A different assemblage, showing a low diversity, is found in the cored interval of the IM-4 well (1429–1432 m in Fig. 7). This assemblage contains only a few genera (*Turborotalia, Subbotina and Globigerina*), the genus *Globigerinatheka* is absent.

Turborotalia cerroazulensis s. l. Zone — upper P 16 and P 17

This zone is characterized by a low diversity association of planktonic foraminifera. *Globigerinatheka index* occurs rarely and disappears below the Eocene/ Oligocene boundary. Close to that boundary there are also the last representatives of *Turrborotalia cerroazulensis* group. *Cribrohantkenina inflata* Howe is very rare. After the extinction of many species during the uppermost part of the Middle Eocene and during the Late Eocene, the relevant ecological niche was occupied by large *Globigerina* species: *G. gortanii*, *G. tripartita*, *G. ampliapertura*, *G. venezuelana*, *G. angiporoides*, *G. corpulenta*, and *G. officinalis*.

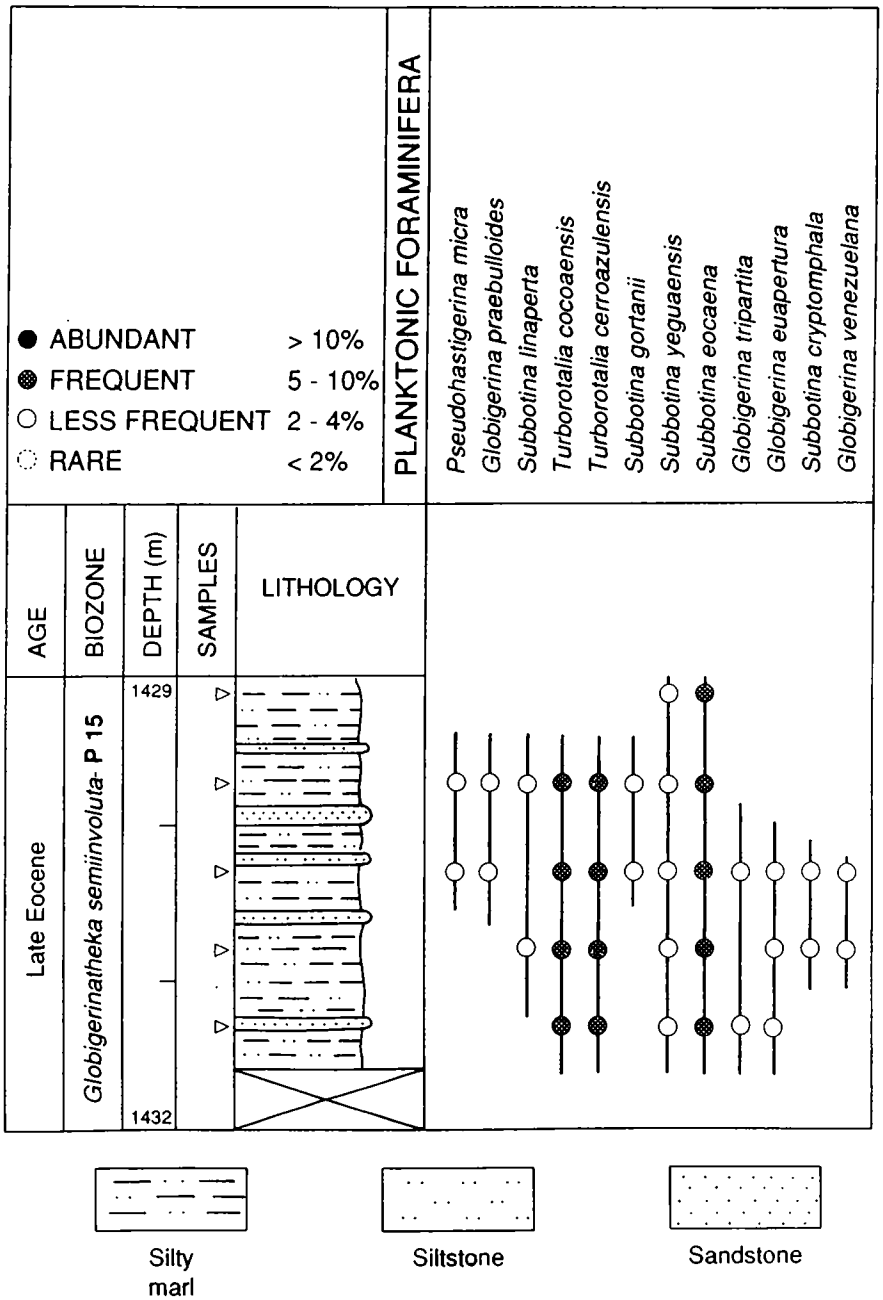

Fig. 7: Lithostratigraphic column and planktonic foraminiferal distribution of the cored interval in Istra more-4 (IM-4) well, (1429–1432 m).

PALEOECOLOGY

Planktonic foraminifera have a great potential in palaeoecological studies (Murray, 1991). Both biotic and abiotic factors may be reflected by species diversity and in the morphology of foraminiferal tests.

Temperature

The Middle to Upper Eocene succession contains planktonic foraminiferal associations which include the majority of species typical for low latitudes (Stainforth *et al.*, 1975; Toumarkine & Luterbacher, 1985). Those associations are generally both rich in individuals and highly diversified. However, the marker species such as *Morozovella lehneri, Orbulinoides beckmanni*, and *Hantkenina* spp. are rare or absent. The specimens of other species, such as *Globigerinatheka semiinvoluta*, possess small tests and smaller number of secondary apertures (Pl. 4, Fig. 6–7). Generally, the tests of all species found were smaller than the tests of the same species encountered in successions deposited under tropical climate (Bolli, 1957; Premoli Silva & Boersma, 1988). All these facts indicate that the area of the Northern Adriatic belonged to the subtropical to warm-

temperate climatic bioprovince of the Mediterranean area during the Middle-Late Eocene.

During the Middle to Late Eocene the climatic bioprovinces were more or less constant and less expressed than today. The climatic conditions were favourable for the evolution of several genera (*Morozovella, Truncorotaloides, Acarinina*) during the Middle Eocene and *Globigerinatheka* and *Turborotalia* during the Middle and Late Eocene. Many species have short stratigraphic ranges and are extremely useful in biostratigraphy (Murray, 1991).

Planktonic foraminiferal associations show a constant increase in the species diversity, which continued during the Middle Eocene. After reaching its maximum at the end of the Middle Eocene, the diversity gradually decrease until the Oligocene, when the number of species reached a minimum (Fig. 8). Our diversity trends correspond with data of other autors (Stainforth *et al.*, 1975; Toumarkine & Luterbacher, 1985; Premoli Silva & Boersma, 1988) and could be in connection with global temperatures changes and other global events (eustatic changes, oceanic circulation, fluctuacions in the trophic resource continuum, etc.; Hallock, 1987; Ottens & Nedebragt, 1992).

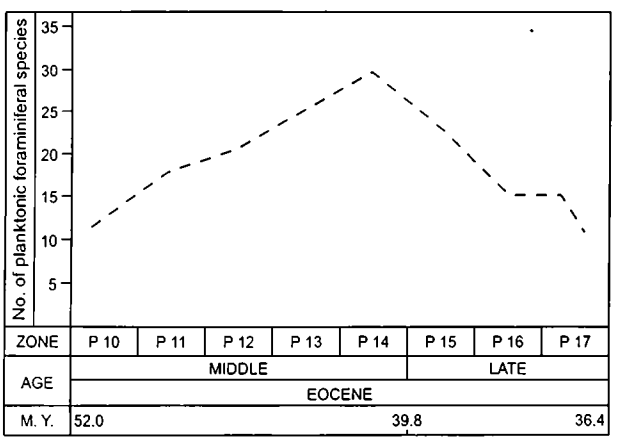

Fig. 8: Planktonic foraminiferal diversity trend in the Middle to Upper Eocene of the Istra more wells.

Trophic resources

Within the area investigated, planktonic foraminiferal associations show lateral differences in composition during the Middle and lower part of the Late Eocene. This variability resulted from the influence of local environmental conditions. The well IM-5, which is located to the north of the other two wells, yielded a high diversity association, which contained muricate species (genera *Morozovella, Acarinina, Truncorotaloides*). In contrast, the wells IM-3 and IM-4 contained only a low-diversity association (genera *Subbotina, Turborotalia* and *Globigerinatheka*) with a large number of individuals.

These differences might have been caused by differences in trophic recources, because planktonic communities are strongly influenced by this factor (Hallock, 1987). However, the relation between taxonomic diversity and nutrient supply is very complex (Hallock, 1987; Hallock *et al.*, 1991, Hemleben *et al.*, 1989). The IM-5 well could have been situated more closely to the Istrian Platform, and in the same time its position was more close to the northern land area (Fig. 1; mixed sources). This would have enabled a high supply of nutrients from the shallow sea. Planktonic foraminifera feed on phytoplankton, which, in turn, uses nitrates and phosphates derived from decomposition of macroalgae and seagrass available in the shallow sea. Additional nutrient sources were continental areas. Planktonic foraminiferal assemblages of the IM-3 and IM-4 wells, showing a lower diversity and a high abundance of individuals, reflect mesotrophic conditions (see Hallock *et al.*, 1991), and were probably situated more distantly to the land areas.

This is in contrast to the open ocean environments, where nutrient supply is more constant than in the regions with a strong influence of upwelling, runoff etc.

Depth habitats based on symbiosis-related morphologies

The Eocene genus *Globigerinatheka* include spinose forms (Pl. 4, Fig. 2) and their habitat was probably similar to recent *Globigerinoides ruber, G. sacculifer, G. conglobatus* etc. (Bé, 1982). These recent spinose planktonic foraminifera, like many other species in tropical and subtropical regions, possess algal symbionts (Bé, 1982; Hemleben *et al.*, 1989). They are limited to the uppermost waters because of the photosyntetic requirements of their algae (Bé, 1982; Murray, 1991). The Eocene *Globigerinatheka* must also have possessed a predisposition to host algal symbionts and must have occupied shallow habitats of the euphotic zone. Isotopic analyses for *Globigerinatheka index* also correspond to this environment (Pearson *et al.*, 1993). This species was a mixed layer dweller.

Oxygen isotope paleotemperatures suggested that a number of muricate species from the genera *Acarinina, Morozovella* and *Muricoglobigerina* were apparently depth stratified within the mixed layer (Pearson *et al.*, 1993). Muricate species (*Truncorotaloides rohri, T. topilensis, Morozovella spinulosa, Acarinina spinuloinflata* etc.) also had predispositions for hosting single-celled algal symbionts in their richly ornamented tests.

On the other hand, *Subbotina inaequispira* and *Turborotalia frontosa* must have occupied a deeper near- or sub-thermocline habitat, as the morphology of these two species can not be related to the presence of symbionts (Pearson *et al.*, 1993).

Later representatives of *Turborotalia cerroazulensis* lineage show smooth tests similar to that of the recent nonspinose *Globorotalia menardii*. Recent nonspinose species, which are usually without symbionts, are not re-

stricted to the euphotic zone and occur over a greater depth range, frequently below the euphotic zone (Bé, 1982). It is possible that similar habitats were occupied by forms of the *Turborotalia cerroazulensis* lineages.

CONCLUSION

The Northern Adriatic offshore area contains a succession of Middle to Late Eocene deposits, which recorded a complete sequence of standard planktonic foraminiferal zones (P 10 to P 17). During the zones P 10, P 11 and the early portion of the P 12 zone the depositional environment corresponds to a slope or base of the slope. The slope was connecting the Istrian Platform and the Venetian Basin. During the later portion of P 12, and during P 13 and P 14, the environment was likely to represent the base of a slope or basin floor. During the Late Eocene, the area was either a slope (P 16 and 17) or, alternatively, an early slope environment was later replaced by an outer shelf setting at the end of the Late Eocene.

During the Middle and Late Eocene, the North Adriatic Sea was a part of Mediteranean bioprovince with a subtropical to warm-temperate climate.

The area investigated contains two, laterally different types of planktonic foraminiferal associations, which differ in species diversity and test morphologies. These differences might have been due to different nutrient supply as a result of close *versus* distant positions of the ivestigated wells relative to the coast and shallow sea area. These differences define the two subenvironments.

The constant increase of the species diversity continued during Middle Eocene. After reaching its maximum at the end of the Middle Eocene, the diversity gradually decreased until the Oligocene, when the number of species dropped to a minimum. Diversity trends correspond to global events during Middle to Late Eocene (temperature changes, eustatic fluctuations of sea level, etc).

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The SEM photos were taken at INA-Naftaplin, Laboratory Research Department, and we thank Renata Slavković and Dunja Selinger-Kocijan for assistance.

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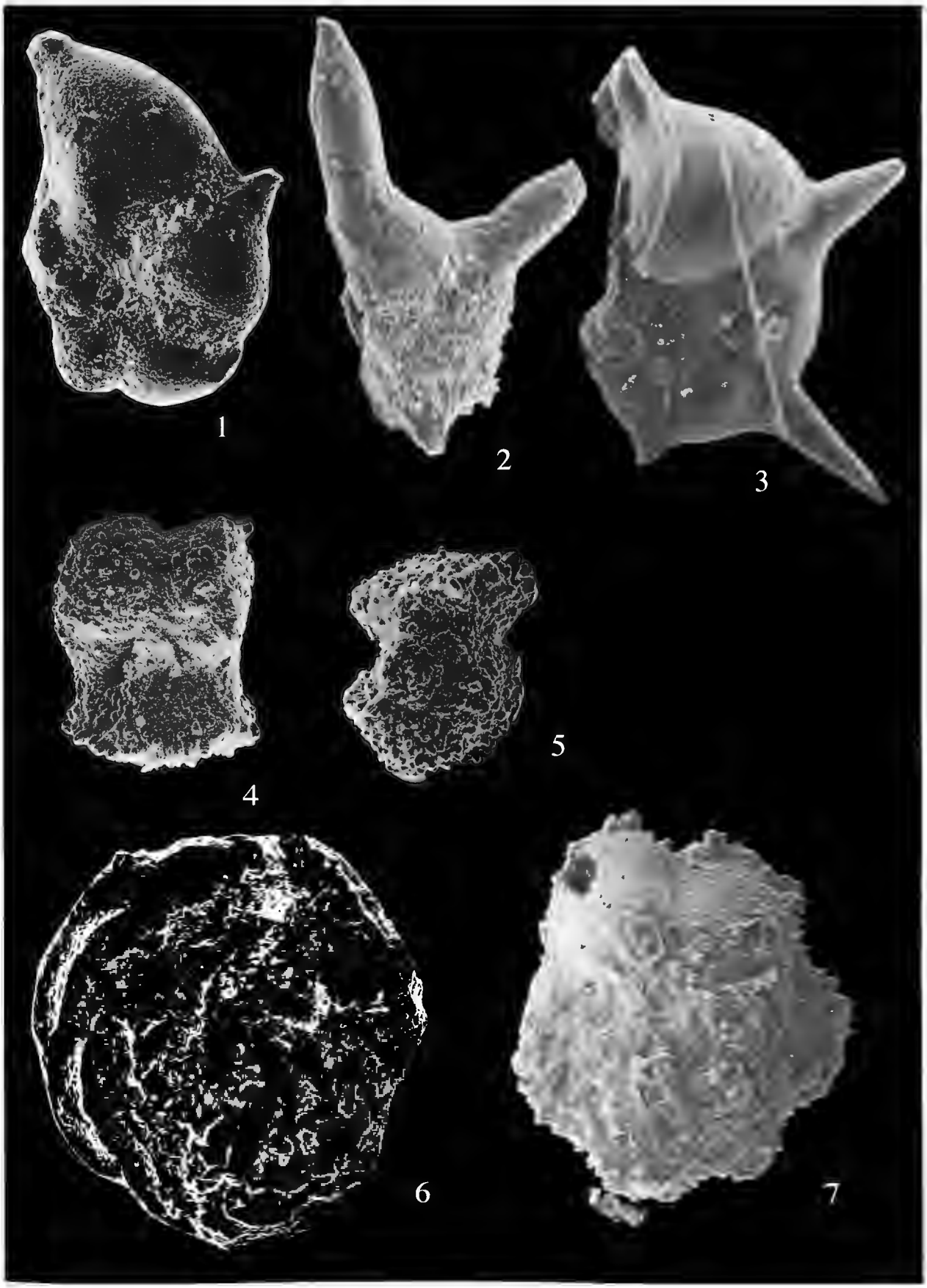
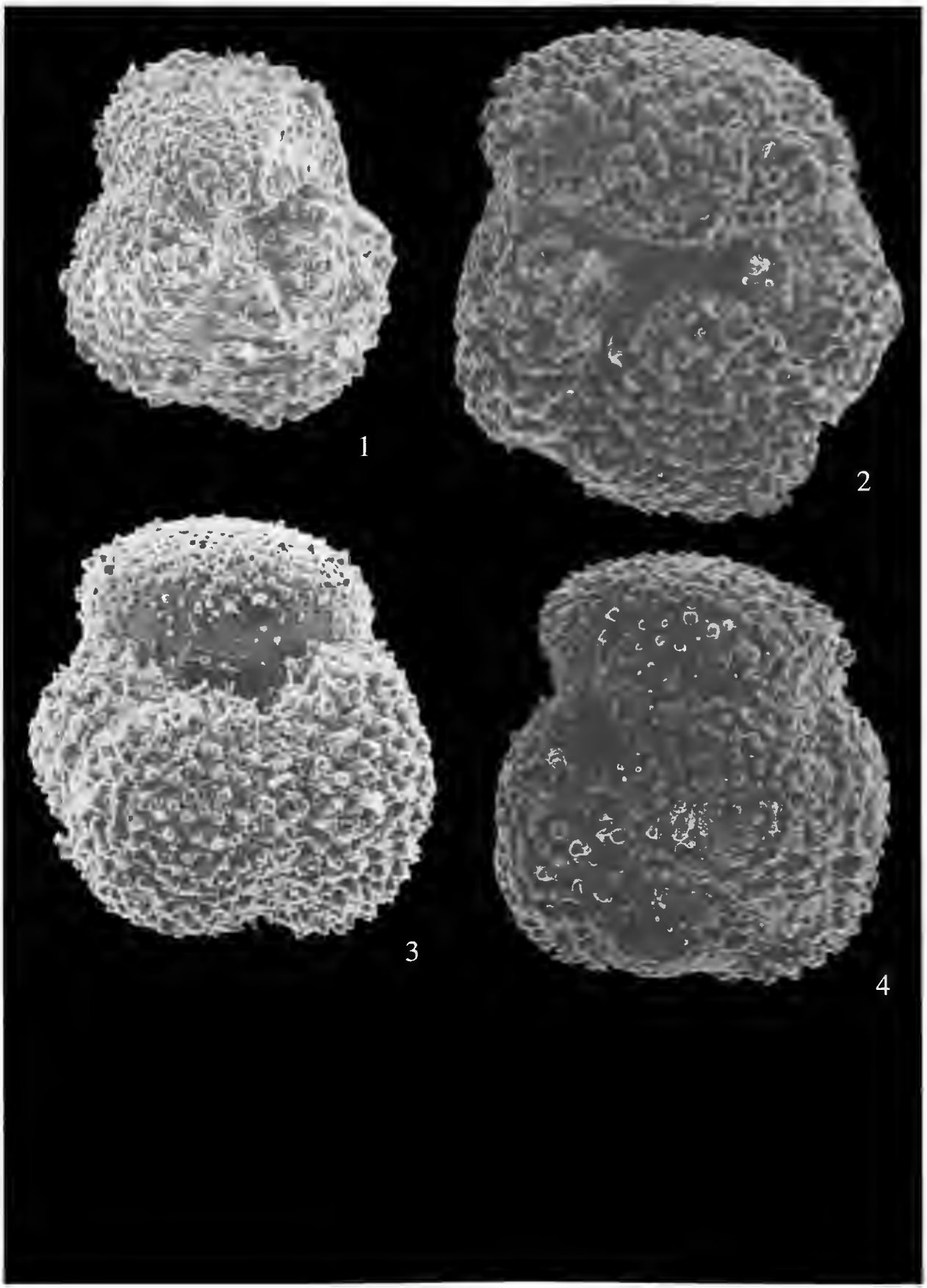
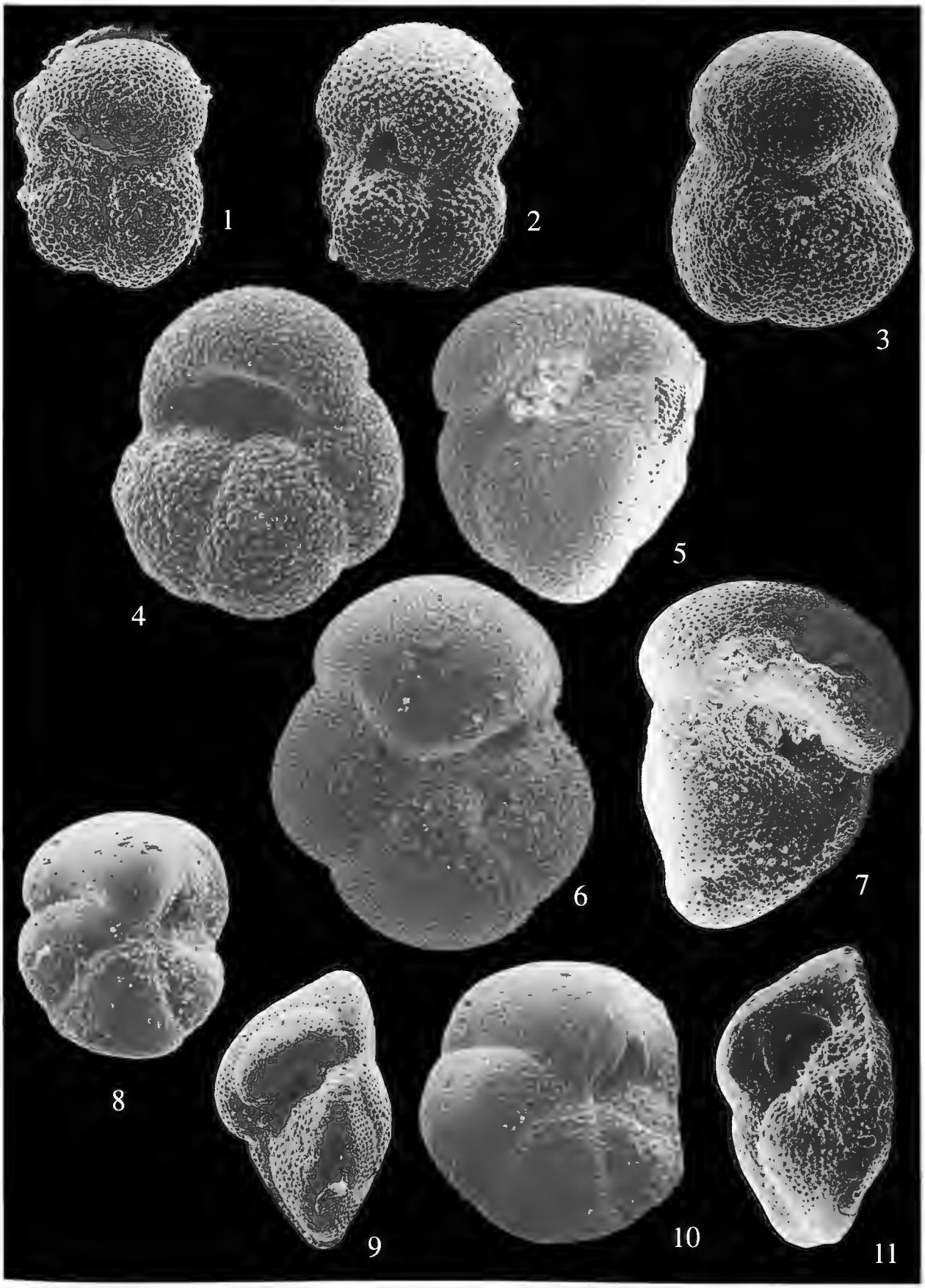


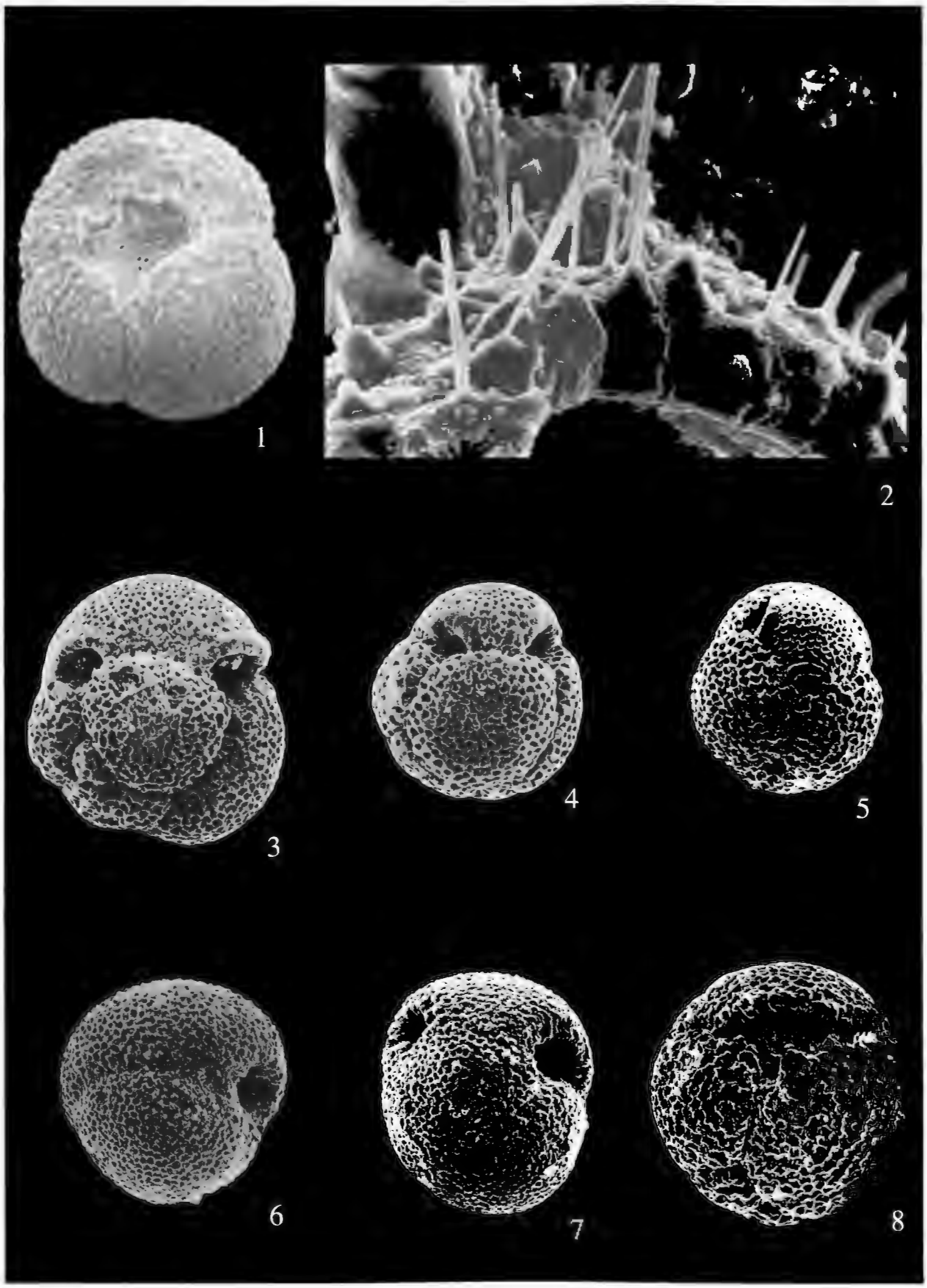
1. *Hantkenina dumblei*; **2.** *Hantkenina mexicana*; **3.** *Hantkenina alabamensis*; **4–5.** *Truncorotaloides topilensis*; **6.** *Morozovella aragonensis*; **7.** *Morozovella lehneri*; (all figures × 150, except 7 × 250).



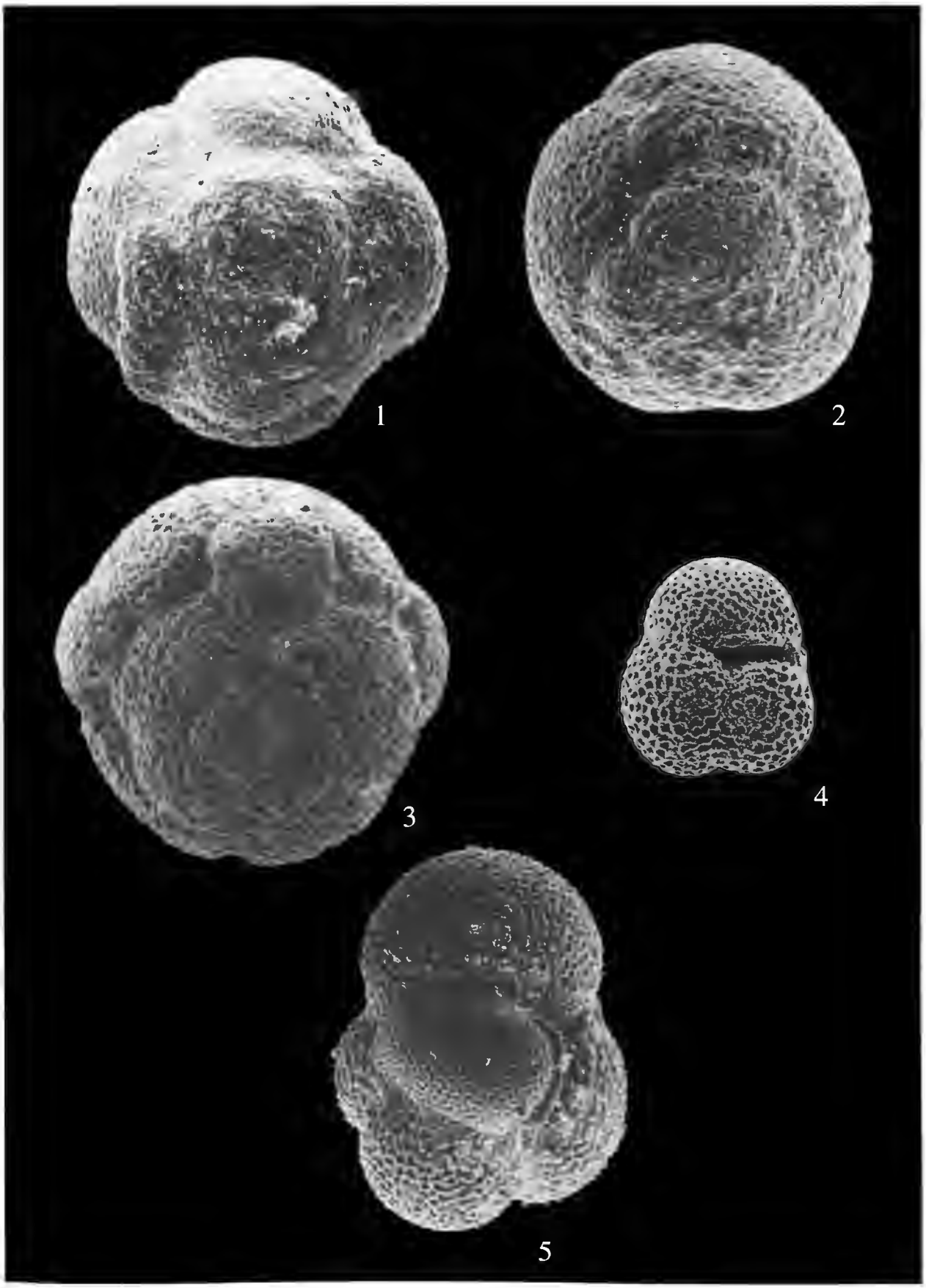
1. *Morozovella spinulosa*; **2.** *Acarinina spinuloinflata*; **3–4.** *Truncorotaloides rohri*; (all figures × 300, except 1. × 250).



1–2. *Turborotalia frontosa*; **3.** *T. possagnoensis*; **4–5.** *T. pomeroli*; **6–7.** *T. cerroazulensis*; **8–9.** *T. cocoaensis*; **10–11.** *T. cunialensis*; (all figures × 150, except 10–11 × 200).



1– *Globigerinatheka index*, **2.** *G. spines*; **3.** *G. tropicalis*; **4.** *G. mexicana*; **5.** *G. barri*; **6–7.** *G. semiinvoluta*; **8.** *G. subconglobata*; (all figures × 150, except 2. × 1310).



1. *Globigerinatheka curryi*; **2.** *G. euganea*; **3.** *G. luterbacheri*; **4.** *Globigerina angiporoides*; **5.** *G. eocaena*; (all figures × 150).

Dela – Opera SAZU 4. razr.	34/2	273–345	4 Figs	8 Plate	8 Tables	Ljubljana 1998

MAASTRICHTIAN AND PALEOCENE OSTRACODE ASSEMBLAGES OF MALI (WESTERN AFRICA)

Jean-Paul Colin[1], Yvette Tambareau[2] and Valerij A. Krasheninnikov[3]

Abstract

The ostracode faunas from the eight outcrops and boreholes in the Late Maastrichtian and the Paleocene of the Adrar des Iforas Massif in Mali uppermost Cretaceous have been studied. Seventy (70) species belonging to forty-three (43) genera have been identified; they are all illustrated and their taxonomy, stratigraphy and geographical distribution discussed. One new genus is erected, *Teiskotella* gen. nov. and 7 new species created: *Cytherelloidea christianae* sp. nov., *Bairdoppilata nafaensis* sp. nov., *Bopaina hottingeri* sp. nov., *Moosina terlineata* sp. nov., *Hornibrookella bellioni* sp. nov., *Hornibrookella apostolescui* sp. nov. and *Paracytheridea ? talackensis* sp. nov.

Two main ostracode assemblages have been recognized:

— a Maastrichtian *Rayneria tilemsiensis* and *Megommatocythere terrechtensis* assemblage, corresponding to the Horizon I with *Laffitteina* cf. *L. monodi*

— an Upper Paleocene (Thanetian) *Nucleolina tatteuliensis* assemblage corresponding to the horizons II–IV with *Elphidiella prima* (SBZ2?, SBZ3?), then with *Ranikothalia bermudezi* and *Lockhartia* sp. (SBZ3-4).

The first assemblage shows a strong endemism indicating a lack of communication with the Atlantic Gulf of Guinea during the Maastriehtian. In the second assemblage elosest faunal links with the Tethys can be recognized as well as with the Atlantic basins. The highest diversity, lowest endemism and strongest affinities both with the Tethyan and southern faunas were found in Horizon III (SBZ3) that may be indieative of a highest sea level rise, opening marine corridors between the Tethys and the Atlantic Gulf of Guinea.

Résumé

Les faunes d'ostracodes de huit affleurements et forages d'eau dans le Maastrichtien supérieur et le Paléocène supérieur autour du Massif des Adrar des Iforas, au Mali, ont été étudiées. Soixante-dix (70) espèces appartenant à quarante-trois (43) genres ont été identifiées; elles sont toutes illustrées et leur taxonomie, stratigraphie et distribution géographique discutées. Un nouveau genre est créé, *Teiskotella* gen. nov. et sept nouvelles espèces décrites: *Cytherelloidea christianae* sp. nov., *Bairdioppilata nafaensis* sp. nov., *Bopaina hottingeri* sp. nov., *Moosina terlineata* sp. nov., *Hornibrookella bellioni* sp. nov., *Hornibrookella apostolescui* sp. nov. et *Paracytheridea ? talackensis* sp. nov.

Deux associations principales d'ostracodes ont été reconnues:

— une association maastrichtienne à *Rayneria tilemsiensis* et *Megommatocythere terrechtensis*, correspondant à l'Horizon I à *Laffitteina* cf. *L. monodi*.

— une association paléocène à *Nucleolina tatteuliensis* correspondant aux Horizons II à IV à *Elphidiella prima* (SBZ2?, SBZ3?) puis à *Ranikothalia bermudezi* et *Lockhartia* sp. (SBZ3-4).

La première association, d'âge maastrichtien supérieur, se caractérise par un fort endémisme indiquant une absence de communication avec le Golfe de Guinée pendant cette période. Dans la deuxième association d'âge thanétien, des liens faunistiques plus étroits sont observés avec d'une part la Téthys, d'autre part les bassins atlantiques africains. La plus grande diversité, l'endémisme réduit et les fortes affinités avec les bassins sud-téthysiens et sud-atlantiques sont observés dans l'Horizon III (SBZ3). Ceci indique certainement un niveau marin élévé permettant l'ouverture d'un corridor marin entre la Téthys et le Golfe de Guinée.

Key words: Ostracoda, systematics, stratigraphy, Late Maastrichtian, Paleocene, paleobiogeographic distribution, Atlantic and Tethys.

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CONTENTS

INTRODUCTION

The investigated ostracode assemblages were collected by one of us (V.K.) in the uppermost Cretaceous and lowermost Tertiary sediments occurring around the Adrar des Iforas Massif studied by a soviet specialist team associated with the BRGM (Bureau de Recherches Géologiques et Minières) of Mali, from 1962 to 1967.

The sampled formations were divided into five horizons, termed, in an ascending order: 0 to IV (Krasheninnikov *et al.,* 1969). The limnic and brackish-water ostracodes associated with Upper Campanian-Lower Maastrichtian charophytes from the Horizon 0 were described and interpreted in previous works (Colin *et al.,* 1996a–b). This study concerns the ostracodes of the Horizons I, II, III and IV (Table 1). West of the Massif, in the Sudanese Straits (Tilemsi valley and Gao Trough), they were found, from the North to the South, in the Upper Cretaceous Aït Nafa outcrops, the Upper Cretaceous-Lower Tertiary NE Asselar (point 399) outcrops, the Lower Tertiary In Ori outcrops, then in the Lower Tertiary of the Agamor and In Orphan boreholes. South-East of the Adrar des Iforas, in the north-western margin of the Iullemmeden Basin, they have been recovered in the Upper Cretaceous and Lower Tertiary successions drilled by the In Talack and Takhabanat boreholes, in the Tertiary outcrops of Ibegan and in the Upper Cretaceous-Lower Tertiary outcrops of Creb d'Aginger (Figs 1, 2).

Meanwhile, a revision of the associated foraminifera has been undertaken by L. Hottinger who has kindly given us some preliminary indications about the index species of the four horizons.

About seventy species of ostracodes representing 43 genera were identified, forming two main successive assemblages and giving new information that will aid stratigraphic analysis and palaeogeographic interpretations. Since most of the species recorded and illustrated in this work have been previously described particularly in Mali and Nigeria, only brief taxonomic remarks, emendations or descriptions of new forms are made where necessary .

ACKNOWLEDGEMENTS

We would like to sincerely aknowledge the following persons: L. Hottinger (Basel) for providing the samples and information on the foraminifera, M.C. Keen (Glasgow) for data on Paleocene ostracode faunas from the Sirte Basin (Libya), D. Horne (Greenwich) for having carefully reviewed and corrected the English, all the colleagues who over the years send us reprints of their works on Late Cretaceous and Paleogene ostracodes from Africa and the Middle East, C. Chancogne-Weber (Paris) who took all the S.E.M. photographs.

This work was realized in the frame of the IGCP No. 286 ("Early Paleogene Benthos").

Table I: Location of samples in bore-holes and outcrops.

Holes and outcrops / Horizons	Outcrop 393 (Ait-Nafa)	Outcrop 399 (north-east of Asselar)	Outcrop 1155 (In-Ori)	Outcrop 1154 (In-Ori)	Bole-hole 2 (Agamor, Wadi Tilemsi)	In-Orphan bore-hole	In-Talack bore-hole	Bole-hole Ic (Takhabanat)	Outcrop 487 486 (Ibegan)	Outcrop 498 (Creb d'Aginger)
IV. Horizon with Lockhartia haimei			N88 (1155/4)	N89 (1154/1)	N59 (38,5 m) N58 (47,2 m) N57 (49,0 m) N56 (51,5 m) N55 (53,0 m) N54 (58,5 m) N53 (59,2 m) N52 (59,5 m) N51 (60,0 m) N50 (60,5 m) N49 (61,5 m) N48 (62,5 m)		N32 (44,5 m) N31 (46,0 m) N30 (47,0 m) N29 (48,0 m) N28 (48,5 m) N27 (50,5 m)			
III. Horizon with Operculinoides bermudezi			N87 (1155/3a) N86 (1155/3)		N47 (63,0 m) N46 (64,0 m) N45 (65,0 m) N44 (68,4 m) N43 (68,7 m) N42 (70,0 m) N41 (71,0 m) N40 (74,5 m) N39 (76,0 m) N38 (76,8 m) N37 (77,0 m) N36 (77,1 m) N35 (77,35 m) N34 (78,0 m)		N26 (52,5 m) N25 (53,0 m) N24 (55,5 m) N23 (58,0 m) N22 (67,0 m) N21 (67,5 m) N20 (90,0 m) N19 (92,0 m) N18 (93,0 m)	N70 (7,3 m) N69 (13,0 m) N68 (15,0 m) N67 (21,0 m)	N91 (487/2) N95 (486/3) N94 (486/4) N90 (487/3) N93 (486/6)	
II. Horizon with Elphidiella africana		N81 (399a/1)			N33 (79,0 m)	N79 (IV/c; 66,4 m)	N17 (93,5 m) N16 (102,0 m) N15 (105,0 m)	N66 (22,8 m) N65 (24,0 m) N64 (25,0 m)	N92 (486/7)	N78 (498/1) N77 (498/2) N76 (498/4) N75 (498/6)
I. Horizon with Laffitteina bibensis	N85 (393/6b) N84 (393/7b) N83 (393/8b) N82 (393/9b)	N80 (399/3)					N14 (115,0 m) N13 (116,08 m) N12 (121,0 m) N11 (122,6 m) N10 (122,65 m) N9 (125,0 m) N8 (127,0 m) N7 (128,5 m) N6 (128,8 m) N5 (131,0 m) N4 (132,5 m) N3 (136,5 m)	N63 (55,1 m) N62 (59,1 m) N61 (60,5 m)		N74 (498/23) N73 (498/25) N72 (498/27)
0. Horizon with Chara							N2 (233,0 m) N1 (248,5 m)	N60 (116,7 m) N71 (123,0 m)		

GEOLOGICAL SETTING AND PREVIOUS WORKS

The uppermost Cretaceous-lowermost Paleogene sedimentation succession extends to the south of the equivalent Algerian Tanezrouft basin succession by more than 1000 km, from Mali to Niger and Nigeria. It surrounds the crystalline basement of the Adrar des Iforas in the fossil Tilemsi valley and the Gao Trough then runs along the northern and eastern margin of the Iullemmeden Basin as far as the Sokoto Province in Nigeria (Fig. 1). This marine series overlies the continental Maastrichtian sequence, resting unconformably on the basement in a depression around the Adrar des Iforas. It is succeeded by the "Continental terminal", a thick clastic formation, the youngest levels of which unconformably overlie the Gourma basement. Because of its western and southern gentle dip, the marine series is easily reached, under the wide exposures of the "Continental terminal", by the numerous water boreholes drilled in the Gao and Iullemmeden basins.

The fossiliferous marine series has been diligently explored ever since the beginning of the century. During the geological mapping of the ex "AOF" (Afrique Occidentale Française), Radier (1953, 1959) had the opportunity to subject the whole sedimentary succession to minute investigations both in exposures and boreholes, especially in the Gao Basin. In his thesis (1959), he published a compilation of previous data preceding his observations and inferences. On palaeontological and lithostratigraphical basis, he divided the marine series occurring between the continental Maastrichtian below and the "Continental terminal" above, into four "stratigraphic groups" of various thickness with an obvious thinning near the threshold between the Sudanese Straits and the Iullemmeden Basin. These groups are composed of:

1. Limestone beds responsible for the cuesta overlooking the Maastrichtian depression, also called Terrecht I (Monod, 1939), suggested to be Danian.

2. Alternating sands, clays and thin calcareous levels, some of them with abundant marine shells, regarded as Lower Paleocene.

3. Highly fossiliferous marly limestones exposed in wide plateaux, ranging from Upper Paleocene to Ypresian and described as Terrecht II by Monod (1939).

4. Foliated shales with phosphatised levels related to the withdrawal of the sea during the Middle Eocene.

Afterwards, these data were completed, in Mali, by micropalaeontological studies (Monciardini, 1959, 1966 in Geigert and Pougnet, 1967; Krasheninnikov and Trofimov, 1969) which allow the characterization of four biostratigraphical/lithostratigraphic units defined as Horizon I with *Laffitteina bibensis,* Horizon II with *Elphidiella africana*, Horizon III with *Operculinoides bermudezi*, Horizon IV with *Lockhartia* cf. *haimei,* occurring all around the Adrar des Iforas and in a large part of the Iullemmeden Basin. These horizons are closely similar to the Radier's stratigraphic groups. They are generally acknowledged in further works but some of their ages, especially the age of the first one, are still debated despite diversified palaeontological studies (foraminifera, ostracodes, spores and pollen, microplankton, cephalopods, molluscs, echinoids, vertebrates ...) concerning them and their correlated formations in Niger or Nigeria (Fig. 2).

In most of the recent works concerning the Tilemsi valley (Bellion, 1989; Bellion *et al.,* 1990, 1992) or the Iullemmeden Basin (Dikouma *et al.*, 1993, 1994), similar ages are proposed for these horizons, based on new records of microfaunas in the Tilemsi and on a critical analysis of the whole palaeontological data added to updated correlations between the various formations in the Iullemmeden Basin. For all these authors, Horizon I belongs still to the Maastrichtian and is overlain by Horizons II, III, and IV assigned to the Upper Paleocene (at least non basal Paleocene) which led them, quite obviously, to suppose a Lower Paleocene hiatus. These equivalencies are well summed up in table 12 (Dikouma *et al.,* 1994). On the contrary, in their study of Malian ostracodes, Carbonnel and Monciardini (1995) and Boulard and Carbonnel (1995) retained Radier's dating of Danian to Ypresian following Krasheninnikov and Trofimov (1969) and Berggren (1974), without mentioning and discussing the new interpretations; moreover, they designated five ostracode biochronozones which are expected to be isochronous, different from the previous described Horizons I to IV which they regarded as diachronous.

Horizon I with *Laffitteina* cf. *monodi*

The marine Horizon I yielded the ammonite *Indoceras africanense* (= *Libycoceras ismaeli* Zitell for various authors) in six outcrops spread out from Tichet to Creb d'Aginger (Krasheninnikov and Trofimov, 1969; Ilyin *et al.*, 1970), (Fig. 3). It is well known from the Tanezrouft as far as the western part of the Iullemmeden Basin. It can be correlated with the upper part of the clastic series termed Upper Sandstones in Nigeria (Greigert, 1966) and corresponds to the In Wagar Formation defined in Niger (Dikouma *et al.,* 1993, 1994). This horizon, 5 to 6 m thick in the cuesta known as Terrecht I on the right side of the Tilemsi valley, decreases near the Gao Trough (2 m) then attains its greater thickness between the Azgaret and Azaouak valleys (more than 20 m) to decrease again eastward and disappear beyond Mentes on the southeastern margin of the Iullemmeden Basin. In the In Talack and Takhabanat boreholes respectively it occurs 96.5 m and 56 m above the charophytes and limnic ostracodes of Horizon 0 assigned to the Campanian-Maastrichtian passage (Colin *et al.*, 1996a, b).

There has been considerable debate as to whether this horizon is Maastrichtian or basal Paleocene (that is to say Danian). After giving a condensed account of the various age determinations of this fossiliferous index horizon in other basins, Radier (1959, p. 389) pro-

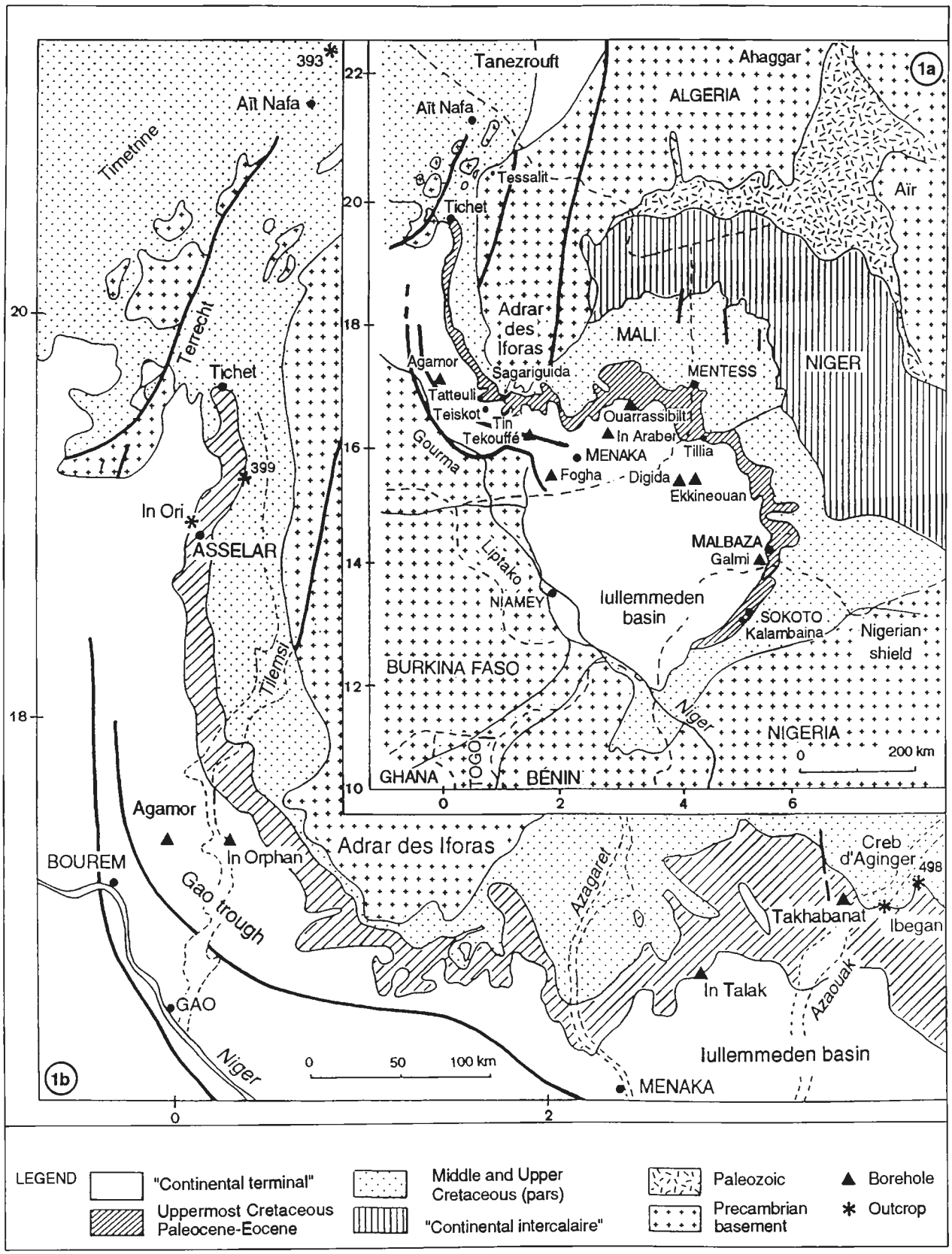

Fig. 1: Location map of the uppermost Cretaceous-Lower Eocene in the Terrecht Plateau, the Tilemsi valley, the Gao trough and the Iullemmeden Basin.

a. Outcrops and bore-holes studied by Apostolescu (1961), Damotte (1989) and Carbonnel (1995).

b. Outcrops and bore-holes studied in the present paper.

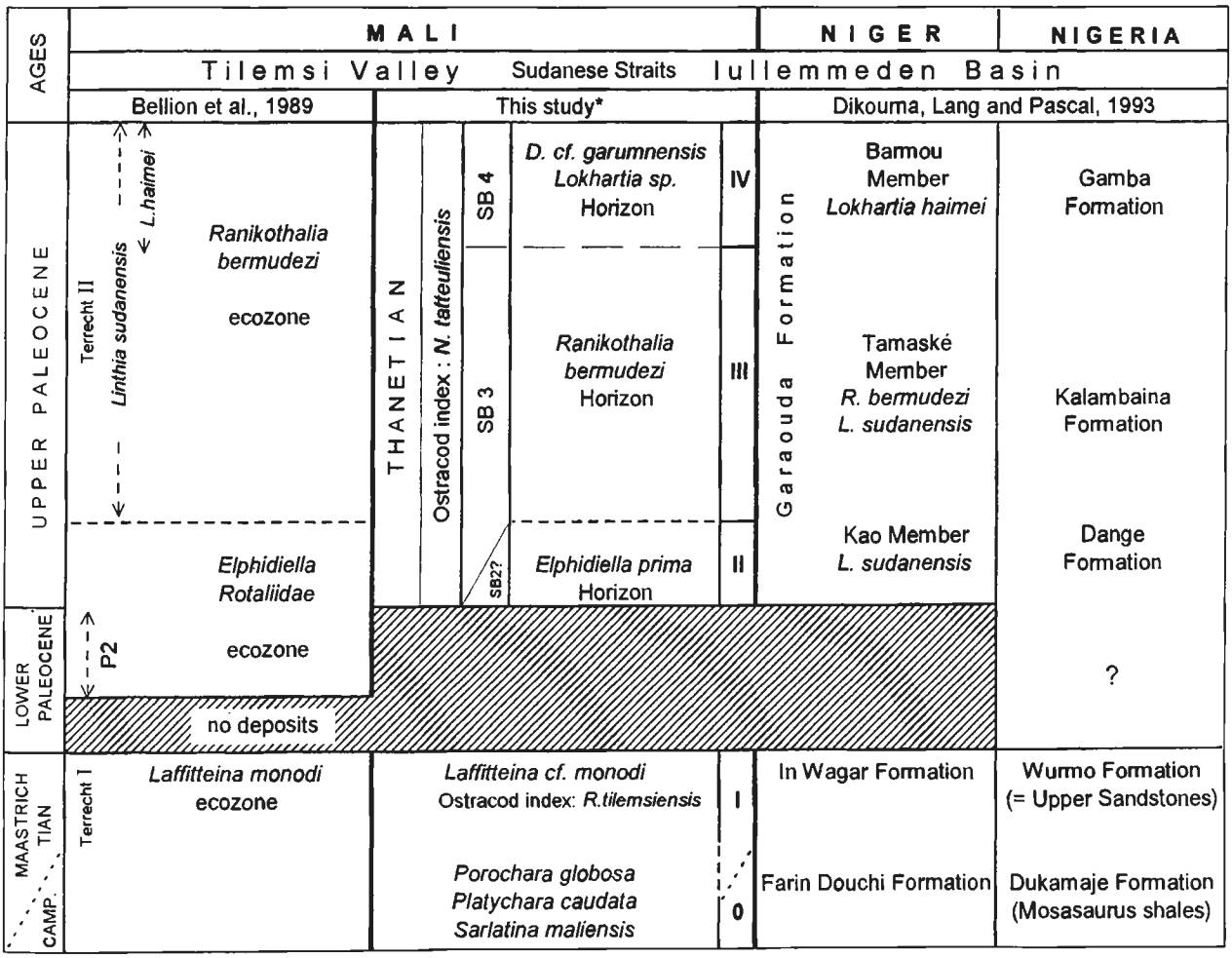

Fig. 2: Correlations of the Upper Cretaceous and Paleocene formations from Mali to northern Nigeria as proposed by various authors.

nounced it Danian, but specified that this term here meant only: "occurring between well dated Maastrichtian below and Montian-Paleocene above" and could be replaced by uppermost Maastrichtian or Danian-Montian. Apostolescu (1961) not only followed Radier's advice but correlated this uncertain Danian with the well dated "Zone à Globigerines" of the West African coastal basins. Krasheninnikov and Trofimov (1969), despite the occurrence of ammonites, assigned a Danian age to this horizon, essentially because it yields a lot of small benthic foraminifera similar to those occurring above, in the Horizon II of obvious Paleocene age. Berggren (1974) agreed with this age determination; moreover, he suggested a correlation between Horizon I and the Danian planktonic foraminifera zone P1 of Denmark and Libya because of some similarities between the small benthic foraminifera assemblages and because it underlies Horizon II corresponding to P2. With the exception of Carbonnel and Monciardini (1995), the authors recently concerned with the West African platform deposits regarded them as Maastrichtian, considering the ammonites as the most valuable stratigraphic index (as Peresbaskine 1932, Greigert and Pougnet 1967 did before them) and taking into account the diversified new palaeontological data. For Boudouresque (1980, Boudouresque *et al.*, 1982), this Horizon can be correlated with the Maastrichtian palynozone Z1 with *Buttinia andreevi* and *Longapertites microbaculatus*; for Dikouma *et al.* (1994, table 12), it is the most recent of the two *Laffitteina* levels named Z1b in the Upper Maastrichtian of the Iullemmeden Basin. For Hottinger too, (personal communication), the abundant *Laffitteina* cf. *monodi* MARIE previously assigned to the species *Laffitteina bibensis* MARIE (Krasheninnikov and Trofimov, 1969; Bellion *et al.* 1987; Carbonnel and Monciardini, 1995) or *Laffitteina monodi* (Radier, 1959; Saint-Marc in Bellion *et al.*, 1989, p. 1989) and the associated "elphidiellid" forms would indicate a Late Cretaceous, possibly Maastrichtian age for Mali Horizon I.

Overlying some marly sands yielding remains of fishes and crocodiles, the most part of Horizon I is made up of massive limestones with an abundant and diverse macrofauna of molluscs occurring near their top. Only two of the examined boreholes penetrate this Horizon and its underlying and overlying formations (Fig. 3). In In Talack and in Takhabanat, Horizon I is respectively 21 m and 17 m thick, located 96.5 m and 56 m above the Campanian to Lower Maastrichtian levels with charophyte oogonia and non-marine ostracodes.

Horizon II with *Elphidiella*

Horizon II reaches about 20 m thickness in the northern part of the Tilemsi valley and about 8 m thick between the Azagaret and the Azaouak valleys but, like Horizon I, it is getting thinner near the threshold (stratigraphic group 2 in Radier, 1959, p. 343), (Fig. 3).

For Krasheninnikov and Trofimov (1969) and Berggren (1974), this Horizon with *Elphidiella africana* (Le Roy) corresponds to the upper part of the Lower Paleocene, but for Berggren, partly to the basal Upper Paleocene too. Its microfauna, if not more abundant, appears to be more diversified than the previous one . Moreover, in its Tichet area outcrops, Bellion *et al.* (1989) did not find any *Elphidiella africana* but obtained a poor planktonic foraminifera assemblage composed of *"Globorotalia"* cf. *chapmani* and *"Globorotalia"* cf. *uncinata* said to be characteristic of P2. For these authors, this age determination, added to the occurrence of desiccation cracks at the top of the subjacent limestones Terrecht I indicates the lack of the basal Paleocene (P1).

According to Dikouma *et al.* (1993, 1994) working in south-western Niger, this gap represents the whole Lower Paleocene in the Iullemmeden basin where Horizon II would be equivalent to the lower clayey series of the Garouada Formation, named Kao Member, at least partly dated as Upper Paleocene by its fauna, *Linthia sudanensis, Plesiolampas saharae* and various molluscs, fish and ostracodes (Carbonnel *et al.,* 1990). Its assignment to the Lower Paleocene (Monciardini, 1959 *in* Greigert and Pougnet, 1967, Boudouresque, 1980) is said not to be demonstrated, the benthic foraminifera being analogous to those of Horizon III and Boudouresque's Palynozone II being "highly hypothetical". No reference is made to the discovery of planktonic foraminifera of P2, evidence that a Lower Paleocene occurs, if not in the whole Iullemmeden Basin, at least in the Tilemsi valley.

For Hottinger (personal communication), according to the ranges of some genera of rotaliids present such as *Thalmannita* or *Lockhartia*, Horizon II cannot be older than SBZ2, this meaning that there is a gap in the marine series equivalent to at least SBZ1 if not including SBZ2 (Serra-Kiel *et al.*, in press).

If they do not quite agree with its duration, all the authors (except Carbonnel and Monciardini, 1995) writing now about the Sudanese Straits and the Iullemmeden Basin notice the occurrence of a basal Paleocene gap, as do numerous other authors, interested in western African platform series: Kogbe in Nigeria (1979), Dubois and Lang (1981) in Niger, Masala, Laurin *et al.,* 1994 in the Congo basin and even N'da *et al.*, 1995 in the Ivory Coast basin.

In the studied outcrops and boreholes, Horizon II occurs in Asselar 399, Agamor, In Orphan, In Talack, Takhabanat, Ibegan, Creb d'Aginger. In In Talack and Takhabanat, its thickness reaches respectively 11.5 m and 2.2 m; its first fossiliferous level occurs 10 m and 30 m above the last one of Horizon I which indicates a rather significant gap of palaeontological data between Horizons I and II (Fig. 3).

Horizon III with *Ranikothalia bermudezi* and IV with *Lockhartia* cf. *haimei*

Horizons III and IV, responsible for the cliff and the calcareous plateaux, are described as Terrecht II (Monod, 1939) in the Tilemsi valley and as "stratigraphic group 3", from Upper Paleocene to Ypresian, in the Gao basin (Radier, 1959). They are characterised by the abundance of their fauna: molluscs, echinoids with *Linthia sudanensis* as below, and larger foraminifera with *Ranikothalia* and later *Lockhartia.*

For Bellion (1987), they comprised a single formation, the second Paleocene one, 5 to 20 m thick in the Sudanese straits, and reaching 50 m in the middle part of the Iullemmeden basin. *Ranikothalia bermudezi* occurs in the whole formation but large *Lockhartia* cf. *haimei* appears only near its top where clayey levels are interbedded in the massive limestone.

Following Monciardini *in* Greigert and Pougnet (1967, p. 158), Horizon III with *R. bermudezi*, the base of which coincides with limestones, is Paleocene; Horizon IV, that corresponds to the last metres of the limestones and to the first ones of the overlying shaly series may belong either to Upper Paleocene or to Ypresian.

Krasheninnikov and Trofimov (1969) also separated Horizon III from Horizon IV but considered both to be Paleocene. So did Dikouma *et al.* (1993, 1994) who divided the marine Paleocene Garadoua Formation of Niger into 3 members (Fig. 2), the second one (i.e. "Tamaske Member") characterized by *Ranikothalia bermudezi* would correspond to Horizon III, the last one (i.e. "Barmou Member" = Schistes papyracés *auct.*) containing some *Lockhartia*, to Horizon IV.

For Hottinger, the occurrence of *Ranikothalia bermudezi* found in SBZ3 (Pyrenees) and large *Lockhartia* sp. in Horizon III, then of *Lockhartia* cf. *haimei* together with *Daviesina* cf. *garumnensis,* an index fossil of SBZ4, in Horizon IV indicates a Late Paleocene (Thanetian) age.

Horizon III has been sampled in In Ori and Agamor then in In Talack and Takhabanat where its superposition to Horizon II can be seen, and finally in Ibegan. Horizon IV occurs only in In Ori, Agamor and In Talack (Fig. 3).

Thus, according to the benthic foraminifera, the Mali marine sequence seems to represent a Late Maastrichtian cycle corresponding to the Mali Unit I and a Late Paleocene, Thanetian cycle comprising possibly SBZ2 and certainly SBZ3 and 4. This corresponds to the global pattern of sequences characterized by a particularly high eustatic sea level during SBZ3.

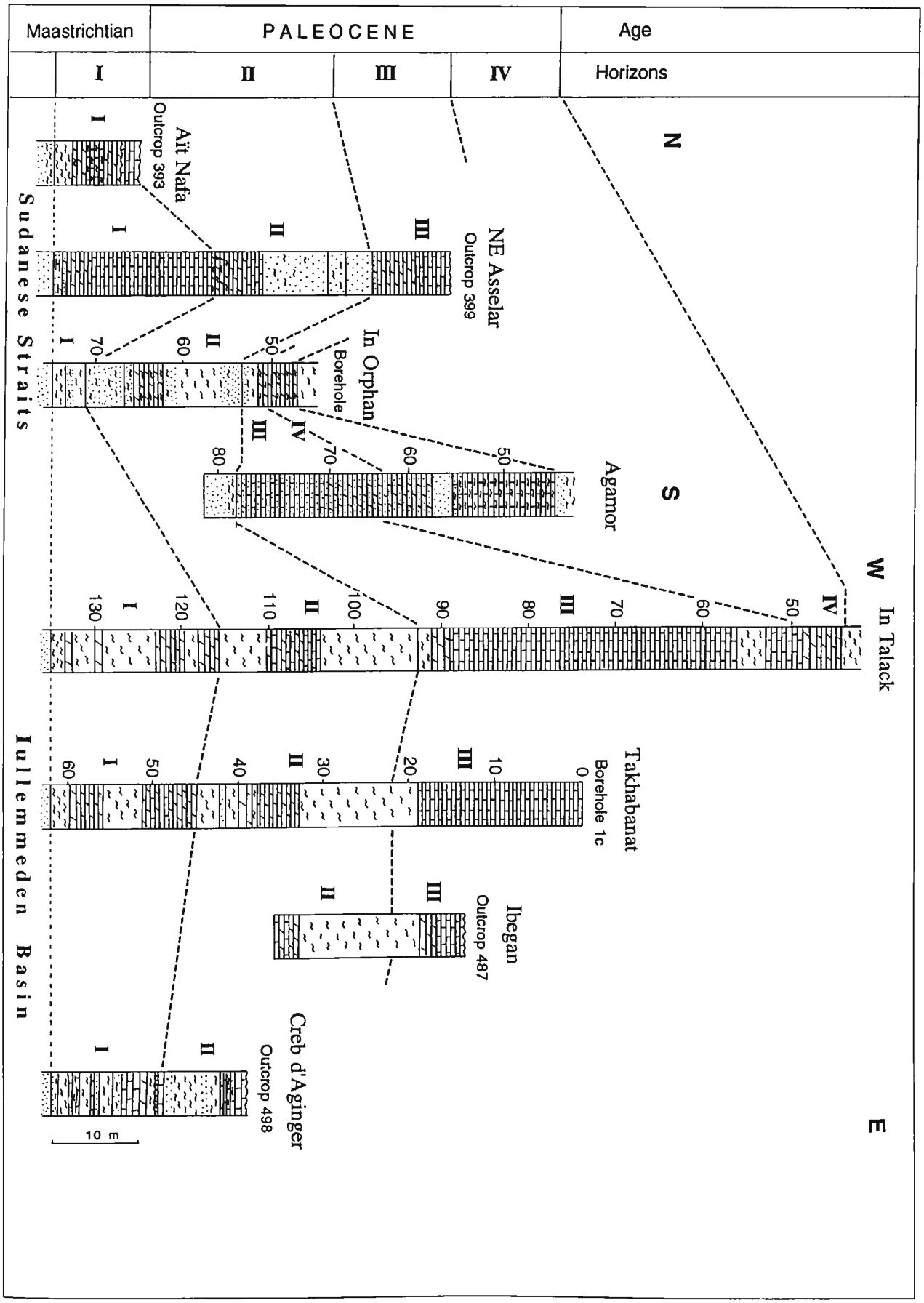

Fig. 3: Upper Cretaceous and Paleocene section of the investigated outcrops and bore-holes.

OSTRACODS FROM UPPER CRETACEOUS AND PALEOCENE OF MALI		OCCURRENCE IN OTHER COUNTRIES			
Studied species	Horizons I-II-III-IV	UPPER RETACEOUS	EARLY PALEOCENE	LATE PALEOCENE	EOCENE
Cytherelloidea christianae n. sp.	I				
Bairdoppilata nafaensis n. sp.	I				
Paijenborchellina sp. 1	I				
Hornibrookella apostolescui n. sp.	I				
Dameriacella ? tessalitensis	I				
Paracytheridea talackensis	I				
Rayneria tilemsiensis	I	N			
Brachycythere oguni	I	N Ns T Gh A Tu E	Ns A	A	
Buntonia issabaensis	I	N	Ns B T S G	N Ns S B I G	
Ovocytheridea pulchra	I		S L	N Nn S B	S
Paracypris sp. A	I-II	N A Tu	Tu		
Iorubaella sp.1	I-II	N		L	
Megammocythere terrechtensis	I-II				
Moosina terlineata n. sp.	I-II				
Cytherella gr. *meijeri*	I-II-III	A ? Nn Mc	A Tu L	A L	L
Uroleberis glabella	I-II-III	Ar	L S	N Nn S L E	S E
Bythocypris olaredodui	I-II-III	Nn	M S G I Ns	N Na S T I G B	Ns EGS T I
Xestoleberis sp. 1	I- -III				
Buntonia bopaensis	I-II-III	Nn	Tu L C I	N Nn B Tu L C I	
Acanthocythereis niameyensis	I-II-III-IV			N Nn	
Propontocypris sokotoensis	I- -III-IV		S	N Nn S E	S E
Ponticulocythere cf.*austraegyptiaca*	I-II-III-IV			N E	E
Dahomeya alata	I-II-III-IV		L Cg	N Nn S I T Tu E B Cg	S Tu
Propontocypris nigeriensis	I-II-III-IV	Nn Gh	Ns T L	N Na T L	E
Cytherella sylvesterbradleyi	I-II-III-IV	Na L Gh	Ns S L Cg	N Na B S L	I Na S
Buntonia apatayeriyerii	I-II-III-IV	Gh	S L Ns	N Na S L	S
Buntonia tilemsiensis	I-II- -IV	N		S	
Krommelbeinella trapezoidalis	I-II-III-IV			N	
Iorubaella virgulata	I-II-III-IV		S L	N S	S
Trachyleberis teiskotensis	I-II-III-IV	Nn	Ns I C Su L Cg	N S I T B Na C Su LE Cg	E
Paragrenocythere sehouensis	I-II-III-IV		S	N Nn L S	S
Paragrenocythere cultrata	I-II-III-IV	Nn		I Nn N L E	L E
Isalocopocythere teiskotensis	I-II-III-IV	Ar	L Ar	N Na L Ar	
Isohabrocythere teiskotensis	I-II-III-IV		B	N I Na L E B	T E L
Occultocythereis confirmatus	I-II-III-IV		L	N E L	E L
Buntonia tichittensis	I-II-III-IV		S	N Nn S L	T S L
Oertliella vesiculosa	I-II-III-IV		S	N Nn L	
Parakrithe kalambanaensis	I-II-III-IV		L Is	N Nn L E	E
Teiskotella teiskotensis	I-II-III-IV		Ns L G	N Ns S G B E	S
Soudanella cf *laciniosa laciniosa*	II		S I Cg Ns Br ?Mc	N Ns S I T B Cg ?Mc	S T
Hermanites sp. 1	II				
Evisceratocythere? sp. 1	II				
Paracypris gr. *jonesi*	II-III	Tu	Tu L	N S T L E	E
Bairdoppilata ilaroensis	II-III	Gh E L	?S G Ns L E	N Na ?S G B L E	S E L
Iorubaella ologuni ologuni	II-III		Ns S B C L	N Na S B C L	S
Paracosta warriensis	II-III	Nn A L N	L	N L E	?E ?L ?A
Bopaina hottingeri n. sp.	II-III			N	
Buntonia pyriformis	II-III			N	
Buntonia isobopaensis	II-III			N Ns B L	L
Pataviella cf. *digidaensis*	II-III			N	
Nucleolina tatteuliensis	II-III-IV		S L	N Nn S L ?E	E S
Cytherelloidea musacea	II-III-IV		L	N L	E
Propontocypris ? mentesensis	II-III-IV			N	
Schizoptocythere usmandanfodioi	II-III-IV	Gh	L	N Na B	
Foveoleberis teiskotensis	II-III-IV		L Ar Cg	N E L Ar Cg	E
Bythocypris fosteralii	II-III-IV		L S T	N Na T M S L E	S E
Parakrithe ? sp 1	III				
Cytherella sp. 1	III				
Cytherella sp. 2	III				
Neonesidea ilaroides	III		S	N Nn T S	S
Neonesidea sp. 1	III				
Oertliella tubra	III			N Nn L E	
Paragrenocythere aff.*mudhensis*	III				aff In
Dameriacella kaoensis	III			N E	E
Neonesidea elongatoilaroensis	III-IV		I S	N Nn I B S	S
Patrizia cf. *lagaghiroboensis*	III-IV	?T	S C	N Ns I C S L	S E
Hornibrookella bellioni n. sp.	III-IV				
Schizocythere salahii	IV	N		N	E L
Buntonia misreia lineata	IV			E L	
Stigmatocythere brmgensis	IV			S	S

OSTRACODE ASSEMBLAGES

The total ostracode fauna numbers about 70 species belonging to 43 genera. It was found by one of us (V.K.) in samples located in table 1 and studied by the two others (J.P.C. & Y.T.). The ranges and abundance of the different species in the main investigated sections are given in tables 3–8. One new genus and 5 new species are described. The diversity of the assemblages increases from Horizon I reaching a maximum in Horizon III. The trend is then reverse in Horizon IV (Table 2).

→

Table 3: Ostracode distribution chart in In Ori outcrop.

IN ORI		Parakrithe ? kalambainaensis	Hornibrookella bellioni	Neonesidea ilaroelongatoides	Foveoleberis teiskotensis	Isalocopocythere teiskotensis	Cytherella sylvesterbradleyi	Paragrenocythere cultrata	Buntonia tichittensis	Trachyleberis teiskotensis	Schizocythere salahii	Nb. of specimens	Species Diversity S
Horizon IV	N89				2	11	2	3	2	1	1	22	7
	N88					1	1					2	2
Horizon III	N87					12						12	1
	N86	1	2	1	10	6						20	5

AGAMOR		Bairdoppilata ilaroensis	Buntonia apatayeriyerii	Isohabrocythere teiskotensis	Isalocopocythere teiskotensis	Oertliella vesiculosa	Paracypris sokotoensis	Uroleberis glabella	Bythocypris fosteralii	Schizoptocythere usmandanfodioi	Nucleolina tatteuliensis	Paragrenocythere cultrata	Parakrithe sp.	Oertliella tubra	Cytherella sylvesterbradleyi	Trachyleberis teiskotensis	Cytherella gr. meijeri	Pataviella digidaensis	Dameriacella kaoensis	Paragrenocythere aff. P. mudhensis	Neonesidea sp. 1	Occultocythereis confirmatus	Paraplatycosta ? sp.	Buntonia tichittensis	Foveoleberis teiskotensis	Xestoleberis sp.	Buntonia sp.	Parakrithe ? kalambainaensis	Buntonia misreia lineata	Stigmatocythere brgmensis	Schizocythere salahii	Nb. specimens	Species diversity S
Horizon IV	N59				1	1																			1							3	3
	N58			1																				2								3	2
	N57					1											1				1			2								5	4
	N56					2																								1		3	2
	N55														4	1								2								7	3
	N54																							2								2	1
	N53															1																1	1
	N52				1											5								14					1	1		22	5
	N51				1							1				2																4	3
	N50				2																										1	3	2
	N49			1	5							2													3			3	3	3		20	7
	N48																										2					2	1
Horizon III	N47				1											1																2	2
	N46										2					1										1						4	3
	N45		1		4	2						1			1	2									1							12	7
	N44				7											3																10	2
	N43				3	1									1	1																6	4
	N42				2	1										2								2								7	4
	N41				1						1				1																	3	3
	N40	1			1						3				1								1									7	5
	N39			2																	1											3	2
	N38			2	6	2				1	1			1	3	2	2	5	2	1	1											29	13
	N37				2				1			2			1	2																8	5
	N36				1						2				1																	4	3
	N35		5	4	9					1	3	5	3	2	8	1	1															42	11
	N34	5	2	2	13		2	2	1	1	6	2																				36	10
Horizon II	N33	1	1	3	1	1																										7	5

←Table 2: Stratigraphic and paleogeographic distributionof the studied ostracode species.

↑ Table 4: Ostracode distribution chart in Agamor borehole.

I												II			III									IV						
N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23	N24	N25	N26	N27	N28	N29	N30	N31	N32	IN TALACK
1	1					1																								Buntonia issabaensis
3				3	1			2	1																					Rayneria tilemsiensis
1								4		1																				Brachycythere oguni
	1																													Moosina terlineata
	1	2		9	5				3		2	1																		Cytherella gr. meijeri
	1			1	7			1				1												1						Megommatocythere terrechtensis
		1																												Ponticulocythere aff. austraegyptiaca
		2				1																								Paracytheridea ? sp.
		1															1													Uroleberis glabella
		4																			5	5								Paragrenocythere sehouensis
		1												1				1			3		1							Isohabrocythere teiskotensis
		1											1	2				1			3		1			1				Oertiella vesiculosa
		13																						1	1	1			2	Buntonia tichittensis
		5							1					4							5	3	1	1	2	2	1		2	Trachyleberis teiskotensis
		3		1				1					7		1	2	2	2	1	2	6			1		2			5	Isalocopocythere teiskotensis
			1	2	1			1																						Xestoleberis sp. 1
			6	13	5	3		9		6																				Propontocypris nigeriensis
			1																						1	1				Bythocypris ? sp.
				2																										Kroemmelbeinella trapezoidalis
				3	2																									Iorubaella sp. 1
				1			1																							Paracypris sp.
				2	1			5																						Dameriacella ? tessalitensis
				3	3				1					4																Buntonia tilemsiensis
					1		1	4		1																				Hornibrookella apostolescui
					1						2		1																	Parakrithe sp.
						1																								Paijenborchellina sp. 1
						3			1																					Paracypris sp. A
							1									1		1	1		2					2		1		Paragrenocythere cultrata
										1																				Cytherelloidea weberae
												1		4									5							Buntonia bopaensis
												1	3								1	3				1	1	2		Cytherella sylvesterbradleyi
														2																Soudanella cf. S. laciniosa laciniosa
														1																Teiskotella teiskotensis
														1																Dahomeya alata
														1																Evisceratocythere ? sp. 1
														1																Paracypris gr. jonesi
														3																Buntonia pyriformis
														7									18							Bopaina hottingeri
															1															Bairdoppilata sp.
															1	1			1											Nucleolina tatteuliensis
																1	2													Bythocypris fosteralii
																		1												Cytherella sp. 1
																		1												Neonesidea ilaroides
																		1								1				Buntonia apatayeriyeri
																					1									Patrizia? lagaghiroboensis
																					1	1								Paracosta warriensis
																					6		7							Buntonia isobopaensis
																					1			6		1				Foveoleberis teiskotensis
																						1				1		1	1	Hornibrookella bellioni
																							3							Iorubaella virgulata
																							1							Propontocypris ? mentesensis
																							1							Bythocypris olaredodui
																							1							Cytherella sp. 2
																													1	Stigmatocythere brgmensis
5	4	33	8	40	27	9	3	27	7	9	4	4	12	31	3	5	5	8	3	2	34	13	39	10	4	13	2	4	11	Nb. of specimens
3	4	10	3	11	10	5	3	8	5	4	2	4	4	12	3	4	3	7	3	1	11	5	10	5	3	10	2	3	5	Species Diversity S

Table 5: Ostracode distribution chart in In Talack borehole.

TAKHABANAT		Buntonia issabaensis	Cytherella gr. meijeri	Megommatocythere terrechtensis	Rayneria tilemsiensis	Buntonia tilemsiensis	Propontocypris nigeriensis	Trachyleberis teiskotensis	Parakrithe sp.	Hornibrookella apostolescui	Iorubaella sp. 1	Buntonia apateyeriyerii	Buntonia bopaensis	Kroemmebeinella trapezoidalis	Hermanites sp. 1	Bythocypris ? sp.	Propontocypris ? mentesensis	Buntonia pyriformis	Bopaina hottingeri	Cytherella sylvesterbradleyi	Paragrenocythere sehouensis	Oertliella vesiculosa	Isohabrocythere teiskotensis	Paragrenocythere cultrata	Isalocopocythere teiskotensis	Nucleolina tatteulensis	Bythocypris fosteralii	Parakrithe ? kalambainaensis	Uroleberis glabella	Paracypris sokotoensis	Bairdoppilata ilaroensis	Neonesidea sp.1	Cytherella sp. 1	Nb. of specimens	Species Diversity S
III	N70																									1				1			2	2
	N69																								1	1						1	3	3
	N68																									6	1				3	1		11	4
	N67																						2	1		9	2		1	2	1			18	7
II	N66							1														1		1		3	7	1	1	1				16	8
	N65							3			1							3	2	5	2	1	6	1	6	9	2							41	12
	N64							9				1	2	1	2	4	2	1	1	8	3	2	4	4	12	10								65	16
I	N63			4	1	2	2			2	2																							13	6
	N62		1						1																									2	2
	N61	3	8	6	5	3	5	1																										31	7

Table 6: Ostracode distribution chart in Takhabanat borehole.

IBEGAN	Horizon III N91	N95	N94	N90	N93	Horizon II N92
Paracypris gr. jonesi						1
Bythocypris olaredodui						1
Paracypris sp. A						1
Buntonia sp.						1
Parakrithe ? kalambainaensis						1
Paragrenocythere sehouensis						4
Paracypris sokotoensis						1
Paragrenocythere cultrata					1	3
Trachyleberis teiskotensis				2		3
Oertliella vesiculosa				1		18
Cytherella sylvesterbradleyi	1				2	5
Nucleolina tatteuliensis	1	2	2	2	2	33
Bythocypris fosteralii	3	2	5	2	4	3
Hermanites tahouensis					1	
Cytherelloidea musacea					1	
Pataviella digidaensis					1	
Bairdoppilata ilaroensis		1		5	2	
Isalocopocythere teiskotensis	1			2	1	
Uroleberis glabella				1		
Oertliella tubra				1		
Neonesidea elongatoilaroensis		1		2		
Isohabrocythere teiskotensis		1				
Bairdoppilata nafaensis	2					
Nb. of specimens	8	5	8	18	15	75
Species Diversity S	5	4	3	9	9	13

Table 7: Ostracode distribution chart in Ibegan outcrop.

CREB D'AGINGER	II N78	N77	N76	N75	I N74	N73	N72
Kroemmelbeinella trapezoidalis							1
Bythocypris olaredodui							1
Cytherella gr. meijeri					1		2
Parakrithe sp.				1	3		5
Rayneria tilemsiensis					1	14	
Megommatocythere terrechtensis				4	5	1	
Brachycythere oguni					3		
Ovocytheridea pulchra					3		
Propontocypris nigeriensis					7		
Hermanites sp. 1				2			
Isalocopocythere teiskotensis			13	6			
Isohabrocythere teiskotensis			1	4			
Nucleolina tatteuliensis	2	2	2	1			
Trachyleberis teiskotensis	2	2	1	1			
Paragrenocythere cultrata	2	2	2	5			
Acanthocythereis nyameyensis	2	2	5	5			
Bythocypris fosteralii	1		3	3			
Teiskotella teiskotensis	1	3	1	4			
Oertliella vesiculosa	1	4	3	3			
Cytherella sylvesterbradleyi	4	15	5	4			
Iorubaella ologuni ologuni		2					
Paracypris gr. jonesi		1					
Buntonia sp.		1					
Parakrithe ? kalambainensis		1					
Propontocypris ? mentesensis		1					
Paracosta warriensis	1	5					
Soudanella cf. S. laciniosa laciniosa	2	3					
Nb. of specimens	14	44	33	43	23	15	9
Species Diversity S	8	14	9	13	7	2	4

Table 8: Ostracode distribution chart in Creb d'Aginger outcrop.

Maastrichtian: *Rayneria tilemsiensis* and *Megommatocythere terrechtensis* assemblage

The Horizon I has yielded 39 species of ostracodes belonging to 31 genera. More than 30 % of these species are confined to the studied basin (Mali, Western Niger), especially the seven never recorded in Tertiary levels.

The majority of the species recorded in Horizon 1 appear to have a long time range on both sides of the Cretaceous-Tertiary boundary and to be widespread in Western and Northern Africa (Table 2). By contrast, half of the four species crossing over the Cretaceous-Tertiary boundary but reaching only the Horizon II are confined to the studied basin (Mali, Western Niger); so are the seven Cretaceous ones (about 18 % of the population of Horizon 1) which have never been recorded within any Tertiary levels. One of them, *Rayneria tilemsiensis*, belonging to a genus originally recorded in the Upper Cretaceous of Australia and subsequently in South Africa, occurs in most samples collected in Horizon I as a dominant species. Consequently, it appears to be stratigraphically useful and it is regarded as an index species of the microfaunal assemblage of Horizon I as *Laffitteina* cf. *monodi* is. Moreover, although five specimens of *Megommatocythere terrechtensis* have been found in the lowermost samples of Horizon II in In Talack and Creb d'Aginger, we consider this other endemic species to be typical of the Malian Maastrichtian (Horizon I) since it is not possible for us to investigate if these few specimens are reworked or if they really survive at the lowermost part of Horizon II.

About a third of the 39 species of Horizon I were definitively confined to the Mali-Niger basin, even when surviving in Paleocene and Eocene. Moreover, except *Brachycythere oguni* and *Cytherella sylvesterbradleyi* long-ranging and widespread species, none of the 37 other ones were known in the Upper Cretaceous of southern coastal basins or in Senegal but five of them were receded in the Upper Cretaceous of the Tethyan realm.

The composition of the fauna and its relative diversity indicate shallow marine near shore conditions. Its marked endemism and the non existent faunal relationships with the southern coastal basins suggest at least uneasy relations with the Tethys and no connection with the Southern Atlantic basins.

Upper Paleocene: *Nucleolina tatteuliensis* assemblage

The Late Paleocene assemblage, ranging from Horizons II to IV is dominated by the inherited Late Cretaceous species *Isalocopocythere teiskotensis, Trachyleberis teiskotensis* and *Isohabrocythere teiskotensis*, long-ranging and widespread African species. Okosun (1997) erected a *Trachyleberis teiskotensis* Zone covering the Late Paleocene (Thanetian).

Two other species, appearing in Horizon II, are also abundant and typified the Malian Paleocene assemblage: *Nucleolina tatteuliensis* and *Bopaina hottingeri*.

Horizon II

The assemblage of Horizon II appears to be more diverse than the previous one with 44 species belonging to 33 genera: 28 species previously found in Horizon I, 4 of which only restricted to Horizons I and II; 16 appearing in Horizon II in the studied basin but only 12 or 13 of them never recorded in the Upper Cretaceous of other African basins (Table 2). Despite the hiatus of the marine Early Paleocene, more than two third of the Horizon II assemblage correspond to inherited Cretaceous species; it implies that any considerable change in ostracode populations did not take place at the Cretaceous-Tertiary boundary. About 15 % of these 28 inherited species remain restricted to Horizon II or basal Late Paleocene: two of them confined to the basin, the two others also recorded in the Tethyan realm (Algeria, Tunisia, Libya). Most of them like most of the 16 species appearing in Horizon II i. e. 65 % of the fauna persist till the Eocene, particularly in the Tethyan realm, the marine Eocene being commonly missing in western Africa except in the coastal basins.

The whole fauna of Horizon II in the Tilemsi valley is also known in the Tethyan realm; some of the species occurred also in Senegal and a few of them in Southern Nigeria. By contrast some endemic species still occurred eastwards of the Gao trough, in the north-western part of the Iullemmeden Basin; the other ones were also recorded in the Tethyan realm, with a majority of them also known southwards, in the Atlantic coastal basins. The drastic decline of endemism seems to be linked to the beginning of the Paleocene transgressive cycle opening marine corridors between the Tilemsi valley and the Tethys realm but also, even still not very important, between the Iullemmeden and the southern Atlantic coastal basins.

Horizons III and IV

The assemblage of Horizon III is composed of 47 species belonging to 36 genera. The specific diversity of the fauna is increasing with the first appearance of 11 species compensating for the disappearance of 7 species of Horizon II, one of them surviving in the Eocene of other basins. The less diverse fauna occurs in Horizon IV with 32 species belonging to 26 genera The number of the inherited Horizon I species decreased with 5 species less than in Horizon III. Among the Paleocene ones, 16 occurring in Horizon III are missing in Horizon IV, 6 of them surviving in the Eocene of other basins; three species only appeared, one of them already recorded in the Upper Cretaceous of Niger. So, no biotic discontinuity between Horizon III and IV has been noticed but only an impoverishment of the fauna related to probably less favourable environmental conditions.

Despite the incomplete nature of the basal Paleocene record, there is no significant evolutionary interruption within the studied benthic ostracode fauna which crossed the Cretaceous-Tertiary boundary. However, as shown in table 2, some changes occur between the various horizons, the main ones between the faunas of Horizons I and II surely magnified by the lack of marine earliest Paleocene levels and between Horizon III and IV, related to the decreasing diversity in the uppermost marine levels.

In connection with the Paleocene transgressive cycle affecting the studied basin, new forms gradually appeared in Horizon II, more numerous in Horizon III and even a few in the impoverished Horizon IV; meanwhile the disappearance of species which was quite equivalent (25 and 22 %) between the three first horizons, almost doubled between Horizons III and IV, that can be related to the regressive trend. Half of the Paleocene taxa are recorded in Lower Eocene levels of other basins, essentially in the Tethyan realm and in Senegal where the Eocene is well known.

Almost 30 % of the Paleocene species already known in Horizon I and restricted to the studied basin and the Tethyan realm during the Upper Cretaceous were recorded in the Paleocene of southern western African basins; all of them reached at least the Horizon III, those disappearing earlier remained restricted to the North. This distribution pattern corresponds to the higher sea level rise as do the greatest rate of first appearances and the maximum diversification recorded in Horizon III. It produced the most widespread epicontinental transgression, allowing easy exchanges of faunas between the Tethyan realm, the Iullemmeden basin and the southern coastal basins of Western Africa. The Malian Paleocene ostracode fauna is a perfect example of the inner shelf (epineritic) Afro-Tethyan type of Bassiouni and Lüger (1990) characterized by amongst other species *Isohabrocythere teiskotensis, Nucleolina tatteuliensis, Paragrenocythere cultrata.*

CONCLUSIONS

A zonation based upon ostracodes of more than local significance cannot be yet established because some problems remain concerning the exact correlations of the African ostracode records from the various basins. But the study of the Malian ostracode fauna allow us to recognize successive assemblages.

1. Late Maastrichtian: *Rayneria tilemsiensis* and *Megommatocythere terrechtensis* assemblage.

The total range of this first assemblage, endemic to Mali and Niger (Horizon I), cannot be determined precisely, the underlying Horizon 0 (Campanian to Maastrichtian) being non-marine to lagoonal and marine basal Paleocene being missing in this basin.

2. Upper Paleocene: *Nucleolina tatteuliensis* assemblage.

The studied Upper Paleocene assemblage is dominated by *Isalocopocythere teiskotensis, Isohabrocythere teiskotensis* and *Trachyleberis teiskotensis*, ubiquitous African species but also by two more characteristic ones: *Bopaina hottingeri* and *Nucleolina tatteuliensis*. The first one is endemic to the basin and restricted to the Upper Paleocene (Horizons II, III, IV), the second one is also well known in the Tethyan realm and in Senegal where it reached the Eocene. Despite its probable Tethyan origin, it occurred first eastwards of the Gao trough (Horizon II) then in the Tilemsi valley (Horizon III). *Nucleolina tatteuliensis-Bopaina hottingeri* Assemblage appears to be typical of the Malian Thanetian.

The shallow marine ostracode record has not indicated any turnover in their evolutionary trend from Maastrichtian to Thanetian. Because of the incompleteness of the series, its has not yiedled any information about a possible temporary crisis in their assemblages as observed in other basins at the Cretaceous/Tertiary boundary. Because of their sensistivity to environmental modifications such as sea-level fluctuations, their fossil record mirrored mainly the various changes in transgression or regression patterns.

The development of two main inner shelf assemblages succeeding the lacustrine and lagoonal one (Horizon 0) implies two marine sequences occurring in the investigated area, the characteristics of which were mirrored by the composition, at a specific level, of the successive ostracode faunas. Within the first assemblage, the endemism and the dominance of thick shelled reticulate species are indicators of very shallow marine conditions maybe in bays located far from the open Tethyan sea with no fossil evidence of southern Atlantic influences during the Maastrichtian (Fig. 4).

The analysis of the second assemblage separated from the former by the gap of marine Lower Paleocene ascertains an Upper Paleocene marine cycle. Closest faunal links with the Tethys can be recognized all along the cycle; faunal links with the Atlantic southern basins already noticeable at the beginning of the transgression (Horizon II, East of the Gao trough) can be then identified as far as the Tilemsi valley. Thus, the highest diversity, lowest endemism and strongest affinities both with the Tethyan and southern faunas were found in Horizon III that may be indicative of a highest sea level rise, opening marine corridors between the Tethys and the Atlantic Gulf of Guinea. Such a marine connection, especially expressed by the ostracode faunas, through a trans-Saharan seaway (Fig. 4) has already been recognized and discussed by numerous authors (Kogbe *et al.*, 1976; Petters, 1977; Reyment and Reyment, 1981; Reyment, 1980; Carbonnel *et al.*, 1994; Damotte, 1995).

A main ostracode change-over of the same age was

also recognized by Bassiouni and Lüger in the Egyptian Paleocene of the *Pseudomenardii* Zone (P4). The study of the associated shallow benthic foraminifera allows to precise the age of this sequence: according to L. Hottinger presently studying these foraminifera, Horizons II, III and IV represent the Late Paleocene, Thanetian cycle comprising possibly SBZ2 and certainly SBZ3 and SBZ4 which corresponds to the global pattern of sequences characterized by a particularly eustatic sea level during P4 and more precisely during SBZ3.

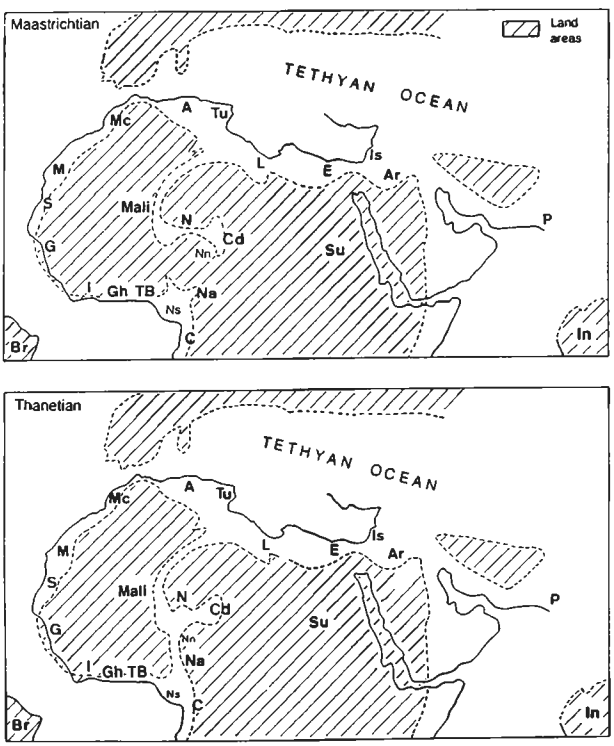

Fig. 4: Schematic paleogeographic maps of North and West Africa during the Upper Maastrichtian and the Upper Thanetian (after Reyment, 1987; Kogbe, 1980 in El Waer, 1982; Keen *et al.*, 1994).

PALAEOBIOGEOGRAPHICAL AFFINITIES

Maastrichtian

As already stated, the Late Maastrichtian ostracode faunas from Mali are relatively endemic (Table 2). Amongst the 39 species recorded in the Horizon I, 10 are restricted to the Late Cretaceous. However some palaeobiogeographic remarks and comparisons with other regions of the Tethyan domain can be made.

West African coastal basins

Besides various non-diagnostic species of *Cytherella (Cytherella* gr. *meijeri, Cytherella sylvesterbradleyi)* and *Bairdia* s. l., *Brachycythere oguni* is about the only species common during the Maastrichtian between Niger and the West African coastal basins.

North Africa

Affinities are slightly more pronounced with North Africa (Morocco, Algeria, Tunisia, Lybia, Egypt). *Brachycythere oguni* and related species and *Paracosta warriensis* are common in these countries as well as early representatives of the *Oertliella vesiculosa* group. Recently, a species closely related to *Rayneria tilemsiensis* has been described (as *Costa* sp.) by Andreu and Tronchetti (1996) in the Maastrichtian of Morocco.

Saudi Arabia and Middle East

As in Mali, the first species of *Paragrenocythere, Hornibrookella* and *Uroleberis* appear in the Maastrichtian of Saudi Arabia (Al Furaih, 1980, 1984). The genus *Brachycythere* is represented by numerous species as is the Persian Gulf (Al-Furaih, 1985; Grosdidier, 1973; Athersuch, 1994), Lebanon (Damotte and Saint-Marc, 1972) and Israel (Honingstein, 1983; Honingstein *et al.*, 1991). Species of *Occultocythereis* possessing affinities with species described from the Maastrichtian of Iraq (Al-Sheikhly, 1982) occur in the Late Maastrichtian of Mali.

Paleocene

In the late Paleocene of the studied area, 60 species of ostracodes have been identified. Amongst those, only 15 are up to now restricted to Mali, Niger and northern Nigeria. The other ones are also known in the African coastal basins, in North Africa and the Middle East.

African coastal basins

Affinities with African Coastal basins, from Mauritania to Congo, are very important during the Paleocene. Amongst the 28 species in common, the most characteristic ones are: *Uroleberis glabella, Bythocypris olaredodui, Buntonia bopaensis, Dahomeya alata, Buntonia apatyeriyerii, Cytherella sylvesterbradleyi, Iorubalella virgulata, Paracosta warriensis, Patrizia lagaghiroboensis, Paragrenocythere cultrata, Soudanella laciniosa laciniosa, Buntonia* spp., *Schizoptocythere usmandanfodioi, Teiskotella teiskotensis, Actinocythereis teiskotensis* ...

North Africa

Affinities with North Africa and especially with Libya and Egypt are well marked during the Late Paleocene. Amongst the 60 species found in Mali, 36 species are common with North Africa and only 20 in common with North Africa and the West African coastal basins. Some of the more typical species restricted to Mali and North Africa are *Cytherella* gr. *meijeri, Occultocythereis confirmatus, Paracosta warriensis, Buntonia misreia lineata, Schizocythere salahii* ...

Saudi Arabia

Affinities with Saudi Arabia during the Paleocene are essentially expressed by the presence of *Isalocopocythere teiskotensis, Foveoleberis teiskotensis, Uroleberis glabella.* At the generic level, similarities are also noticeable with various species of *Paragrenocythere, Hornibrookella, Nucleolina, Occultocythereis, Isohabrocythere, Schizoptocythere* (Al-Furaih, 1975, 1977, 1980, 1983, 1984a–b, 1986, 1993; Siddiqui and Al-Furaih, 1981).

Pakistan and India

Amongst the ostracod species reported by various authors from the Paleocene of India and Pakistan (Sohn, 1970; Siddiqui, 1971, 1981; Siddiqui and Al-Furaih, 1981; Brouwers and Fatmi, 1992a–b; Sohn, Bhandari, 1992 1995a–b, 1996) none is yet known with certainty from Mali. However, there are strong similarities in the generic composition expressed by the common occurrence of species of *Foveoleberis, Iorubaella, Uroleberis, Schizocythere, Paragrenocythere, Teiskotella, Stigmatocythere, Schizoptocythere, Bopaina, Nucleolina* ...

SYSTEMATIC DESCRIPTIONS

The classification used is the one of Hartmann and Puri (1974), slightly adapted.

All the specimens illustrated are deposited in the Collections of the Museum of Natural History of Basel, Switzerland.

Species are arranged in alphabetical order within each genus, those in open-nomenclature at the end.

The plate-explanations are included in the text, following the description of each species.

Subclass OSTRACODA Latreille, 1806
Order PODOCOPIDA Müller, 1894
Suborder PLATYCOPA Sars, 1866
Family CYTHERELLIDAE Sars, 1866

Genus *Cytherella* JONES, 1849

***Cytherella* gr. *C. meijeri* ESKER, 1968**
Plate 2, Fig. 4.

1968 *Cytherella meijeri* ESKER. Esker, p. 230, pl. 1, figs 4–5.
1982 *Cytherella meijeri* ESKER. Donze *et al.*, p. 280, pl. 1, fig. 1.
1985 *Cytherella meijeri* ESKER. Vivière, p. 138–139, pl. 1, fig. 10.
1988 *Cytherella meijeri* ESKER. Damotte and Fleury, p. 93, pl. 1, figs 1–2.
?1992 *Cytherella ghalilae* EL-WAER. El-Waer, p. 35, pl. 1, figs 8–12, pl. 2, fig. 1.
1993 *Cytherella symetrica* ALEXANDER. Whatley and Arias, p. 128, pl. 1, figs 2, 3.
?1995 *Cytherella* aff. *kunradensis* VAN VEEN. Swain *et al.*, p. 47–48, pl. 1, figs 1–2.
1996 *Cytherella meijeri* ESKER. Andreu, p. 100–101, pl. 1, fig. 1.

Remarks

Valve surface ornamented with tiny pits near the anterior and posterior margins. Especially frequent in the Late Maastrichtian and the Early Paleocene.

Dimensions

L = 0.63–0.73 mm
h = 0.39–0.44 mm

Age and distribution

Mali: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I to III (In Talack, Agamor, Takhabanat, Creb d'Aginger, Ait Nafa).

Algeria: Santonian-Campanian, Early-Middle Paleocene.

Libya: Paleocene-Eocene.

Morocco: Early Campanian.

North-western Nigeria (Iullemmeden Basin): ? Maastrichtian.

Tunisia: Early Paleocene (Danian).

Figured specimens

Pl. 2, fig. 4.
4 — Left view, × 65, In Talack, N8, Horizon 1.

***Cytherella sylvesterbradleyi* REYMENT, 1963**
Plate 2, Fig. 6.

1960 *Cytherella (Cytherella) austinensis* ALEXANDER. Reyment, p. 54, pl. 1, fig. 2a–d, 12a–c.
1963 *Cytherella (Cytherella) sylvesterbradleyi* REYMENT. Reyment, p. 35–67, pl. 1, fig. 1, text-fig. 10.
1982 *Cytherella sylvesterbradleyi* REYMENT. Diop *et al.*, p. 33, pl. 1, fig. 7.
1983 *Cytherella (Cytherella) sylvesterbradleyi* REYMENT. Foster *et al.*, p. 133–134, pl. 14, figs 7, 10, 12–17, non 6–11.
1987 *Cytherella sylvesterbradleyi* REYMENT. Okosun, p. 22–24, pl. 21, figs 1–4; pl. 21, fig. 1.
1989 *Cytherella sylvesterbradleyi* REYMENT. Okosun, p. 672; pl. 1, fig. 21.
1990 *Cytherella sylvesterbradleyi* REYMENT. Carbonnel, pl. 11, figs 8–10.
1991 *Cytherella* spp. DAMOTTE. Damotte, p. 7, pl. 1, figs; 1–2.
1994 *Cytherella sylvesterbradleyi* REYMENT. Digbehi *et al.*, p. 193, pl. 2, fig. 13.
1995 *Cytherella* sp. aff. C. *unguiformis* KOLLMANN. Swain *et al.*, p. 1 pl. 1, figs 3–5.
1995 *Cytherella sylvesterbradleyi* REYMENT. Carbonnel and Monciardini, p. 18–19.

Remarks

Large, smooth and frequent species in the Paleocene, especially in Horizon III. According to Reyment (1963, 1982) this species has a wide range of ornamentation (smooth or punctate) and of convexity of the dorsal margin.

Dimensions

L = 0.75–0.81 mm
h = 0.41–0.52 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian) Horizons II to IV (In Talack, Agamor, Takhabanat, Creb d'Aginger).

— previous studies: Horizons I, II and III of the Tilemsi Valley (Bellion *et al.*, 1989; Damotte, 1991). Reported by Carbonnel and Monciardini (1995) from Horizons I to IV (In Araber, Ouarassibitl, Agamor, Fogha).

Benin: Late Paleocene.

Congo: Early Paleocene (Massala, 1993).

Ghana: Campanian-Maastrichtien (Khan, 1970; Kogbe and Me'hes, 1986).

Ivory Coast: Early Eocene.

Libya: Late Maastrichtian to Paleocene.

Nigerian coastal basins: Late Cretaceous (Late Coniacian) to Middle Eocene.

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Dukamaje Formation), Late Paleocene (Kalambaina Formation, top Horizon I to IV).

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, fig. 6.

6 — Left view, × 65, Takhabanat, N65, Horizon II.

***Cytherella* sp. 1**

Plate 2, Fig. 7.

Remarks

Elongated, sub-rectangular carapace. Anterior margin symmetrically rounded, bordered by a narrow groove, particularly well developed on the left valve. Ornamentation consisting of fossae near the margins, larger and in greater numbers near both extremities; median part smooth. Differs from *Cytherella meijeri* Esker by more symmetrically rounded extremities and its well developed anterior marginal rim. Close by its ornamentation and anterior rim to *Cytherella piacabuensis* Neufville *sensu* Bassiouni and Lüger (1990) and Honigstein *et al.* (1991), but with dorsal and ventral margin parallel and without a median bold area.

Dimensions

L = 0.60 mm
h = 0.36 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (In Talack, Takhabanat).

Figured specimens

Pl. 2, fig. 7.

7 — Left view, × 65, In Talack, N21, Horizon III.

***Cytherella* sp. 2**

Plate 2, Fig. 5.

Remarks

Subovate carapace with dorsal and ventral margins slightly converging toward the anterior end. Maximum height near the posterior third, and presence of a distinct median depression. Ornamentation consisting of small pits especially in the anterior and dorsal parts. Differs from *Cytherella piacabuensis* NEUFVILLE *sensu* Bassiouni and Lüger (1990) from the Maastrichtian of Egypt by the greatest height of its posterior part and the lack of an anterior rim. This species also shows clear affinities with *Cytherella utilis* BERTELS, 1968, *Cytherella* aff. *utilis* BERTELS, 1973 from the Danian of Argentina, *Cytherella araucana* BERTELS, 1974 from the Maastrichtian of Argentina, and *Cytherella* NC 136 COLIN and HOCHULI, 1992 from the Campanian of eastern Niger.

Dimensions

L = 0.68 mm
h = 0.46 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (In Talack).

Figured specimens

Pl. 2, fig. 5.

5 Left view, × 65, In Talack, N26, Horizon III

Genus *Cytherelloidea* ALEXANDER, 1929

***Cytherelloidea christianae* sp. nov.**

Plate 2, Figs 1–3.

Derivation of name: Species dedicated to Christiane Chancogne-Weber, Muséum d'Histoire Naturelle de Paris who took the S.E.M. micrographs of this work.

Holotype: 1 carapace (Pl. 3, fig. 1).

Paratypes: 1 carapace, 1 left valve.

Type locality: In Talack borehole, Mali, Late Maastrichtian, Horizon I, level N13.

Diagnosis

A species of *Cytherelloidea* with the lateral surface coarsely reticulated with strong muri delineating very irregular fossae.

Description

Carapace of medium size, elongate, sub-rectangular with the greatest height at its anterior cardinal angle and greatest width near its posterior end. Narrow and subtriangular in dorsal view. Very weak overlap of the right valve along the dorsal and posterior margin. Dorsal margin straight posteriorly with a slight concavity just anterior to the mid-length. Ventral margin gently concave in its middle part. Anterior and posterior margins symmetrically and narrowly rounded. Entire surface covered with strong and knotty ridges drawing a coarse and irregular reticulum with fossae of various shapes and sizes and rudimentary second order reticulation. Anterior and posterior acute marginal rim. An antero-ventral ridge originates near the concavity of the dorsal margin then runs along the anterior and ventral margin.

Dimensions

Holotype:

L = 0.60 mm

h = 0.33 mm

Paratypes:

L = 0.58–0.60 mm

h = 0.30–0.34 mm

Remarks

Cytherelloidea christianae is easily distinguished from the other species of the genus by its strong and irregular ornamentation. The closest related forms possessing a coarsely reticulate ornamentation are *Cytherella interpunctata* MALZ and JELLINEK, 1989 and *Cytherella cincta* MALZ and JELLINEK, 1989 from recent shallow water environment of Kenya (Indian Ocean).

Age and distribution

Mali: Late Maastrichtian, Horizon I (In Talack, Ait Nafa).

Figured specimens

Pl. 2, figs 1–3.

1 — Right view, × 65, holotype, In Talack, N13, Horizon. I. **2** — Left view, × 65., Ait Nafa, N83, Horizon I. **3** — Dorsal view, × 65, Ait Nafa, N84, Horizon I.

Cytherelloidea musacea CARBONNEL, ALZOUMA and DIKOUMA, 1990

not illustrated

1990 *Cytherelloidea musacea* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 673–674, pl. 1, fig. 23.

1991 *Cytherelloidea musacea* CARBONNEL *et al.* Damotte, p. 7, pl. 1, figs 3–4.

1992 *Cytherelloidea musacea* CARBONNEL *et al.* Carbonnel, pl. 11, fig. 16.

1995 *Cytherelloidea musacea* CARBONNEL *et al.* Carbonnel and Monciardini, p. 19–20, pl. 1, fig. 3.

Remarks

Only one broken specimen of this species has been found in our Malian material.

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon III (Ibegan).

— previous studies: Horizons II and IV of the Tilemsi Valley (Bellion *et al.*, 1989, Damotte, 1991). Horizons III and IV (Agamor, Fogha, In Araber, Ouarassibilt).

Libya: Paleocene (M.C. Keen personal communication — in Gammudi and Keen, 1996).

Western Niger: Late Paleocene (Garadoua Formation).

Suborder PODOCOPA Sars, 1866
Superfamily BAIRDIACEA Sars, 1866
Family BAIRDIIDAE Sars, 1888

Genus *Bairdoppilata* SARS, 1935

Bairdoppilata ilaroensis (REYMENT and REYMENT, 1959)

Plate 1, Figs 4, 5.

1959 *Bairdia ilaroensis* REYMENT and REYMENT. Reyment and Reyment, p. 61, pl. 1, figs 1–7, text-figs 1a–b, 3a–m, 5a–h.

1963 *Bairdoppilata magna* (ALEXANDER). Barsotti, p. 206, pl. 1, fig. 1.

1963 *Bairdia ilaroensis* REYMENT and REYMENT. Reyment, p. 71, text-fig. 19.

1965 *Bairdia ilaroensis* REYMENT and REYMENT. Reyment, pl. 13, fig. 1.

1976 *Bairdia magna* ALEXANDER. Ficarelli, pl. 90, fig. 1 non fig. 2.

1981 *Bairdia* cf. *ilaroensis* REYMENT and REYMENT. Reyment, pl. 1, fig. 18.

1981 *Bairdia ilaroensis* REYMENT and REYMENT. Reyment, p. 56, pl. 9, figs 6, 7

1981 *Bairdia ilaroensis* REYMENT and REYMENT. Krstic, pl. 1, fig. 2.

1987 *Bairdia ilaroensis* REYMENT and REYMENT. Okosun, p. 26, pl. 20, figs 9, 1, non fig . 7.

1990 *Bairdoppilata ilaroensis* (REYMENT and REYMENT). Carbonnel *et al.*, p. 374, pl. 1, fig. 19.

1990 *Bairdia ilaroensis* REYMENT and REYMENT. Bassiouni and Lüger, p. 780–781, pl. 1, fig. 15.

1991 *Bairdoppilata ilaroensis* (REYMENT and REYMENT). Carbonnel and Oyédé, p. 69–70, pl. 1, fig. 1.

1992 *Bairdia ilaroensis* REYMENT and REYMENT. El-Waer, p. 47, pl. 4, figs 4–9.

1992 *Bairdoppilata ilaroensis* (REYMENT and REYMENT). Carbonnel, pl. 17, fig. 1.

non 1992 *Bairdia ilaroensis* REYMENT and REYMENT. Ismail, p. 45, pl. 1, fig. 5.

1993 *Bairdoppilata magna* (ALEXANDER). Whatley and Arias, p. 129, pl. 1, fig. 7.
1994 *Bairdia* gr. *ilaroensis* REYMENT and REYMENT. Keen *et al.*, pl. 16. 1, fig. 5.

Remarks

This species is the most common *"Bairdia"* in the Paleocene of the studied area. Reyment (1981) described a size change from smaller specimens in Nigeria to larger in Libya.

Dimensions

L = 1.07–1.16 mm
h = 0.64–0.79 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizons II and III (Agamor, Takhabanat, Ibegan).
Benin: Late Paleocene.
Egypt: Maastrichtian to Early Eocene.
Ghana: Maastrichtian.
Guinea Bissau: Paleocene.
Libya: Maastrichtian to Middle Eocene.
Nigerian coastal basin (Iullemmeden Basin): Paleocene (Ewekoro Formation).
North-western Nigeria (Iullemmeden Basin): Late Paleocene (Dange and Kalambaina Formations) (Okosun, 1989).
Senegal: Paleocene? to Middle Eocene.
Tunisia: Paleocene.
Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, figs 4, 5.
4 — Right view, × 65, Agamor, N34, Horizon III. **5** — Right valve, lateral view, × 65, Takhabanat, N68, Horizon. III.

Bairdoppilata nafaensis sp. nov.

Plate 1, Figs 1, 2, 3.

Name derivation: from its occurrence in Ait Nafa.

Holotype: 1 carapace (Pl. 2, fig. 3).

Paratypes: 17 carapaces.

Type-locality: Ait Nafa, Mali, Late Maastrichtian, Horizon I, level N85.

Diagnosis

Species of *Bairdoppilata* characterized by a high and subtriangular left valve strongly overlapping the right one which shows only the faintest suggestion of the upturned posterior end of a typical bairdioid outline.

Description

Species of *Bairdoppilata* characterized by a high carapace, sub triangular in lateral view with the greatest height just anterior of mid-length. The larger left valve strongly overlaps the right one except at the ventral posterior end. Dorsal margin of the left valve forms a salient angle of about 115° in its middle part, and slopes in a straight line towards each end; very slightly concave postero-dorsal margin on the right valve only. Ventral margin almost straight. Anterior margin narrowly rounded below the mid-height; posterior margin tapering not very sharply at the lower quarter of the height. In dorsal view, the carapace is sub-ellipsoidal with the maximum inflation occurring slightly anterior of mid-length. Carapace very slightly punctuated.

Remarks

In general outline this species is close to *Bairdia* sp. from the Maastrichtian of Togo, figured and not described by Damotte (1982), but it shows a stronger overlapping of the left valve and a posterior end in a more ventral position. It differs from *Bairdia andersoni aequalis* (CHAPMAN) in Dingle (1981), from the Late Cretaceous of South Africa by a higher and more angular dorsal margin and from *Bairdoppilata* sp. aff. *B. roemeri* DEROO in Swain *et al.* (1993, 1995) from the Paleocene of north-western Nigeria.

Dimensions

Holotype:
L = 0.81 mm
h = 0.58 mm
Paratypes:
L = 0.81–0.91 mm
h = 0.58–0.66 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (Ait Nafa).

Figured specimens

Pl. 1, figs 1, 2, 3
1 — Right view, × 65, **2** — Left view, × 65, **3** — Dorsal view, × 65, Ait Nafa, N85, Horizon I.

Genus *Neonesidea* MADDOCKS, 1969

Neonesidea elongatoilaroensis FOSTER, SWAIN and PETTERS, 1983

Plate 1, Fig. 6.

1983 *Neonesidea elongatoilaroensis* FOSTER, SWAIN and PETTERS. Foster *et al.*, p. 108, pl. 1, figs 4–6.
1991 *Neonesidea elongatoilaorensis* FOSTER *et al.* Carbonnel and Oyédé, p. 70, pl. 1, figs 1–4.
1995 *Neonesidea elongatoilaroensis* FOSTER *et al.* Carbonnel and Monciardini, p. 22.

Remarks

A very characteristic strongly elongated species of *Neonesidea*.

Dimensions

L = 1.12 mm
h = 0.67 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon III (In Ori, Ibegan).

— previous studies: Horizons III and IV (In Araber, Ouarassibilt).

Benin: Late Paleocene.

Ivory Coast: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, fig. 6.

6 — Right view, × 65, Ibegan, N95, Horizon III.

Neonesidea ilaroides Foster, Swain and Petters, 1983

Plate 1, Figs 8, 9.

1983 *Neonesidea ilaroides* Foster, Swain and Petters. Foster *et al.*, p. 107–108, pl. 1, fig. 3, pl. 3, fig. 1.

1990 *Neonesidea ilaroides* Foster *et al.* Carbonnel *et al.*, p. 674, pl. 1, figs 15–16.

1992 *Neonesidea ilaroides* Foster *et al.* Carbonnel, pl. 17, fig. 7.

1995 *Neonesidea ilaroides* Foster *et al.* Carbonnel and Monciardini, p. 21.

Remarks

Carapace of medium size, punctate as in Foster *et al.* (1982), with the concavities of the dorsal and ventral margins more pronounced than in the type, as in *Bairdia* sp. Guernet (*in* Diop *et al.*, 182) from the Paleocene and Early Eocene of Senegal which is more elongated especially at its anterior and posterior ends.

Dimensions

L = 0.81–0.84 mm

h = 0.52–0.55 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon III (In Talack, Ibegan).

— previous studies: Horizons III (Fogha, Ouarassibilt).

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation);

Senegal: Paleocene-Early Eocene.

Togo: Late Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, figs 8–9.

8 — Left view, × 65, In Talack, N21, Horizon. III. **9** — Right view, × 65 Ibegan, N91, Horizon III.

Neonesidea sp. 1

Plate 1, Fig. 7.

Remarks

Close to *Neonesidea*? sp. 1 Foster *et al.*, 1983 from the Paleocene of northwestern Nigeria, but with a postero-ventral margin bending upwards and a posterior extremity higher, at about central third height.

Dimensions

L = 1.25 mm

h = 0.68 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (Takhabanat, Agamor).

Figured specimens

Pl. 1, fig. 7.

7 — Right view, × 65, Takhabanat, N68, Horizon III.

Family Bythocyprididae Maddocks, 1969

Genus *Bythocypris* Brady, 1880

Bythocypris fosteralii Carbonnel, Alzouma and Dikouma, 1990

Plate 1, Fig. 12.

1986 *Bythocypris* sp. 1 Foster, Swain and Petters. Foster *et al.*, p. 109, pl. 2, figs 12–15, pl. 5, figs 12–13.

1988 *Bythocypris* sp. 1 Foster *et al.* Carbonnel, pl. 2, fig. 10.

1989 *Bythocypris* sp. 1 Foster *et al.* Carbonnel and Johnson, p. 416.

1990 *Bythocypris fosteralii* Carbonnel, Alzouma and Dikouma. Carbonnel *et al.*, p. 675, pl. 1, figs 17–18.

1995 *Bythocypris fosteralii* Carbonnel *et al.* Carbonnel and Monciardini, p. 22–23, pl. 1, fig. 12, 16.

Remarks

The specimens from Mali are generally higher than those from western Niger measured by Carbonnel *et al.* (1990), with a dorsal margin more strongly arched as in the specimens from Nigeria described by Foster *et al.* (1981) as *Bythocypris*? sp. A and considered as *Bythocypris fosteralii* by Carbonnel *et al.* (1990).

Dimensions

L = 1.01–1.09 mm

h = 0.51–0.56 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II, (Takhabanat, Creb d'Aginger, Ibegan, In Talack, Agamor).

— previous studies: Horizons III and IV (Fogha, In Araber)

Egypt: latest Paleocene-earliest Eocene.

Libya: Paleocene.

Mauritania: Late Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Nigerian coastal basin: Late Paleocene.

Senegal: Paleocene-Early Eocene.

Togo: Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, fig. 12.

12 — Right view × 65, Creb d'Aginger, N75, Horizon II.

Bythocypris olaredodui REYMENT, 1963

Plate 2, Figs 11–12.

1963 *Bythocypris olaredodui* REYMENT. Reyment, p. 75–76, pl. 9, fig. 1.

1963 *Bythocypris alejo* REYMENT. Reyment, p. 76–77, pl. 2, fig. 1, pl. 9, figs 2–4.

1965 *Bythocypris alejo* REYMENT. Reyment, pl. 8, fig. 7.

1970 *Aglaiocypris* sp. SOHN. Sohn, p. 61, pl. 1, figs 7–9.

1976 *Bythocypris olaredodui* REYMENT. Ficcarelli, p. 733, pl. 90, fig. 3.

?1978 *Krithe* cf. *perratica* ALEXANDER. Ducasse *et al.*, pl. 9, fig. 6.

?1982 *Bythocypris* cf. *olaredodui* REYMENT. Diop *et al.*, p. 23, pl. 1, fig. 4.

non 1983 *Bythocypris olaredodui* REYMENT. Foster *et al.*, p. 110, pl. 2, figs 10–11.

1986 *Bythocypris alejo* REYMENT. Carbonnel, p. 67, pl. 5, figs 1–3.

1987 *Bythocypris olaredodui* REYMENT. Okosun, p. 27–28, pl. 15, figs 17–22.

1988 *Bythocypris alejo* REYMENT. Carbonnel, pl. 2, fig. 13.

1989 *Bythocypris olaredodui* REYMENT. Okosun, p. 672, pl. 2, figs 1–3.

1989 *Bythocypris alejo* REYMENT. Carbonnel and Johnson, p. 417, pl. 3, fig. 7.

1992 *Bythocypris alejo* REYMENT. Carbonnel, pl. 7, figs 1–4.

1994 *Bythocypris* sp. 260 cf. *B. alejo* REYMENT. Digbehi *et al.*, p. 192, pl. 2, figs 1–4.

1995 *Bythocypris* sp. cf. *B. goodlandensis* ALEXANDER. Swain *et al.*, p. 48, pl. 1, figs 18, 19.

1995 *Bythocypris olaredodui* REYMENT. Carbonnel and Monciardini, p. 23, pl. 1, fig. 15.

?1995 *Bythocypris alejo* REYMENT. Carbonnel and Monciardini, p. 22

Remarks

We follow Okosun (1987) who considers *Bythocypris olaredodui* and *Bythocypris alejo* REYMENT, 1963 whose lateral outlines differ only slightly, as conspecific. *Argilloeacia* sp. 1 BROUWERS and FATMI, 1992 from the Late Paleocene-Early Eocene of Pakistan, *Cushmanidea bhatiai* BHANDARI, 1995 and *Aglaiocypris? indica* BHANDARI, 1995 respectively from the Early Paleocene and Early Eocene of India and *Argilloecia ghalilae* EL-WAER, 1992 from the Eocene of Libya are very similar to *Bythocypris olaredodui* and might be junior synonyms.

Dimensions

L = 0.73–0.95 mm

h = 0.30–0.46 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian); Horizons I to III (Creb d'Aginger, Ibegan, In Talack).

— previous studies: reported by Carbonnel and Monciardini from Horizons II to IV (Fogha, In Araber, Ouarassibilt).

Benin: Late Paleocene (Akpiti *et al.*, 1986).

Guinea Bissau: Paleocene-Eocene.

Ivory Coast: Early Paleocene-Late Eocene.

Mauritania: Early Paleocene.

Nigerian coastal basin: Paleocene-Middle Eocene.

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Wurno and Dukamaje Formations)- Late Paleocene (Kalambaina Formation).

Senegal: Paleocene-Eocene.

Togo: Late Paleocene-Middle Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, figs 11–12.

11 — Left view, × 65, **12** — Right view, × 65, Creb d'Aginger, N72, Horizon I.

Superfamily CYTHERACEA Baird, 1850
Family CYTHERIDAE Baird, 1850
Subfamily CYTHERINAE Baird, 1850
Tribe SCHIZOCYTHERINI Mandelstam, 1960

Genus *Schizocythere* TRIEBEL, 1950

Schizocythere salahii BASSIOUNI and LÜGER, 1990

Plate 2, Figs 8–9.

1966 *Schizocythere* sp. 1 SALAHI. Salahi, p. 20, pl. 3, figs 22–24.

1990 *Schizocythere salahii* BASSIOUNI and LÜGER. Bassiouni and Lüger, p. 814–815, pl. 12, figs 6–8.

1992 *Schizocythere salahii* BASSIOUNI and LÜGER. El-Waer, p. 78–80, pl. 12, figs 1–6.

1995 *Schizocythere salahii* BASSIOUNI and LÜGER. Carbonnel and Monciardini, p. 28, pl. 1, fig. 9.

Remarks

Bassiouni and Lüger's species from the earliest Eocene of Egypt differs from *Schizocythere nigeromeridionalis* CARBONNEL *et al.*, 1992 from the Paleocene of western Niger by the absence of a wide anterior lamellar extension. This species shows very strong affinities with several species from the Paleocene and Eocene of Pakistan (Siddiqui, 1981) and India (Guha, 1968; Neale and Singh, 1985; Bhandari, 1996) and especially *Schizocythere gujaratensis* GUHA, 1968 and *Schizocythere prolata* SIDDIQUI, 1981.

Dimensions

L = 0.40–0.50 mm
h = 0.25–0.30 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon IV (In Ori, Agamor).

— previous studies reported by Carbonnel and Monciardini (1995) from Horizons III and IV (Agamor).

Egypt: earliest Eocene.

Libya: Early to Middle Eocene.

Western Niger: Late Maastrichtian (Horizon I)-Late Paleocene (Garadoua Formation)

Figured specimens

Pl. 2, figs 8–9.

8 — Left view, × 65, Agamor, N50, Horizon IV. **9** — Right view, × 65, In Ori, N89, Horizon IV.

Tribe PAIJENBORCHELLINI Deroo, 1960

Genus *Paijenborchellina* KUZNETSOVA 1957

Paijenborchellina sp. 1

Plate 2, Fig. 10.

Remarks

This small species is very similar in lateral outline to *Paijenborchellina* sp. A REYMENT, 1980, but our single specimen is too badly preserved to be correctly compared to the Paleocene Nigerian form. Other species of *Paijenborchellina* have been reported in the Paleocene of the Niger/Mali region: *Paijenborchellina* sp. DAMOTTE, 1991, *Paijenborchellina* ? sp. Digida 177 CARBONNEL and MONCIARDINI (1995), and *Paijenborchellina* sp. 1 (DUCASSE *et al.*, 1978) in Carbonnel and Monciardini. Other species have been described by Reyment (1959) in the Early Eocene of Nigeria.

Dimensions

L = 0.56 mm
h = 0.28 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (In Talack).

Figured specimens

Pl. 2, fig. 10.

10 — Left view, × 65, In Talack, N9, Horizon I.

Tribe PERISSOCYTHERIDEINI van den Bold, 1953

Genus *Kroemmelbeinella* MOSTAFAWI, 1984

Kroemmelbeinella trapezoidalis (CARBONNEL, ALZOUMA and DIKOUMA 1990)

Plate 7, Figs 14–17.

1990 *Eocytheropteron trapezoidalis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 677, pl. 2, figs 3–4, pl. 4, fig. 15.

1991 *Eocytheropteron trapezoidalis* CARBONNEL, ALZOUMA and DIKOUMA. Damotte, p. 8, pl. 1, figs 10–11.

1992 *Eocytheropteron trapezoidalis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel, pl. 10, figs 5–6.

1995 *Eocytheropteron trapezoidalis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel and Monciardini, p. 66–67, pl. 7, figs 9–12.

Remarks

The specimens found in our Malian material are smaller than the ones from western Niger described by CARBONNEL *et al.* (1990). This species has strong affinities with *Cytheropteron* sp. DM 1629 BELLION and DONZE, 1973 from the Campanian of Algeria and of *Eocytheropteron devius* APOSTOLESCU, 1961 from the Early Eocene of Senegal. The overall morphology, with especially the presence of a depressed antero-dorsal area leads us to transfer this species from the genus *Eocytheropteron* to the genus *Kroemmelbeinella* MOSTAFAWI which is a common component of nearshore West African ostracode faunas, and is typical of very shallow or intertidal environments (Keen, 1996). The Malian species shows striking similarities with *Kroemmelbeinella rokelensis* KEEN, 1996 from the Miocene of Sierra Leone.

Dimensions

L = 0.42–0.46 mm
h = 0.30–0.32 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene, Horizons I and II (In Talack, Takhabanat, Creb d'Aginger, Ait Nafa).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizon III of the Tilemsi Valley. Also reported by Carbonnel and Monciardini (1995) from Horizons II–IV (In Araber, Fogha, Ekkineouan).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 7, figs 14–17.

14 — Left view, × 65, Takhabanat, N64, Horizon II.

15 — Right view, × 65, Ait Nafa, N82, Horizon I.

16 — Left view, × 65, In Talack, N7, Horizon I. **17** — Right view, Ait Nafa, N84, Horizon I.

Family CYTHERIDEIDAE Sars, 1925
Subfamily CYTHERIDEINAE Sars, 1925

Genus *Isohabrocythere* APOSTOLESCU, 1961

Isohabrocythere teiskotensis APOSTOLESCU, 1961

Plate 2, Figs 13–15.

1961 *Isohabrocythere teiskotensis* APOSTOLESCU. Apostolescu, p. 794–795, pl. 1, figs 15–17, pl. 15, figs 297–298.
1963 *Isohabrocythere teiskotensis* APOSTOLESCU. Barsotti, p. 1524, pl. 1, fig. 2.
1966 *Isohabrocythere* aff. *I. teiskotensis* APOSTOLESCU. Salahi, p. 14, pl. 2, fig. 20.
1976 *Isohabrocythere teiskotensis* APOSTOLESCU. Ficcarelli, p. 734. pl. 90, fig. 8.
1981 *Habrocythere teiskotensis* (APOSTOLESCU). Reyment, p. 57, pl. 1, figs 13–14, pl. 3, fig. 1.
1981 *Isohabrocythere teiskotensis* APOSTOLESCU. Reyment and Reyment, pl. 1, fig. 1.
1983 *Isohabrocythere teiskotensis* APOSTOLESCU. Foster *et al.*, p. 113, pl. 3, figs 11–13, pl. 8, figs 1, 2.
1990 *Isohabrocythere teiskotensis* APOSTOLESCU. Carbonnel *et al.*, p. 676–677, pl. 2, fig. 12, pl. 4, fig. 11.
1990 *Isohabrocythere teiskotensis* APOSTOLESCU. Bassiouni and Lüger, p. 794, pl. 6, figs 1–2, 4–5, 7–8.
1991 *Isohabrocythere teiskotensis* APOSTOLESCU. Damotte, p. 7, pl. 1, figs 7–8.
1992 *Isohabrocythere teiskotensis* APOSTOLESCU. Carbonnel, pl. 14, fig. 12.
1995 *Isohabrocythere teiskotensis* APOSTOLESCU. Carbonnel and Monciardini, p. 56–7.

Remarks

It is possible that *Cuneocythere (Monsmirabilia) altinota* AL-FURAIH, 1980 from the latest Maastrichtian-Early Paleocene of Saudi Arabia is synonym of *Isohabrocythere teiskotensis.*

Dimensions

L = 0.57–0.68 mm
h = 0.39–0.44 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–IV (In Talack, Agamor, Takhabanat, Creb d'Aginger, Asselar).

— previous studies: originally described by Apostolescu (1961) from the Late Paleocene of the Teiskot borehole. Also reported from Fogha, In Araber and Menaka.

Benin: Paleocene.

Egypt: Late Paleocene (*velascoensis* Zone)-Early Eocene.

Ivory Coast: Late Paleocene.

Libya: Late Paleocene-Early Eocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation). Nigerian coastal basin: Late Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl 2, figs 13–15.

13 — Left view, × 65, **14** — Right view, × 65, **15** — Right valve, lateral view, × 65, In Talack, N5, Horizon I.

Genus *Ovocytheridea* GRÉKOFF, 1951

Ovocytheridea pulchra REYMENT, 1963

Plate 2, Fig. 19.

1963 *Ovocytheridea pulchra* REYMENT. Reyment, p. 78, pl. 1, figs 1–3, 10, pl. 9, figs 5–8.
1983 *Ovocytheridea* sp. aff. *pulchra* REYMENT. Foster *et al.*, p. 114, pl. 3, fig. 14, pl. 4, fig. 1.
1987 *Ovocytheridea pulchra* REYMENT. Okosun, p. 64, pl. 3, fig. 10, pl. 6, figs 22–24.
1990 *Isohabrocythere langi* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 676, pl. 2, fig. 10.
1994 *Isohabrocythere teiskotensis* APOSTOLESCU. Keen *et al.*, pl. 16–1, figs 3, 6.
Non 1995 *Ovocytheridea pulchra* ? REYMENT. Carbonnel and Monciardini, p. 60, pl. 6, figs 13–14.

Remarks

A diagnostic species assigned to the genus *Ovocytheridea* essentially characterised by a densely punctate valve surface.

Dimensions

L = 0.81–0.85 mm
h = 0.48–0.59 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (Creb d'Aginger).

Benin: Late Paleocene.

Libya: Early Paleocene (Danian) of the Sirte Basin.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, fig. 19.

19 — Right view, × 65, Creb d'Aginger, N74, Horizon I.

Genus *Bopaina* APOSTOLESCU, 1961

Bopaina hottingeri nov. sp.

Plate 3, Figs 1–8.

Name derivation: In honour of Prof. L. Hottinger (Basel) who is studying the benthic foraminifera associated

with the ostracode fauna and has kindly informed us of his preliminary results.

Holotype: one carapace (pl. 3, fig. 2)

Paratypes: 26 carapaces.

Type-locality: In Talack.

Diagnosis

Species of *Bopaina* characterised by a medium-sized carapace, subovate with greatest height before mid-length, anterior margin compressed and denticulate, antimerodont hinge with anterior element as long as medium element.

Description

Carapace with a subovate lateral outline and a left valve overlapping the right valve around the entire margin, widely but in the ventral part of the anterior and posterior ends where the overlap is not always distinct especially in some adult carapaces. Dorsal margin arched with its higher point at the anterior cardinal angle, just before the mid-length. Posterior end ventrally rounded. In dorsal view, gently inflated in the posterior part. Anterior margin almost symmetrically rounded, compressed with a narrow groove, especially along the margin of the right valve, and denticulate with about 18 denticles. Central margin straight in the right valve, convex in the left valve, with a slight concavity in its anterior part on both valves.

The ornamentation consists of pits larger and more numerous in the median part than near the periphery of the valves, almost smooth.

Some specimens are less elongated, with a dorsal margin strongly arched. Sexual dimorphism not very pronounced, with females slightly more inflated posteriorly

Internal features: antimerodont hinge as in the type-species *Bopaina bopaensis* APOSTOLESCU, 1961, but with a longer anterior element and a shorter median one. The muscle scars arrangement seems to be as in the type-species with a vertical row of four adductor scars.

Remarks

This species differs from the Maastrichtian species *Bopaina bopaensis* APOSTOLESCU, 1961 (see also Damotte, 1982 and Okosun, 1987) by its more ovate lateral outline, its more distinct anterior cardinal angle, its less tapered dorsal outline, the presence of an anterior groove and by the relative proportions of the elements of its hinge. It is closer by its lateral outline and compressed anterior margin to *Bopaina* sp. W7 CARBONNEL *et al.* 1990 from the Late Paleocene of western Nigeria than to *Bopaina* sp. CARBONNEL 1992 (= *Dactylia* sp. CARBONNEL, 1986) from the Paleocene of Senegal. *Bopaina hottingeri* differs from both species by the denticulations of its anterior margin. *Ovocytheridea pulchra* ? from the Late Paleocene of Mali, in Carbonnel and Monciardini (1995) differs by the absence of compressed margin and of anterior marginal denticulations. *Schuleridea* sp. 1 BROUWERS and FATMI, 1992b and *Schuleridea* sp. 2 BROUWERS and FATMI, 1992a, from the Late Paleocene-Early Eocene of Pakistan are morphologically very close but do not seem to have marginal denticulations. *Ovocytheridea raoi* JAIN, 1978 from the Early Paleocene of India (see also illustrations in Bhandari, 1995) is very close but is more elongated and more finely punctate. Genus C sp. A EL-WAER, 1992, from the Paleocene of Libya seems closely related but is more elongated. Another closely related species is *Neocyprideis bhupendri* (SINGH and MISRA, 1968) *fide* Bhandari (1996), from the Early Eocene of Rajasthan.

Dimensions

Holotype:

L = 0.70 mm

h = 0.47 mm

Paratypes:

L = 0.60–0.76 mm

h = 0.40–0.53 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizons II, III (In Talack, Takhabanat).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 3 figs 1–8.

1 — Left view, × 65, Takhabanat, N65, Horizon II. **2** — Right view, × 65, **3** — Left view, × 65, In Talack, N26, Horizon III. **4** — Dorsal view, × 65. **5** — Left view, × 65. **6** — Right view, × 65. **7** — Dorsal view, × 65, In Talack, N17, Horizon II. **8** — Pore canal, × 245.

Family KRITHIDAE Mandelstam, 1960
Subfamily KRITHINAE Mandelstam, 1960

Genus *Parakrithe* VAN DEN BOLD

Parakrithe ? kalambainaensis (REYMENT, 1981)

Plate 2, Fig. 20.

1963 *Krithe* cf. *K. perratica* ALEXANDER. Barsotti, p. 1524–1525, pl . 3, fig. 21.

1981 *Bythocypris kalambainaensis* REYMENT. Reyment, p. 56, pl. 1, figs 2–3, non fig. 4.

1983 *Bythocypris* n. sp. aff. *B. olaredodui* REYMENT. Foster *et al.*, p. 110, pl. 8, figs 3, 4.

1990 *Parakrithe ? kalambainaensis* (REYMENT). Carbonnel *et al.*, p. 678, pl. 2, fig. 9.

1990 *Parakrithe ? kalambainaensis* (REYMENT). Bassiouni and Lüger, p. 797, pl. 7, figs 1–4.

1991 *Bythocypris* sp. DAMOTTE. Damotte, p. 7, pl. 1, fig. 6.

1992 *Krithe kalambainaensis* (REYMENT). Carbonnel, pl. 5, fig. 18.

1994 *Krithe* gr. *kalambainaensis* (REYMENT). Keen *et al.*, pl. 16–1 fig. 13.

1995 *Krithe kalambainaensis* (REYMENT). Carbonnel and Monciardini, pl. 6, fig. 7.
1995 *Parakrithe ? kalambainaensis* (REYMENT). Honingstein and Rosenfeld, p. 53, pl. 1, fig. 7.

Remarks

Rather characteristic species with the greatest height at the level of the widely rounded anterior extremity. *Parakrithella* sp. 1 BROUWERS and FATMI, 1992 from the Late Paleocene of Pakistan seems closely related. Other closely related species and probable ancestors of *Parakrithe ? kalambainaensis* are *Krithe* sp. M 535 Bellion *et al.* (1973) from the Santonian-Maastrichtian of Algeria and *Parakrithe* NC 111 Colin and Hochuli (1992) from the Late Campanian of Eastern Niger (Aschia-Tinamou Formation).

Dimensions

L = 0.56 mm
h = 0.26–0.27 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II to IV (Takhabanat, Creb d'Aginger, Ibegan, In Ori, Agamor).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizons I and II of the Tilemsi Valley. Also found by Carbonnel and Monciardini (1995) from Horizons I to IV (Agamor, Fogha, In Araber, Ouarrassibitl).

Egypt: latest Paleocene ?-earliest Eocene.

Israel: Early Paleocene.

Libya: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, fig. 20.

17 — Left view, × 65, Agamor, N49, Horizon IV.

***Parakrithe* ? sp. 1**

Plate 2, Fig. 17.

Remarks

Close to *Parakrithe kalambainaensis* REYMENT, 1983 and to *Parakrithe crolifera* BASSIOUNI and LÜGER, 1990 from the Paleocene-Eocene of Egypt, but different from the Egyptian species by its anterior end more ventrally rounded, halfway between those of *Parakrithe kalambainaensis* and *Parakrithe crolifera.*

Dimensions

L = 0.56 mm
h = 0.26 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (In Talack).

Figured specimens

Pl. 3, fig. 16.

16 — Right view, × 65, In Talack, N21, Horizon III.

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948
Tribe TRACHYLEBERIDINI Sylvester-Bradley, 1948
Tribe TRACHYLEBERIDINI Sylvester-Bradley, 1948

Genus *Acanthocythereis* HOWE, 1963

***Acanthocythereis nyameyensis* CARBONNEL, ALZOUMA and DIKOUMA, 1990**

Plate 5, Figs 1–2.

1961 *Actinocythereis teiskotensis* APOSTOLESCU. Apostolescu, pl. 13, figs 256–258, non 253–255.
?1983 *Echinocythereis*, sp. 1 FOSTER, SWAIN and PETTERS. Foster *et al.*, p. 125–126, pl. 11, figs 7–8.
1990 *Acanthocythereis nyameyensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 681, pl. 1, figs 7–11, pl. 4, fig. 14.
1993 *Trachyleberis teiskotensis* (APOSTOLESCU). Damotte, p. 8, pl. 1, figs 17–18.
1995 *Acanthocythereis nyameyensis* CARBONNEL ALZOUMA and DIKOUMA. Carbonnel and Monciardini, p. 30–31, pl. 2, figs 1–10, pl. 7, fig. 21.

Remarks

The specimens found in Mali are very similar to *Acanthocythereis meslei paleocenica* BASSIOUNI and LÜGER, 1990 from the Late Paleocene of Egypt, which shows only slight differences such as a little more elongated carapace and an anterior margin slightly more ventrally rounded. Both are different from *Acanthocythereis meslei meslei* DONZE and OERTLI, 1982 from the Campanian-Maastrichtian of Tunisia, with its lateral margins convergent posteriorly, its more tapering posterior end and its prominent postero-dorsal tubercle. We consider the anteroventral rostrum reported as characteristic of the species by Carbonnel *et al.* (1990) as a preservation artefact.

Dimensions

L = 0.88 mm
h = 0.45 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon II (Creb d'Aginger)

— previous studies: reported by Bellion *et al.* (1989) from Horizons I (Late Maastrichtian) and II (Late Paleocene) of the Tilemsi Valley. Reported by Carbonnel

and Monciardini (1995) from Horizons II–IV (In Araber, Agamor, Fogha, Ouarassibilt).

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation), (see also Kogbe *et al.*, 1976).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 5, figs 1–2.

1 — Right view, × 65. **2** — Left view, × 65, Creb d'Aginger, N75, Horizon II.

Genus *Megommatocythere* COLIN and OERTLI, 1982

Megommatocythere terrechtensis (APOSTOLESCU, 1961)

Plate 5, Figs 4–6.

1961 *Trachyleberis terrechtensis* APOSTOLESCU. Apostolescu, p. 826, pl. 13, figs 265–267

Remarks

This species is characteristic of the Horizon I (Late Maastrichtian) but persists, although less common, in Horizon II (Late Paleocene). It agrees very well with the description of the genus *Megommatocythere* with its tapering lateral outside and strongly projecting eye tubercle.

Dimensions

L = 0.73 (female) – 0.88 mm (male)
h = 0.45 mm (female) – 0.48 mm (male)

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–II (In Talack, Takhabanat, Creb d'Aginger, Ait Nafa).

— previous studies: originally described by Apostolescu (1961) from the Maastrichtian (Danian auct.) of the Terrecht borehole.

Figured specimens

Pl. 6, figs 4–6.

4 — Right view, male, × 65, In Talack, N8, Horizon I. **5** — Left view, female, × 65, Takhabanat, N61, Horizon I. **6** — Left view, female, × 65, Creb d'Aginger, N75, Horizon II.

Genus *Trachyleberis* BRADY, 1898

Trachyleberis teiskotensis (APOSTOLESCU, 1961)

Plate 5, Figs 7–16

1961 *Actinocythereis teiskotensis* APOSTOLESCU. Apostolescu, p. 814, pl. 13, figs 253–255, non 256–258.
1961 *Actinocythereis modesta* APOSTOLESCU. Apostolescu, p. 813, pl. 13, fig. 259–263.
1963 *Actinocythereis teiskotensis* APOSTOLESCU. Barsotti, p. 1526, pl. 1, figs 7–8.
1963 *Actinocythereis modesta* APOSTOLESCU. Barsotti, p. 1526, pl. 1, fig. 6.
1963 *Trachyleberis teiskotensis* (APOSTOLESCU). Reyment, p. 165, pl. 4, figs 3a–b, 4a–c, pl. 14, figs 7–11, pl. 15, figs 3a–b.
1965 *Trachyleberis teiskotensis* (APOSTOLESCU). Reyment, pl. 8, fig. 5.
1966 *Trachyleberis teiskotensis* (APOSTOLESCU), Salahi, p. 26, pl. 4, fig. 19.
1976 *Trachyleberis modesta* (APOSTOLESCU). Ficcarelli, p. 735, pl. 90, figs 11, 12.
1980 *Trachyleberis teiskotensis* (APOSTOLESCU). Reyment, fig. 12b–c.
1980 *Trachyleberis teiskotensis* (APOSTOLESCU). Reyment and Reyment, pl. 1, figs 9–10.
1981 *Trachyleberis teiskotensis* (APOSTOLESCU). Reyment, p. 61, pl. 7, figs 10–14.
1981 *Actinocythereis* cf. *modesta* APOSTOLESCU. Krstic, p. 122, pl. 1, fig. 9.
1983 *Trachyleberis teiskotensis* (APOSTOLESCU). Foster *et al.*, p. 131, pl. 8, figs 5, 7–16, pl. 9, fig. 11, pl. 11, figs 5, 6.
1987 *Trachyleberis teiskotensis* (APOSTOLESCU). Okosun, p. 44, pl. 5, figs 10–14, 20.
1990 *Trachyleberis modesta* (APOSTOLESCU). Bassiouni and Lüger, p. 820, pl. 13, figs 19–24, pl. 14, figs 1–2.
1990 *Trachyleberis teiskotensis* (APOSTOLESCU). Carbonnel *et al.*, p. 684, pl. 4, fig. 2–3.
1990 *Trachyleberis spininodosa* (EL SWEIFY). Bassiouni and Lüger, p. 820, pl. 14, figs 3–8.
1990 *Trachyleberis gagaensis* BASSIOUNI and LÜGER. Bassiouni and Lüger, p. 821, pl. 14, figs 5, 9–14.
1991 *Trachyleberis teiskotensis* (APOSTOLESCU). Carbonnel and Oyede, p. 85–87, pl. 4, figs 13–16.
non 1991 *Trachyleberis teiskotensis* (APOSTOLESCU). Damotte, p. 8, pl. 1, figs 17–18.
1992 *Trachyleberis teiskotensis* (APOSTOLESCU). Carbonnel, pl. 4, figs 1–5.
1994 *Trachyleberis modesta* APOSTOLESCU. Keen *et al.*, pl. 16.2, fig. 4.
1995 *Acanthocythereis* ? sp. aff? *multispinosa* AL-FURAIH. Swain *et al.*, p. 204, pl. 3, fig. 23.
1995 *Trachyleberis teiskotensis* (APOSTOLESCU). Carbonnel and Monciardini, p. 37–38.

Remarks

One of the most common, widespread (from the West African basins to Egypt), and long ranging species from Late Maastrichtian to Early Eocene. The populations collected in Mali are important enough in several outcrops to show that this form displays a great polymorphism as previously described by Reyment (1963) and by Carbonnel and Oyede (1991). This polymorphism gave rise to several new species or sub-species hereby consid-

ered as morphological variants. Some specimens from the Late Maastrichtian (pl. 5, fig. 16) shows a reticulation as complete as in *Trachyleberis gagaensis* BASSIOUNI and LÜGER, 1990 from the Middle Paleocene of Egypt which could be another variant of *Trachyleberis teiskotensis*. *Acanthocythereis* sp. 2 BROUWERS and FATMI, 1992a from the Paleocene of Pakistan could also belong to this group.

Dimensions

L = 0.63–0.82 mm
h = 0.36–0.46 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–IV (In Talack, Agamor, Takhabanat, Creb d'Aginger, In Ori, Ibegan).

— previous studies: originally described by Apostolescu (1961) from the Late Paleocene of the Teiskot borehole. Horizons I–IV (Ouarassibilt, In Araber).

Benin: Late Paleocene (Akpiti *et al.*, 1986).

Cameroon: Paleocene.

Congo: Paleocene (Massala, 1993; Damotte and Massala, 1996)

Egypt: Middle Paleocene-basal Early Eocene (*angulata* to *edgari* Zone).

Ivory Coast: Paleocene.

Libya: Paleocene.

Nigerian coastal basin: Paleocene.

North-western Nigeria (Iullemmeden Basin): Maastrichtian-Late Paleocene (Kalambaina and Dange Formations) (Okosun, 1989).

Senegal: Late Paleocene.

Sudan: Paleocene (Masoli, 1968: as *Actinocythereis exanthemata*).

Togo: Late Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 5, figs 7–16.

7 — Left view, × 65, In Talack, N12, Horizon I. **8, 11** — Left views, × 65, In Talack, N24, Horizon III. **9** — Left view, × 65, In Talack, N29, Horizon II. **12, 13** — Left views, × 65, In Talack, N5, Horizon I. **14** — Right view, × 65, Agamor, N52, Horizon IV. **15** — Left view, × 65, Agamor, N47, Horizon III. **16** — Right view, × 65, Takhabanat, N64, Horizon IV.

Genus *Teiskotella* gen. nov.

Derivation of name: After the type-species *teiskotensis*.

Type species: *Bradleya teiskotensis* APOSTOLESCU, 1961.

Diagnosis

Trachyleberid genus with the following characters: posterior extremity obliquely truncated, distinct hinge-ear and eye tubercle; anterior margin evenly rounded bordered by a distinct furrow; well developed muscle-node; short and arched ventral ridge not connected to the anterior one; surface of the valves smooth or reticulated; hinge heterodont.

Remarks

Since its original description the type-species has been assigned to the following genera: *Bradleya, Cythereis, Phyrocythere, Stigmatocythere* and *Mauritsina*. *Teiskotella* gen. nov. differs clearly from these genera by its overall shape and its obliquely truncated posterior extremity.

Other species belonging to this new genus are *Veenia* sp. 1 BROUWERS and FATMI 1992a, *Veenia* sp. 2 BROUWERS and FATMI, 1992b and possibly *Actinocythereis* ? *quasibathonica* SIDDIQUI, 1971 all from the Paleogene of Pakistan.

Teiskotella teiskotensis (APOSTOLESCU, 1961)

Plate 5, Figs 20–24.

24 — Left view, × 65, In Talack, N17, Horizon II. 1961 *Bradleya teiskotensis* APOSTOLESCU. Apostolescu, p. 819, pl. 12, figs 241–245.

1963 *Cythereis teiskotensis* (APOSTOLESCU). Reyment, p. 161, pl. 2, fig. 3, pl. 4, fig. 1a–c, pl. 15, figs 1–2.

1963 *Bradleya teiskotensis* APOSTOLESCU. Barsotti, p. 1527, pl. 2, fig. 19.

1966 *Cythereis teiskotensis* (APOSTOLESCU). Salahi, p. 24, pl. 4, fig. 24.

1980 *Bradleya (?) teiskotensis* (APOSTOLESCU). Reyment, fig. 8 g–h.

1980 *Cythereis teiskotensis* (APOSTOLESCU). Reyment and Reyment, pl. 1, figs 7.

1981 *Cythereis teiscotensis* (APOSTOLESCU). Krstic, p. 122, pl. 1, fig. 6.

1986 *Phyrocythere teiskotensis* (APOSTOLESCU). Carbonnel, p. 108–109, pl. 2, fig. 15.

1987 *Stigmatocythere teiskotensis* (APOSTOLESCU). Okosun, p. 43, pl. 14, figs 4–7.

1990 *Mauritsina teiskotensis teiskotensis* (APOSTOLESCU). Bassiouni and Lüger, p. 813, pl. 12, fig. 1.

1990 *Mauritsina teiskotensis subteiskotensis* BASSIOUNI and LÜGER. Bassiouni and Lüger, p. 813–814, pl. 12, figs 2–5.

1990 *Phyrocythere teiskotensis* (APOSTOLESCU). Carbonnel *et al.*, p. 683, pl. 2, fig. 17.

1991 *Mauritsina teiskotensis* (APOSTOLESCU). Damotte, p. 10, pl. 2, figs 5–6.

1992 *Phyrocythere teiskotensis* (APOSTOLECU). Carbonnel, pl. 17, figs 11–14.

1994 *Cythereis teiskotensis* (APOSTOLESCU). Keen *et al.*, pl. 16.2, figs 10–11.

1995 *Phyrocythere teiskotensis* (APOSTOLESCU). Carbonnel and Monciardini, p. 30, pl. I, fig. 19.

Remarks

Two morphs have been found in our Malian material. The smooth morph, more common similar to the species described by Apostolescu, and a weakly reticulate morph showing affinities with the Danian specimens illustrated by Keen *et al.* (1994) from Libya. We consider the subspecies *subteiskotensis* of Bassiouni and Lüger (1990) has been part of the morphological range of the species.

Dimensions

L = 0.73–0.95 mm
h = 0.38–0.50 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon II (In Talack, Creb d'Aginger).

— previous studies: originally described by Apostolescu (1961) from the Late Paleocene of the Teiskot borehole. Reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizons I (Late Maastrichtian) and III (Late Paleocene) of the Tilemsi Valley. Also found by Carbonnel and Monciardini (1995) in Horizons II and IV (Fogha, In Araber).

Benin: Late Paleocene.

Guinea-Bissau: Paleocene.

Libya: Early Paleocene (Danian) of the Sirte Basin-Late Paleocene.

Egypt: Middle (*angulata* Zone)-Late Paleocene (*velascoensis* Zone).

Nigerian coastal basin: Paleocene.

Senegal: Late Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, figs 20–24.

20, 22 — Right views × 65, Creb d'Aginger, N75, Horizon II. **21** — Right view, × 65, **23** — Dorsal view, × 65, Creb d'Aginger, N77, Horizon II.

Genus *Rayneria* Neale, 1975

Rayneria tilemsiensis (Apostolescu, 1961)

Plate 6, Figs 1–6.

1961 *Orionina* ? *tilemsiensis* Apostolescu. Apostolescu, p. 824–825, pl. 11, figs 220–223.

1995 *Costa tilemsiensis* (Apostolescu). Carbonnel and Monciardini, p. 32–33, pl. 1, figs 18, 20.

Remarks

Close by its shape to *Rayneria neali* in Dingle (1976, 1981), but with a more complex ornamentation. Variable in its shape with a more or less developed postero-ventral expansion (Plate 6, fig. 1) and in its ornamentation with pustules more or less fused together in vertical muri inside intercostal spaces. *Costa* sp. illustrated by Andreu and Tronchetti (1996) in the Maastrichtian of Morocco shows striking similarities and probably belongs to the genus *Rayneria*.

This species is restricted to the Horizon I (Late Maastrichtian) and disappears before the Paleocene as other species of the genus *Rayneria* known from Late Cretaceous of Australia and South Africa

Dimensions

L = 0.70 (female) – 0.88 (male) mm
h = 0.40 (female) – 0.44 (male) mm

Age and distribution

Mali:

— this study: Late Maastrichtian, Horizon I (In Talack, Takhabanat, Creb d'Aginger, Ait Nafa).

— previous studies: originally described by Apostolescu (1961) from the Late Maastrichtian (Danian auct.) of Ait Nafa, Tilemsi Valley. Reported by Carbonnel and Monciardini (1995) in Horizon I (Ouarassibilt).

Western Niger: Late Maastrichtian.

Figured specimens

Pl. 6, figs 1–6.

1 — Left view, × 65, Ait Nafa, N85, Horizon I. **2** — Right view, × 65, Takhabanat, N61, Horizon. I. **3** — Left view, × 65, **4** — Right view, × 65, In Talack, N11, Horizon I. **5** — Right view, × 65, Takhabanat, N63, Horizon. I. **6** — Left view, × 65, Takhabanat, N61, Horizon. I.

Genus *Schizoptocythere* Siddiqui and Al-Furaih, 1981

Schizoptocythere usmandanfodioi (Reyment, 1981)

Plate 6, Figs 10–11.

1963 *Idiocythere* ? sp. Reyment. Reyment, p. 179, pl. 5, fig. 10.

1966 *Trachyleberis* ? sp. A Salahi. Salahi, p. 26, pl. 4, fig. 20.

1981 *Exophtalmocythere* ? *usmandanfodioi* Reyment. Reyment, p. 59, pl. 4, figs 4–6, pl. 10, fig. 4.

1987 *Idiocythere* ? sp. Okosun. Okosun, p. 36, pl. 15, fig. 1.

1990 *Exophtalmocythere* ? *usmandanfodioi* Reyment. Carbonnel *et al.*, p. 678, pl. 2, fig. 8.

1991 *Exophtalmocythere* ? *usmandanfodioi* Reyment. Damotte, p. 9, pl. 1, fig. 21.

1992 *Exophtalmocythere* ? *usmandanfodioi* Reyment. Carbonnel, pl. 10, fig. 11.

1994 *Schizoptocythere* sp. Keen, Al-Sheikly, Elsogher and Gammudi. Keen *et al.* pl. 16.1, fig. 10.

1995 *Exophtalmocythere usmandanfodioi* Reyment. Carbonnel and Monciardini, p. 69.

Remarks

Schizoptocythere sp. 2 Brouwers and Fatmi from the Paleocene of Pakistan is very close. Several closely re-

lated species have been described by Khosla (1972), Siddiqui and Al-Furaih (1981) and Bhandari (1992) from the Early Tertiary (Early Paleocene to Middle Eocene) of Saudi Arabia, Pakistan and India.

Dimensions

L = 0.80 mm
h = 0.44 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon III–IV (Agamor).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizon II of the Tilemsi Valley. Found in Horizons III–IV (In Araber, Fogha), by Carbonnel and Monciardini (1995).

Benin: Late Paleocene.

Ghana: Maastrichtian.

Libya: Early Paleocene, Danian (Sirte Basin).

Nigerian coastal basins: Late Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, figs 10–11.

10 — Right view, × 65, In Talack, N35, Horizon I. **11** — Right view, In Talack, N38, Horizon. I.

Tribe COSTAINI Hartmann and Puri, 1974

Genus *Paracosta* SIDDIQUI, 1971

(= *Paleocosta* BENSON, 1977; *Reymenticosta* BASSIOUNI and LÜGER, 1990)

Remarks

We consider that *Paleocosta* BENSON and *Reymenticosta* BASSIOUNI and LÜGER are junior synonyms of *Paracosta* SIDDIQUI. Benson himself (1977, p. 36) was already concerned by the similarities between *Paleocosta* and *Paracosta*: "I was concerned at first that the sub-genus *Paleocosta* and *Paracosta* might be variations of the same thing".

***Paracosta warriensis* (REYMENT, 1960)**

Plate 4, Figs 1–2.

1960 *Veenia warriensis* REYMENT. Reyment, p. 180, pl. 13, figs 2a–c, 3, pl. 18, fig. 1a–b.
1963 *Veenia (Veenia) warriensis* REYMENT. Reyment, p. 186–188, pl. 5, figs 3a–c.
?1963 *Veenia (Veenia) acuticosta* REYMENT. Reyment, p. 192, pl. 6, fig. 2, pl. 26, fig. 8, pl. 27, fig. 8.
1966 *Costa dahomeyi* APOSTOLESCU. Salahi, p. 23, pl. 5, figs 18–20.
non 1968 *Costa ? warriensis* (REYMENT). Esker, p. 319, pl. I, fig. 8.
?1969 *Anticythereis* T 1875 GRÉKOFF. Grékoff, p. 246, pl. 3, fig. 47.
1980 *Veenia warriensis* REYMENT. Reyment, fig. 12i.
1981 *Paracosta ? warriensis* (REYMENT). Reyment, p. 63, pl. 8, fig. 14, pl. 9, fig. 5.
1981 *Veenia grekoffi* REYMENT. Krstic, p. 122, pl. 1, figs 10–11.
1986 *Veenia (Veenia) warriensis* REYMENT. Damotte, p. 160, pl. 2, figs 4–6.
1986 *Veenia*. Kogbe and Me'hes, p. 20, fig. 32 (pars).
1987 *Costa (Paracosta) warriensis* (REYMENT). Okosun, p. 33, pl. 2, figs 21, 23–25, pl. 5, fig. 1.
1989 *Paracosta dahomeyi* (APOSTOLESCU). Carbonnel and Johnson, pl. 3, figs 4–5.
1990 *Paracosta transsaharaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 682, pl. 2, figs 13–14, text-fig. 2.
1990 *Reymenticosta zitteli* BASSIOUNI and LÜGER. Bassiouni and Lüger, pl. 21, figs 17–21, l. 22, fig. 16.
1991 *Veenia warriensis* REYMENT. Damotte, p. 10, pl. 2, figs 3–4.
1992 *Paracosta transsaharaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel, pl. 3, figs 3–4.
1992 *Paleocosta* sp. A EL-WAER. El-Waer, p. 114–116, pl. 19, figs 3–7.
?1993 *Paleocosta ? warriensis* (REYMENT). Whatley and Arias, p. 134, pl. 2, figs 14–15.
1994 *Paracosta warriensis* (REYMENT). Keen *et al.*, pl. 16.5, figs 3–5.
1995 *Fissocarinocythere* ? sp. SWAIN, PETTERS and XIE. Swain *et al.*, p. 57, pl. 3, figs 12–14, 17–20.
1995 *Reymenticosta transaharaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel and Monciardini, p. 36–37, pl. 3, figs 5–9.

Remarks

It is strongly suggested that *Veenia acuticosta* REYMENT, *Reymenticosta zitteli* BASSIOUNI and LÜGER and *Paracosta transsaharensis* CARBONNEL, ALZOUMA and DIKOUMA are junior synonyms of *Paracosta warriensis* as suggested by Keen *et al.* (1994).

Dimensions

L = 0.66–0.75 mm
h = 0.40–0.44 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II–III (Creb d'Aginger, In Talack).

— previous studies: reported by Damotte (1991) from Horizons I and II of the Tilemsi Valley. Horizons II (In Araber, Fogha).

Algeria: Late Maastrichtian, ?Early Eocene.

Libya: Maastrichtian-Paleocene, ?Early and Middle Eocene.

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Dukamaje Formation), (see also Kogbe *et al.*, 1976).

Egypt: Late Paleocene to Early Eocene (late *velascoensis* to *subbotinae* Zone).

Western Niger: Late Maastrichtian (Farin-Doutchi Formation)-Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 4, figs 1–2.

1 — Left view, × 65, Creb d'Aginger, N78, Horizon II. **2** — Right view, × 65, In Talack, N24, Horizon III.

Genus *Moosina* Bassiouni and Lüger, 1990

Moosina terlineata n. sp.

Plate 5, Figs 3, 17–19.

Derivation of name: with reference to its three lateral ridges.

Type-locality: Late Maastrichtian, Horizon I.

Holotype: one carapace (pl. 6, fig. 3).

Paratypes: 6 complete carapaces.

Diagnosis

Species of *Moosina* characterised by a small and elongated sub rectangular tricostate carapace with two short sub vertical ridges in its postero-dorsal intercostal area.

Description

Small carapace, sub rectangular and elongated in lateral view, thin with anterior and posterior ends compressed in dorsal view. Rounded anterior margin, symmetrical or with a slight ventral asymmetry; posterior margin narrowly rounded to slightly acute, both surrounded by a strong marginal ridge. Ventral margin concave in its middle part. Three sub parallel ridges, the dorsal and the medium stronger and longer than the ventral one. The medium ridge terminates posteriorly in a right angled bend towards the concave part of the ventral margin. Surface reticulated with deep and regular fossae in the anterior part. In the intercostal area, irregular or incomplete reticulation between the dorsal and the medium ridges, an anterior area almost smooth and a posterior area reticulated with strongly elevated vertical muri forming two short ridges linking the dorsal and the medium ones. Distinct eye tubercle. Distinct sexual dimorphism with presumed males longer and narrower than females

Remarks

Differs from *Moosina barisiensis* Bassiouni and Lüger, 1990 type-species of the genus from the Late Paleocene-Early Eocene of Egypt, in being narrower, more sub rectangular, more compressed and with less broad anterior and posterior marginal areas. Furthermore, details of their ornamentation are different so as the stronger and longer three lateral ridges of *Moosina terlineata* and its two postero-dorsal sub vertical ridges missing in *Moosina barisiensis*.

Dimensions

Holotype:

L = 0.46 mm

h = 0.25 mm

Paratypes:

L = 0.45 (female) – 0.50 (male) mm

h = 0.24 (female) – 0.26 (male) mm

Age and distribution

Mali: Late Maastrichtian-Late Paleocene (Thanetian); Horizons I–II (In Talack, Ait Nafa, In Orphan).

Figured specimens

Pl. 5, figs 3, 17–19.

3 — Right view, x70, In Talack, N4, Horizon I. **17** — Right view, × 70, Ait Nafa, N85, Horizon I. **18, 19** — Left and dorsal views, × 70, In Orphan, N79, Horizon II.

Genus *Stigmatocythere* Siddiqui, 1971

Stigmatocythere brgmensis (Carbonnel and Monciardini, 1995)

Plate 4, Figs 3–6, 11.

1986 *Stigmatocythere* aff. *obliqua* Siddiqui. Carbonnel, p. 131–132, pl. 10, figs 12–15.

1992 *Stigmatocythere* aff. *obliqua* Siddiqui. Carbonnel, pl. 19, figs 15–18.

1995 *Moosina brgmensis* Carbonnel and Monciardini. Carbonnel and Monciardini, p. 34–35, pl. 3, figs 1–3, 11.

Remarks

This species resembles *Phyrocythere irrigata* Alfuraih, 1980 from the Paleocene of Saudi Arabia by its general ornamentation but differs by its dorsal and ventral margins not converging posteriorly and its less tapered posterior end. It is also very close in general outline and ornamentation pattern to *Stigmatocythere siddiquii* Keen and Racey, 1991 from the Early Eocene of Oman and to *Stigmatocythere obliqua* Siddiqui, 1971 from the Early Eocene of Pakistan and Middle Eocene of Natal (Dingle, 1976).

Dimensions

L = 0.52–0.56 mm

h = 0.25–0.34 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon IV (In Talack, Agamor).

— previous studies: Horizon IV (Fogha).

Senegal: Late Paleocene-Early Eocene.

Figured specimens

Pl. 4, figs 3–6, 11.

3, 11 — Left views, × 65, **5** — Right view, × 65, **4** — Left view, × 65, Agamor, N52, Horizon IV. **6** — Dorsal view, × 65, Agamor, N49, Horizon IV

Tribe PTERYGOCYTHERIDEIDINI Puri, 1957

Genus *Ponticulocythere* DINGLE, 1981

***Ponticulocythere* cf. *P. austraegyptiaca* (BASSIOUNI and LÜGER, 1990)**

Plate 6, Fig. 7.

cf. 1990 *Pterygocythereis austraegyptiaca* BASSIOUNI and LÜGER. Bassiouni and Lüger, p. 788–789, pl. 4, figs 1–4.

1995 *Pterygocythereis austraegyptiaca* BASSIOUNI and LÜGER. Carbonnel and Monciardini, p. 38, pl. 3, figs 12–13.

Remarks

The single specimen found in our Malian samples differs only from the type-species of the genus *Ponticulocythere biremis* DINGLE, 1981 from the Maastrichtian of SE Africa by its dorsal rib which is not clearly ponticulate (perforated), the lack of the sail-like projection behind the eye spot and its posterior end more dorsally acuminate. It is closely related to *Pterygocythereis austraegyptiaca* BASSIOUNI and LÜGER, 1990 from the latest Paleocene or basal Eocene of Egypt, which has more posteriorly converging dorsal and ventral margins.

Dimensions

L = 0.80 mm
h = 0.46 mm

Age and distribution

Mali:

— this study: Late Maastrichtian, Horizon I (In Talack), Late Paleocene (Thanetian), Horizon IV (Agamor).

— previous studies: reported by Carbonel and Monciardini (1995) from Horizon IV (Agamor).

Egypt: uppermost Paleocene or basal Eocene.

Western Niger: Late Maastrichtian (In Wagar Formation).

Figured specimens

Pl. 6, fig. 7.

7 — Left view, × 65, In Talack N5, Horizon I.

Genus *Dahomeya* APOSTOLESCU, 1961

***Dahomeya alata alata* APOSTOLESCU, 1961**

Plate 6, Fig. 14.

1961 *Dahomeya alata* APOSTOLESCU. Apostolescu, p. 796, pl. 2, figs 23–25.

1963 *Dahomeya alata* APOSTOLESCU. Barsotti, p. 524, pl. 1, fig. 3.

non 1963 *Dahomeya alata* APOSTOLESCU. Reyment, p. 117, pl. 1, fig. 5a–c.

1978 *Dahomeya alata* APOSTOLESCU. Ducasse *et al.*, p. 20, pl. 2, fig. 3.

1980 *Dahomeya* aff. *alata* APOSTOLESCU. Reyment, fig. 8g.

1981 *Dahomeya alata* APOSTOLESCU. Reyment, p. 57, pl. 1, figs 11–12.

1982 *Dahomeya alata* APOSTOLESCU. Donze *et al.*, p. 294, pl. 9, figs 3–5.

1986 *Dahomeya alata* APOSTOLESCU. Carbonnel, p. 81, pl. 5, figs 4–6.

1986 *Dahomeya* KOGBE and ME'HES. Kogbe and Me'hes, p. 18, fig. 29 (pars).

1987 *Dahomeya alata* APOSTOLESCU. Okosun, p. 84, pl. 15, fig. 5, pl. 17, figs 9, 12, 15.

1990 *Dahomeya alata alata* APOSTOLESCU. Bassiouni and Lüger, p. 787.

1991 *Dahomeya alata* APOSTOLESCU. Damotte, p. 10, pl. 2, fig. 7.

1992 *Dahomeya alata* APOSTOLESCU. El-Waer, p. 127, pl. 22, figs 1–7.

1992 *Dahomeya alata* APOSTOLESCU. Carbonnel, pl. 9, figs 8–10.

1993 *Dahomeya alata* APOSTOLESCU. Whatley and Arias, p. 137–138, pl. 3, figs 12–13.

1994 *Dahomeya alata* APOSTOLESCU. Digbehi *et al.*, p. 193, pl. 2, fig. 15.

1994 *Dahomeya alata* APOSTOLESCU. Keen *et al.*, pl. 16.1, fig. 8.

1995 *Dahomeya alata* APOSTOLESCU. Carbonnel and Monciardini, p. 62, pl. 6, fig. 15

Remark

In our Malian material, a single specimen have been found, possessing the diagnostic anterior pits. Forms without the pits from the Early Eocene of Egypt have been assigned to a new subspecies *Dahomeya alata anteroglabra* by Bassiouni and Lüger (1990).

Dimensions

L = 0.46 mm
h = 0.36 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon II (In Talack).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Late Maastrichtian of the Tilemsi Valley and by Carbonnel and Monciardini (1995) in Horizons II–IV (Fogha, Ekkineouan, In Araber, Ouarassibilt).

Benin: Late Paleocene (Akpiti *et al.*, 1985).

Congo: Paleocene (Damotte and Massala, 1996).

Egypt: Late Paleoecene (*pseudomenardii* Zone).

Ivory Coast: Late Paleocene.

Libya: Early Paleocene (Danian) of the Sirte Basin.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina and Dange Formations).

Senegal: Late Paleocene-Early Eocene.

Togo: Late Paleocene.

Tunisia: Late Paleocene-Early Eocene.
Western. Niger: Late Paleocene.

Figured specimens

Pl. 6, fig. 14.
14 — Left view, × 65, In Talack, N17, Horizon II.

Tribe BRACHYCYTHERINI Puri, 1954

Genus *Brachycythere* ALEXANDER, 1933

Brachycythere oguni REYMENT, 1960

Plate 6, Figs 22–24.

1960 *Brachycythere oguni* REYMENT. Reyment, p. 134, pl. 5, fig. 2
1961 *Brachycythere oguni* REYMENT. Apostolescu, p. 798, pl. 8, figs 150–153.
1969 *Brachycythere oguni* REYMENT. Grékoff, p. 242, pl. 3, fig. 42.
1978 *Brachycythere oguni* REYMENT. Ben Abdessalem, pl. 21, fig. 11.
1981 *Brachycythere oguni* REYMENT. Reyment, p. 59, pl. 3, figs 17–18.
1982 *Brachycythere oguni* REYMENT. Damotte, p. 50, pl. 1, figs 11–13.
1986 *Brachycythere oguni* REYMENT. Damotte, p. 158, pl. 1, figs 4–7.
1987 *Brachycythere oguni* REYMENT. Damotte and Fleury, p. 97–98, pl. 3, figs 18–19.
1987 *Brachycythere oguni* REYMENT. Okosun, p. 82, pl. 19, fig. 21.
1990 *Brachycythere* cf. *oguni* REYMENT. Bassiouni and Lüger, p. 786–787, pl. 3, figs 11, 14, 17.
1992 *Brachycythere* NC 211 COLIN and HOCHULI. Colin and Hochuli, pl. 3, fig. 1.
1995 *Brachycthere oguni* REYMENT. Carbonnel and Monciardini, p. 61, pl. 6, fig. 17.
1995 *Brachycythere angulata* GRÉKOFF. Carbonnel and Monciardini, p. 61, pl. 6, fig. 16.

Remarks

Accurate identification of African *Brachycythere* species is not an easy task. In West Africa, several species have been described, amongst them *Brachycythere oguni* REYMENT, *Brachycythere ekpo* REYMENT and *Brachycythere angulata* GRÉKOFF. This last species is closely related to *Brachycythere oguni* from which it differs essentially by a more angular (carinate) ventral surface. Other forms have been referred to the Turonian Brazilian species *Brachycythere sapucariensis* KRÖMMELBEIN. The Malian forms show a dissymetry of the valves with a slightly carinate right valves. A complete revision of this genus seems necessary to be able to identify with more accuracy the various species. Related species have been reported by Damotte and Saint-Marc (1972) in the Senonian of Lebanon (as *Brachycythere angulata* GRÉKOFF), by Grosdidier (1973) in the Persian Gulf (*Brachycythere* IR C 28), by Honingstein (1983) and Honingstein *et al.* (1985) in Israel (as *Brachycythere angulata*) and by Andreu and Tronchetti (1996) in Morocco (as *Brachycythere* cf. gr. *sapucariensis* KRÖMMELBEIN). Amongst the six species of *Brachycythere* described by Al-Furaih (1987) in the Maastrichtian of Saudi Arabia, only *Brachycythere tumida* AL-FURAIH shows affinities with *Brachycythere oguni*.

Dimensions

L = 0.88–1.00 mm
h = 0.56–0.57 mm

Age and distribution

Mali:
— this study: Late Maastrichtian, Horizon I (In Talack, Creb d'Aginger, Ait Nafa).
— previous studies: reported by Apostolescu (1961) in the Maastrichtian (= Danian auct.) and by Carbonnel and Monciardini (1995) in Horizon I, of Ait Nafa.
Algeria: Late Maastrichtian-Paleocene.
Eastern Niger: Campanian (Aschia-Tinamou Formation).
Western Niger: Late Maastrichtian (Farin-Doutchi Formation).
Egypt: Middle Maastrichtian (*gansseri* Zone).
Ghana: Campanian-Maastrichtian (Kogbe and Me'hes, 1986).
Nigerian coastal basins: Late Maastrichtian-Early Paleocene (Danian).
Togo: Maastrichtian.
Tunisia: Maastrichtian.

Figured specimens

Pl. 6, figs 22–24.
22 — Right view, × 65 **23** — Left view, × 65, **24** — Dorsal view, × 65, In Talack, N11, Horizon I.

Tribe ECHINOCYTHEREIDINI Hazel, 1967

Genus *Isalocopocythere* CARBONNEL, ALZOUMA and DIKOUMA, 1990

Remarks

The importance of the morphological differences compared to the genus *Alocopocythere* SIDDIQUI, lead us to consider *Isalocopocythere* as a genus and not a subgenus of *Alocopocythere*.

Isalocopocythere teiskotensis (APOSTOLESCU, 1961)

Plate 4, Figs 12–22.

1961 *Leguminocythereis ? teiskotensis* APOSTOLESCU. Apostolescu, p. 824, pl. 10, figs 206–208.

1963 *Leguminocythereis teiskotensis* APOSTOLESCU. Barsotti, p. 1528, pl. 2, fig. 15.
1966 *Quadracythere* n. sp. 1 SALAHI. SALAHI, p. 25–26, pl. 5, fig. 4.
non 1976 ?*Alocopocythere* cf. ? *A. teiskotensis* (APOSTOLESCU). Dingle, p. 45–46, fig. 9 (1).
1976 *Leguminocythereis teiskotensis* APOSTOLESCU. Ficcarelli, p. 735, pl. 90, fig. 10.
1980 *Alocopocythere immodica* AL-FURAIH. Al-Furaih, p. 24–25, pl. 16, fig. 1–4.
1980 *Alocopocythere circumampla* AL-FURAIH. Al-Furaih, p. 23–24, pl. 15, figs 1–4.
1980 *Alocopocythere tridens* AL-FURAIH. Al-Furaih, p. 26, pl. 18, figs 1–4.
1981 *Alocopocythere* ? *teiskotensis* (APOSTOLESCU). Reyment, p. 59, pl. 4, fig. 1.
1981 *Alocopocythere* ? aff. *teiskotensis* (APOSTOLESCU). Reyment, p. 59, pl. 4, fig. 3.
?1981 *Aurila* sp. indet. REYMENT. Reyment, p. 60, pl. 4, fig. 13a–b.
1983 *Alocopocythere immodica* AL-FURAIH. Al-Furaih, p. 4, pl. 1, figs 1–2.
1983 *Leguminocythereis* ? *teiskotensis* APOSTOLESCU. Foster *et al.*, p. 115, pl. 4, figs 7, 8.
1983 *Schizocythere* ? sp. FOSTER, SWAIN and PETTERS. Foster *et al.*, p. 116, pl. 10, figs 4–5.
1990 *Alocopocythere (Isalocopocythere) immodica* (AL-FURAIH). Carbonnel *et al.*, p. 679, pl. 2, fig. 19–21, pl. 4, figs 1, 16.
1991 *Alocopocythere (Isalocopocythere) teiskotensis* (APOSTOLESCU). Damotte, p. 9–10, pl. 2, figs 1–2.
1992 *Alocopocythere (Isalocopocythere) immodica* (AL-FURAIH). Carbonnel, pl. 1, figs 12–14.
1994 *Alocopocythere teiskotensis* (APOSTOLESCU). Keen *et al.*, pl. 16.2, fig. 9.
1995 *Alocopocythere (Isalococpocythere) immodica* AL-FURAIH. Carbonnel and Monciardini, p. 39, pl. 3, figs 14–15.

Remarks

Carbonnel *et al.* (1990), considered Apostolescu's species *Leguminocythereis teiskotensis* as conspecific with Al-Furaih's species *Isalocopocythere immodica.* Since Apostolescu's species was created in 1961 there is no reason to use Al-Furaih's species name. This coarsely reticulate species, rectangular in male dimorph, quadrate in female dimorph, occurs in every marine Horizon (from I to IV). Rather rare in Horizon I, it becomes very abundant in Horizon III, especially in Agamor. The largest specimens occur in Horizon II but the same morphologic variations in size, length to height ratio, posterior end more or less compressed and differentiated and the aggradation-degradation of the ornamentation are observed through the whole succession. Al-Furaih's species *Alocopocythere circumampla* and *Alocopocythere tridens* from the Paleocene of Saudi Arabia seem to fit into the range of morphological variability of the species.

Dimensions

L = 0.71–0.95 mm
h = 0.41–0.54 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–IV (In Talack, Agamor, Takhabanat, Creb d'Aginger, Asselar, Ait Nafa, In Ori, Ibegan).

— previous studies: reported by Damotte (1991) from Horizons II and III (Late Paleocene) of the Tilemsi Valley. Horizons II–IV (Ouarassibilt, Ekkineouan, Fogha, In Aaraber).

Libya: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Nigerian coastal basin: Late Paleocene.

Saudi Arabia: latest Maastrichtian-Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 5, figs 12–22.

12 — Right view, × 65, Agamor, N51, Horizon IV. **13** — Right view, × 65, **14** — Left view, × 65, Agamor, N50, Horizon IV. **15** — Left view, × 65, In Ori, N89, Horizon IV. **16** — Left view, × 65, Agamor, N35, Horizon III. **17** — Left view, x65, In Talack, N21, Horizon III. **18** — Right view, × 65, **19** — Left view, × 65, Takhabanat, N64, Horizon II. **20** — Right view, × 65, In Talack, N5, Horizon I. **21** — Left view, × 65, Creb d'Aginger, N76, Horizon II. **22** — Left view, × 65, In Talack, N5, Horizon I.

Subfamily BUNTONIINAE Apostolescu, 1961
Tribe BUNTONIINI Apostolescu, 1961

Genus *Buntonia* HOWE, 1935

Buntonia apatayeriyerii REYMENT, 1963

Plate 3, Figs 9–11.

1963 *Buntonia apatayeriyerii* REYMENT. Reyment, p. 239, pl. 7, figs 5a–b.
1966 *Buntonia* nov. sp. 2 SALAHI. Salahi, p. 10, pl. 2, figs 8–9.
1980 *Buntonia apatayeriyerii* REYMENT. Reyment, fig. 8m.
1981 *Buntonia apatayeriyerii* REYMENT. Reyment, p. 62, pl. 5, figs 12, 14.
1983 *Buntonia (Buntonia) pulvinata* APOSTOLESCU. Foster *et al.*, p. 121–122, pl. 7, figs 2, 3.
non 1986 *Buntonia apatayeriyerii* REYMENT. Carbonnel, p. 50–51, pl. 1, figs 2–3.
1987 *Buntonia (P.) apatayeriyerii* REYMENT. Okosun, p. 53, pl. 18, figs 4–6, 8, 16.
1990 *Buntonia apatayeriyerii* REYMENT. Carbonnel *et al.*, pl. 1, figs 12–13, pl. 3, fig. 4.

1990 *Buntonia apatayeriyerii* REYMENT. Carbonnel, pl. 1, fig. 15.
1991 *Buntonia apatayeriyerii* REYMENT. Damotte, p. 10–11, pl. 2, fig. 8.
1992 *Buntonia apatayeriyerii* REYMENT. Carbonnel, pl. 1, fig. 15.
1995 *Buntonia apatayeriyerii* REYMENT. Carbonnel and Monciardini, p. 46–47, pl. 4, figs 17–21.

Remarks

Buntonia sp. 8 CARBONNEL, 1986 from the Early Paleocene of Senegal is very close with its longitudinal median sulcus but differs essentially by the lack of costae. As mentioned by Carbonnel (1986) *Buntonia apatayeriyerii* display a strong polymorphism.

Dimensions

L = 0.51–0.63 mm
h = 0.33–0.38 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II to IV (In Talack, Agamor, Takhabanat).

— previous studies: reported by Damotte (1991) in the Late Maastrichtian and Late Paleocene (Horizon II) of the Tilemsi valley. Horizons III–IV (Ouarassibilt, Fogha, In Araber).

Ghana: ? Maastrichtian (Kogbe and Me'hes, 1986).

Libya: Paleocene.

Nigerian coastal basins: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 3, figs 9–11.

9 — Left view, × 65, Takhabanat, N64, Horizon II. **10** — Right view, × 65, Agamor, N35, Horizon III. **11** — Left view, Agamor, N34, Horizon III.

Buntonia bopaensis APOSTOLESCU, 1961

Plate 3, Figs 23, 26.

1961 *Buntonia bopaensis* APOSTOLESCU. Apostolescu, p. 800, pl. 5, figs 105–109.
1961 *Protobasslerites bopaensis* APOSTOLESCU. Apostolescu, p. 808, pl. 2, figs 38–42, pl. 16, figs 301–303.
non 1963 *Buntonia bopaensis* APOSTOLESCU. Reyment, p. 215–223, pl. 7, fig. 1, pl. 20, fig. 1.
1963 *Buntonia bopaensis afra* REYMENT. Reyment, p. 223–227, text-fig. 59.
? 1966 *Buntonia (Buntonia) bopaensis* APOSTOLESCU. Salahi, p. 10, pl. 2, fig. 16.
1976 *Buntonia bopaensis* APOSTOLESCU. Ficcarelli, pl. 91, figs 1–5.
1978 *Protobasslerites bopaensis* APOSTOLESCU. Ben Abdessalem, pl. 22, figs 7–8.
? 1980 *Buntonia bopaensis* APOSTOLESCU. Reyment, fig. 12f.
non 1983 *Protobasslerites bopaensis* APOSTOLESCU. Foster *et al.*, p. 128, pl. 6, figs 3–4.
1986 *Buntonia bopaensis* APOSTOLESCU. Carbonnel, text-fig. p. 65.
non 1987 *Buntonia (B.) bopaensis bopaensis* APOSTOLESCU. Okosun, p. 45, pl. 1, figs 1–4, pl. 10, fig. 7.
1987 *Buntonia (B.) akinsidensis* (APOSTOLESCU). Okosun, p. 49, pl. 9, figs 7–9, 12
1987 *Buntonia (B.) bopaensis afra* REYMENT. Okosun, p. 46, pl. 9, figs 5, 6, 10, 11, 16.
1991 *Buntonia bopaensis* APOSTOLESCU. Carbonnel and Oyédé, pl. 1, fig. 17.
1992 *Buntonia bopaensis* APOSTOLESCU. Carbonnel, pl. 22, fig. 12.
non 1995 *Buntonia bopaensis afra* REYMENT. Carbonnel, p. 43–44, pl. 4, fig. 9.
1995 *Buntonia bopaensis bopaensis* APOSTOLESCU. Carbonnel and Monciardini, p. 48, pl. 5, fig. 2.

Remarks

The great polymorphism of this species in its size and its more or less elongate lateral outline has generated the creation of various species or sub-species that we consider conspecific. We consider here *Protobasslerites bopaensis* and *Buntonia bopaensis* both described by Apostolescu (1961) from the Early Paleocene (Danian) of Benin, as synonyms. *Buntonia (B.) bopaensis bopaensis* in Okosun (1987) is in fact *Buntonia isobopaensis* CARBONNEL and OYÉDÉ, 1991.

Dimensions

L = 0.55–0.70 mm
h = 0.32–0.45 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–III (In Talack, Takhabanat).

— previous studies: Horizons II–III (In Araber).

Benin: Late Paleocene.

Cameroon: Paleocene (Kogbe and Me'hes, 1986).

Ivory Coast: Paleocene (Kogbe and Me'hes, 1986).

Libya: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Wurno Formation)-Late Paleocene (Dange and Kalambaina Formations) (Okosun, 1989).

Tunisia: Paleocene (Metlaoui Formation).

Western Niger: Late Paleocene (Garaouda Formation).

Figured specimens

Pl. 3, figs 23, 26.

23 — Right view, × 65, In Talack, N26, Horizon III. **26** — Left view, × 65, In Talack, N17, Horizon II.

***Buntonia isobopaensis* CARBONNEL and OYÉDÉ, 1991**
Plate 3, Fig. 17.

1963 *Buntonia (B.) bopaensis* APOSTOLESCU. Reyment, p. 215–227, pl. 7, figs 1a–b, pl. 20, fig. 1.
1966 *Isobuntonia* aff. *harpa* APOSTOLESCU. Salahi, p. 11, pl. 5, fig. 14.
1987 *Buntonia (B.) bopaensis bopaensis* APOSTOESCU. Okosun, p. 45, pl. 9, figs 1–4, pl. 10, fig. 7.
1991 *Buntonia isobopaensis* CARBONNEL and OYÉDÉ. Carbonnel and Oyédé, p. 74, pl. 1, figs 9–10, non 5–8, 15–16.
1992 *Buntonia isobopanesis* CARBONNEL and OYÉDÉ. Carbonnel, pl. 22, fig. 11, non figs 1–5.
1995 *Buntonia isobopaensis* CARBONNEL and OYÉDÉ. Carbonnel and Monciardini, p. 43, pl. 4, figs 7–8.

Remarks

This species is morphologically close to *Buntonia bopaensis* APOSTOLESCU from which it essentially differs in being strongly punctate and possessing a distinct anterior marginal groove.

Dimensions

L = 0.53–0.54 mm
h = 0.34–0.35 mm

Age and distribution

Mali:
This study: Late Paleocene Horizon III (InTalack).
Previous studies: Horizon II.
Benin: Late Paleocene.
Libya: Late Paleocene-Early Eocene.
Nigeria coastal basins: Late Paleocene.
Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 3, fig. 17.
17 — Left view, × 65, In Talack, N26, Horizon III.

***Buntonia issabaensis* APOSTOLESCU, 1961**
Plate 3, Figs 12–13.

1961 *Buntonia issabaensis* APOSTOLESCU. Apostolescu, p. 802, pl. 4, figs 77–79.
1983 *Buntonia issabaensis* APOSTOLESCU. Foster *et al.*, p. 120–121, pl. 12, fig. 10.
1986 *Buntonia issabaensis* APOSTOLESCU. Carbonnel, text-fig. p. 62.
1986 *Buntonia* aff. *issabaensis* APOSTOLESCU. Carbonnel, p. 52, pl. 1, figs 4, 16.
1986 *Buntonia* sp. CP 28–2/7 CARBONNEL. Carbonnel, p. 59, pl. 2, figs 6–7.
1987 *Buntonia (P.) issabaensis* APOSTOLESCU. Okosun, p. 54, pl. 18, figs 7, 11–12, 17–21.
1994 *Buntonia issabaensis* APOSTOLESCU. Digbehi *et al.*, p. 192, pl. 1, fig. 9.
1995 *Buntonia issabaensis* APOSTOLESCU. Carbonnel and Monciardini, p. 44–45, pl. 4, figs 10–14.

Remarks

Buntonia cf. *sehouensis* APOSTOLESCU, 1961 illustrated by Bassiouni and Lüger (1990) in the Maastrichtian of Egypt resembles closely this species by virtue of its ridges parallel to its ventral and posterior margin, which are not present in *Buntonia sehouensis*.

Dimensions

L = 0.41–0.56 mm
h = 0.29–0.30 mm

Age and distribution

Mali:
— this study: Late Maastrichtian, Horizon I (In Talack, Takhabanat).
— previous studies: Horizon I (Ouarassibilt).
Benin: Early Paleocene (Danian).
Guinea Bissau: Paleocene.
Ivory Coast: Late Paleocene.
Nigerian coastal basin: Paleocene.
Senegal: Late Paleocene-Early Eocene.
Western Niger: Late Maastrichtian, Late Paleocene (Garaouda Formation).

Figured specimens

Pl. 4, figs 12–13.
12 — Right view, × 65, In Talack, N8, Horizon I. **13** — Left view, × 65, In Talack, N4, Horizon I.

***Buntonia misreia lineata* BASSIOUNI and LÜGER, 1990**
Plate 3, Fig. 20.

1990 *Buntonia misreia lineata* BASSIOUNI and LÜGER. Bassiouni and Lüger, p. 844, pl. 23, figs 8–13.
1992 *Buntonia aljurfae* EL-WAER. El-Waer, p. 144, pl. 26, figs 1–6.

Remarks

The Malian specimens with their elongate lateral outline and their posterior reticulation arranged in horizontal lines are similar to the Egyptian species and very close to *Buntonia* aff. *issabaensis* APOSTOLESCU, 1961 from the Paleocene of Senegal in Carbonnel (1986, 1990).

Dimensions

L = 0.50 mm
h = 0.26 mm

Age and distribution

Mali: Late Paleocene, Thanetian, Horizon IV (Agamor).
Egypt: Late Paleocene (*pseudomenardii* to *velascoensis* Zone).
Libya: Late Paleocene.

Figured specimens

Pl. 3, fig. 20.
20 — Left view, × 65, Agamor, N49, Horizon IV.

Buntonia pyriformis CARBONNEL, ALZOUMA and DIKOUMA, 1990

Plate 3, Figs 18–19.

1990 *Buntonia pyriformis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 675, pl. 1, fig. 14.
1995 *Buntonia pyriformis* CARBONNEL *et al.* Carbonnel and Monciardini, p. 50, pl. 5, fig. 10.

Remarks

Some specimens show an alignement of small fossae in longitudinal grooves (Pl. 3, fig. 19).

Dimensions

L = 0.61–0.65 mm
h = 0.36–0.39 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizons II and III (In Talack, Takhabanat).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 3, figs 18–19.

18 — Left view, × 65, In Talack, N26, Horizon III. **19** — Left view, × 65, In Talack, N17, Horizon II.

Buntonia tichittensis APOSTOLESCU, 1961

Plate 3, Figs 14–16.

1961 *Buntonia tichittensis* APOSTOLESCU. Apostolescu, p. 805, pl. 5, figs 91–93.
1963 *Buntonia tichittensis* APOSTOLESCU. Barsotti, p. 1525, pl. 3, figs, 24–25.
1966 *Buntonia (Buntonia) tichittensis* APOSTOLESCU. Salahi, p. 10, pl. 2, fig. 17.
1981 *Buntonia tenuipunctata* APOSTOLESCU. Reyment, p. 62., pl. 7, figs 4–9, pl. 10, fig. 2.
1983 *Buntonia (Buntonia?) tichittensis* APOSTOLESCU. Foster *et al.*, p. 123, pl. 6, figs 6, 9, pl. 7, fig. 10.
1989 *Buntonia fortunata* APOSTOLESCU. Carbonnel and Johnson, pl. 2, fig. 1, non 2.
non 1990 *Buntonia* cf. *tichittensis* APOSTOLESCU. Bassiouni and Lüger, p. 845, pl. 23, figs 14–16, 18–19.
1995 *Buntonia tichittensis* APOSTOLESCU. Carbonnel and Monciardini, p. 42–43, pl. 4, figs 3–6.

Remarks

Buntonia tichittensis shows slight differences with *Buntonia tenuipunctata* APOSTOLESCU, 1961 from the Paleocene of Mali, considered as conspecific by Reyment (1981) and by Carbonnel (1986), such as a more elongate carapace and a greater density of punctuations.

Dimensions

L = 0.46–0.52 mm
h = 0.32 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I, III–IV (In Talack, Agamor, In Ori).

— previous studies: originally described by Apostolescu (1961) from the Late Paleocene of the Tin Tekouffé borehole.

Libya: Late Paleocene-Early Eocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Senegal: Paleocene-Early Eocene.

Togo: Early Eocene.

Western Niger: Late Paleocene (Horizons II to IV, Garaouda Formation).

Figured specimens

Pl. 3, figs 14–16.

14, 15 — Left views, × 65, Agamor, N52, Horizon IV. **16** — Left view, In Talack, N5, Horizon I.

Buntonia tilemsiensis APOSTOLESCU, 1961

Plate 3, Fig. 21.

1961 *Buntonia tilemsiensis* APOSTOLESCU. Apostolescu, p. 805. pl. 5, figs 97–102.
1986 *Buntonia tilemsiensis* APOSTOLESCU. Carbonnel, text-fig. p. 64.
1986 *Buntonia* aff. *tilemsiensis* APOSTOLESCU. Carbonnel, p. 53–54, text-fig. p. 64, pl. 1, fig. 17.
1992 *Buntonia* aff. *tilemsiensis* APOSTOLESCU. Carbonnel, pl. 20, fig. 10.
1995 *Buntonia tilemsiensis* APOSTOLESCU. Carbonnel and Monciardini, p. 49, pl. 5, fig. 1.

Remarks

In Mali, this species is more common in the Late Maastrichtian than in the Early Paleocene.

Dimensions

L = 0.46 mm
h = 0.31 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–II (In Talack, Takhabanat, Asselar, Ait Nafa).

— previous studies: originally described by Apostolescu (1961) from the Late Maastrichtian ("Danian" auct.) of Ait Nafa section and recorded by Carbonnel and Monciardini (1995) in Danian (p.49) but in Horizon IV (Table 8, p. 84) from In Araber.

Senegal: Late Paleocene.

Western Niger: Late Maastrichtian.

Figured specimens

Pl. 3, fig. 21.

21 — Left view, × 65, In Talack, N7, Horizon I.

Genus *Iorubaella* REYMENT, 1960
Iorubaella ologuni ologuni REYMENT, 1960
Plate 3, Fig. 27.

1963 *Iorubaella ologuni* REYMENT. Reyment, p. 102, pl. 11, figs 1–6.
1966 *Iorubaella* sp. nov. 1 SALAHI. Salahi, p. 12, pl. 1, fig. 9–17 (non 14 ?).
1981 *Iorubaella ologuni* REYMENT. Reyment, p. 57–58, pl. 3, figs 2–7.
1986 *Iorubaella* KOGBE and ME'HES. Kogbe and Me'hes, p. 18, fig. 29 (pars).
1987 *Iorubaella ologuni* REYMENT. Okosun, p. 67–68, pl. 15, fig. 4, pl. 19, fig. 13–16, 17, 19, 20.
1995 *Iorubaella ologuni ologuni* REYMENT. Carbonnel and Monciardini, p. 57, pl. 6, figs 4–5, non 6.

Remarks

Species well characterized by its compressed anterior margin and the presence of distinct longitudinal costulae on the postero-ventral area.

Dimension

L = 0.80 mm
h = 0.43 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II (Creb d'Aginger).

— previous studies: reported by Carbonnel and Monciardini (1995) from Horizon III (Ouarassibilt). In our opinion, specimens reported by these authors from Horizon IV belong to *Iorubaella virgulata*.

Benin: Paleocene.

Cameroon: Paleocene.

Libya: Paleocene.

Nigerian coastal basins: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Dange and Kalambaina Formations) (Okosun, 1989).

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garaouda Formation).

Figured specimens

Pl. 3, fig. 27.

27 — Left view, × 65, Creb d'Aginger, N77, Horizon II.

Iorubaella virgulata (APOSTOLESCU, 1961)
Plate 3, Fig. 22.

1961 *Buntonia virgulata* APOSTOLESCU. Apostolescu, p. 805–806, pl. 4, figs 74–76.
1963 *Buntonia virgulata* APOSTOLESCU. Barsotti, p. 1525, pl. 3, fig. 26.
?1963 *Soudanella* cf. *S. laciniosa laciniosa* APOSTOLESCU. Barsotti, p. 1525–1526, pl. 3, fig. 20.
non 1966 *Buntonia (Buntonia) virgulata* APOSTOLESCU. Salahi, pl. 2, fig. 18.
1980 *Buntonia virgulata* APOSTOLESCU. Reyment, fig. 8k–l.
non 1983 *Buntonia virgulata* APOSTOLESCU. Damotte, p. 52, pl. 1, figs 18–19.
1986 *Buntonia virgulata* APOSTOLESCU. Carbonnel, text-fig. p. 60.
1990 *Iorubaella virgulata* (APOSTOLESCU). Carbonnel *et al.*, p. 675, pl. 2, figs 5–6.
1992 *Iorubaella virgulata* (APOSTOLESCU). Carbonnel, pl. 22, figs 17–18.
1994 *Soudanella* cf. *ioruba* (REYMENT). Keen *et al.*, pl. 16.2, figs 4, 5.
1995 *Iorubaella ologuni ologuni* REYMENT. Carbonnel and Monciardini, p. 57, pl. 6, fig. 6, non 4–5.

Remarks

The Malian specimens are closer to the Niger forms illustrated by Carbonnel *et al.* (1980) than to the Malian type-species described by Apostolescu (1961) because of their less acuminate posterior end. *Buntonia devexa* SIDDIQUI, 1971 from the Paleocene of Pakistan and *Protobuntonia hartmanni* JAIN, 1978 from the Paleocene and Eocene of India show great affinities with *Iorubaella virgulata*.

Dimensions

L = 0.66 mm
h = 0.34 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizon III (In Talack).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) in Horizons I and II in the Tilemsi valley. Found by Carbonnel and Monciardini (1995) as *Iorubaella ologuni ologuni* from Horizon IV (In Araber).

Libya: Early Paleocene (Danian) of the Sirte Basin.

Western Niger: Late Paleocene (Garaouda Formation).

Senegal: Paleocene-Early Eocene.

Figured specimens

Pl. 3, fig. 22.

22 — Right view, × 65, In Talack, N26, Horizon III.

Iorubaella sp. 1
Plate 3, Figs 24–25.

1966 *Buntonia (Buntonia) virgulata* APOSTOLESCU. Salahi, p. 10, pl. 2, fig. 18.
1995 *Soudanella* sp. Digida 266 CARBONNEL and MONCIARDINI. Carbonnel and Monciardini, p. 54, pl. 7, fig. 18.

Remarks

Iorubaella of small size, sub triangular in lateral view with greatest height at the anterior cardinal angle, to-

wards the anterior quarter and greatest length near the ventral third; dorsal and ventral margins strongly convergent posteriorly; anterior margin broadly and ventrally rounded inducing a concave anterior ventral margin; posterior end narrowly and ventrally rounded. External surface smooth in its anterior third, ornamented by about 11–12 ridges converging backwards. Pore canals conspicuous on the whole valve. Possible sexual dimorphism with males more elongate. A similar ornamentation occurs in the Paleocene Libyan species which differ from the Malian form by their lateral outline. *Buntonia virgulata* APOSTOLESCU in Barsotti (1963) and *Buntonia virgulata* APOSTOLESCU in Salahi (1966) are larger, more spindle shaped and their anterior ends less broadly and ventrally rounded. *Iorubaella* sp. 1 SALAHI 1966, pars (pl. 1, fig. 14, non fig. 9–13, 15–17) has a more truncated posterior end and an anterior cardinal angle backwards, just before mid-length.

Dimensions

L = 0.55 mm
h = 0.32 mm

Age and distribution

Mali:

— this study: Late Maastrichtian, Late Paleocene (Thanetian), Horizons I–II, (In Talack, Takhabanat).

— previous studies: reported by Carbonnel and Monciardini (1995) from Horizon I (Digida).

Libya: Late Paleocene .

Figured specimens

Pl. 3, figs 24–25.

24 — Right view, × 65, **25** — Left view, × 65.

Genus *Soudanella* APOSTOLESCU, 1961

Soudanella cf. *S. laciniosa laciniosa* APOSTOLESCU, 1961

Plate 3, Fig. 28.

1961 *Soudanella laciniosa laciniosa* APOSTOLESCU. Apostolescu, p. 809, pl. 6, figs 124–126, pl. 7, fig. 136, pl. 16, figs 304–306.

1963 *Buntonia (Protobuntonia) triangulata* (APOSTOLESCU). Reyment, p. 237–238, pl. 6, figs 6a–b, pl. 7, fig. 4, pl. 20, figs 2–4.

1973 *Soudanella laciniosa triangulata* APOSTOLESCU. Neufville, p. 96–98, pl. 6.11, figs 1a–c.

1979 *Soudanella laciniosa triangulata* APOSTOLESCU. Neufville, p. 153–154, pl. 6, figs 1a–b.

non 1981 *Soudanella laciniosa* APOSTOLESCU. Babinot, pl. 1, fig. 11.

1982 *Soudanella* gr. *laciniosa* APOSTOLESCU. Damotte, p. 52–53, pl. 1, fig. 20.

1982 *Buntonia virgulata* APOSTOLESCU. Damotte, p. 52, pl. 1, figs 18–19.

1982 *Soudanella laciniosa laciniosa* APOSTOLESCU. Guernet, p. 25, pl. 2, fig. 2.

1983 *Soudanella laciniosa laciniosa* APOSTOLESCU. Foster *et al.*, p. 430–431, pl. 5, figs 10–11.

1986 *Soudanella laciniosa laciniosa* APOSTOLESCU. Carbonnel, p. 125–126, pl. 7, figs 1–2 .

1987 *Buntonia (Protobuntonia) laciniosa* (APOSTOLESCU). Okosun, pl. 22, fig. 2.

1988 *Soudanella laciniosa* APOSTOLESCU. Stinnesbeck and Reyment, p. 779–781.

1989 *Soudanella laciniosa* gr. *laciniosa* APOSTOLESCU. Carbonnel and Johnson, p. 423, pl. 4, figs 6–8.

1991 *Soudanella laciniosa* APOSTOLESCU. Reyment and Aranki, pl. 2, fig. 1a–b, 2a–b, 3a–b.

1991 *Soudanella laciniosa* APOSTOLESCU. Carbonnel, text-fig. 2, p. 111.

1991 *Soudanella laciniosa laciniosa* APOSTOLESCU. Carbonnel and Oyede, p. 78, pl. 2, figs 5–6.

1992 *Soudanella laciniosa laciniosa* APOSTOLESCU. Carbonnel, pl. 8, figs 1–8.

1994 *Soudanella laciniosa* APOSTOLESCU. Keen *et al.*, pl. 16.2, fig. 1b.

?1995 *Soudanella laciniosa* APOSTOLESCU. Andreu, p. 110–111, pl. 2, figs 7–8.

Remarks

We follow here Carbonnel's (1986) interpretation of the subspecies *laciniosa* having an ornamented anterior part as opposed to the subspecies *triangulata* which has a smooth anterior part. The Malian specimens are close by their ornamentation to *Soudanella laciniosa laciniosa* but with a lateral outline slightly less elongate and less posteriorly acuminate; more similar to the higher and shorter *Buntonia virgulata* APOSTOLESCU *in* Damotte (1982).

Dimensions

L = 0.78 mm
h = 0.46 mm

Age and distribution

Mali: Late Paleocene, Horizon II (In Talack, Creb d'Aginger)

Benin: Late Paleocene.

Brazil: Early Paleocene (Danian).

Congo: Paleocene (Massala, 1993).

Ivory Coast: Paleocene.

Morocco?: Paleocene.

Nigerian coastal basin: Early (Danian) and Late Paleocene.

Senegal: Paleocene-Middle Eocene.

Togo. Late Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 3, fig. 28.

28 — Right view, × 65, Creb d'Aginger, N77, Horizon II.

Tribe LEGUMINOCYTHERINI Howe, 1961

Genus *Patrizia* BONADUCE and RUSSO, 1990

Patrizia ? *lagaghiroboensis* (APOSTOLESCU, 1961)

Plate 2, Fig. 21

1961 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Apostolescu, p. 832, pl. 9, figs 180–182.

1963 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Reyment, p. 139, pl. 3, fig. 1a–c, pl. 13, figs . 5–10.
1963 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Barsotti, p. 1527, pl. 1, figs 11–12.
1980 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Reyment, fig. 8i–j.
1980 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Reyment and Reyment, pl. 1, fig. 3.
1982 *Leguminocythereis* cf. *lagaghiroboensis* APOSTOLESCU. Damotte, p. 56, pl. 2, fig. 33.
1987 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Okosun, p. 70, pl. 8, figs 13–18.
1990 *Leguminocythereis* cf. *lagaghiroboensis* APOSTOLESCU. Bassiouni and Lüger, p. 792, pl. 5, figs 1–2.
1992 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. El-Waer, p. 172, pl. 34, figs 5–6.
1995 *Leguminocythereis lagaghiroboensis* APOSTOLESCU. Carbonnel and Monciardini, p. 56, pl. 6, figs 1–3.

Remarks

This species, which is very rare in the studied material is tentatively assigned to the modern genus *Patrizia* described by Bonaduce and Russo (1990) from The Gulf of Aden (Somalia) and of which several species have recently been found in Kenya by Jellinek (1993).

Dimensions

L = 0.75 mm
h = 0.43 mm

Age and distribution

Mali:
— this study: Late Paleocene (Thanetian), Horizon III (In Talack).
— previous studies: Horizon IV (Ekkineouan)
Cameroon: Paleocene.
Egypt: basal Eocene.
Ivory Coast: Late Paleocene.
Libya: Late Paleocene.
Nigerian coastal basin: Late Paleocene.
Senegal: Paleocene-Early Eocene.
Togo: ?Maastrichtian.
Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, fig. 21.
23 — Left view, × 65, In Talack, N24, Horizon III.

Genus *Nucleolina* APOSTOLESCU, 1961

Nucleolina tatteuliensis (APOSTOLESCU, 1961)

Plate 4, Figs 7–10.

1961 *Ambocythere ? tatteuliensis* APOSTOLESCU. Apostolescu, p. 814, pl. 9, figs 175–179, pl. 15, fig. 300.
1963 *Ambocythere ? tatteuliensis* APOSTOLESCU. Barsotti, p. 1526, pl. 1, fig. 9.
1976 *Ambocythere tatteuliensis* APOSTOLESCU. Ficarelli, p. 736, pl. 90, figs 13–14.
1980 *Ambocythere (?) tatteuliensis* APOSTOLESCU. Reyment, fig. 8k.
1981 *Ambocythere ? tatteuliensis* APOSTOLESCU. Reyment and Reyment, pl. 1, fig. 4.
1981 *Nucleolina tatteuliensis* (APOSTOLESCU). Reyment, p. 58, pl. 3, figs 8–12.
1983 *Buntonia tatteuliensis* (APOSTOLESCU). Foster *et al.*, p. 122, pl. 5, figs 3–9, pl. 6, fig. 12, pl. 7, figs 4–5.
1990 *Nucleolina tatteuliensis* (APOSTOLESCU). Bassiouni and Lüger, p. 793, pl. 5, figs 9–11.
1990 *Nucleolina tatteuliensis* (APOSTOLESCU). Carbonnel *et al.*, p. 684, pl. 2, fig. 11.
1991 *Nucleolina tatteuliensis* (APOSTOLESCU). Damotte, p. 11, pl. 2, figs 13–14.
1992 *Nucleolina tatteuliensis* (APOSTOLESCU). Carbonnel, pl. 6, fig. 9.
1994 *Buntonia tatteuliensis* (APOSTOLESCU). Keen *et al.*, pl. 16.2, figs 11, 14.
1995 *Nucleolina tatteuliensis* (APOSTOLESCU). Carbonnel and Monciardini, p. 55, pl. 5, figs 16–17.

Remarks

This species appears in Horizon II and is restricted to Horizons II and III with the two main variants described in Nigeria by Reyment (1981) then Foster *et al.* (1983) and previously illustrated in Apostolescu (1991). The first one ornamented with punctuations either concentrically arranged (pl. 4, fig. 8) or in longitudinal row between tiny ribs (pl. 4, fig. 9), the first pattern found only in Horizon II. The second variant, larger than the previous, ornamented of thin longitudinal ribs in the median part with anterior and posterior ends smooth and more strongly compressed than in the variant 1 (pl. 4, figs 7, 10). *Nucleolina diluta* AL-FURAIH, 1980 from the Maastrichtian-Lower Paleocene of Saudi Arabia and doubtfully reported by Bhandari (1995b) from the Early Paleocene (Danian) of India, is a species closely related to our species but it has a smooth and more elongated carapace.

Dimensions

L = 0.63–0.77 mm
h = 0.38–0.48 mm

Age and distribution

Mali:
— this study: Late Paleocene (Thanetian); Horizons II–III (In Talack, Agamor, Takhabanat, Creb d'Aginger, Ibegan).
— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from Horizons II and III (Late Paleocene) of the Tilemsi valley. Horizons II–IV (Ekkineouan, Ouarassibilt, In Araber, Fogha)
Egypt: latest Paleocene?-basal Eocene.
Libya: Paleocene.
North-western Nigeria: Late Paleocene (Kalambaina Formation), (see also Kogbe *et al.* 1976).
Senegal: Paleocene-Early Eocene.
Western Niger: Late Paleocene.

Figured specimens

Pl. 4, figs 7–10.

7 — Right view, × 65, Takhabanat, N64, Horizon II. **8** — Left view, × 65, Agamor, N65, Horizon II. **9** — Right view, × 65, Agamor, N38, Horizon III. **10** — Right view, × 65, Agamor, N34, Horizon III.

Family HEMICYTHERIDAE Puri, 1953
Subfamily BRADLEYINI Benson, 1972

Genus *Oertliella* POKORNY, 1964

(= *Martinicythere* BASSIOUNI, 1969; *Phalcocythere* SIDDIQUI, 1971)

Remarks

We consider that the differences between the genera *Martinicythere* BASSIOUNI, 1969, *Phalcocythere* SIDDIQUI, 1971 and *Oertliella* POKORNY, 1964 (details of the hinge and muscle scars), are not significant enough to be able to differentiate these genera. It is therefore proposed to use only the older genus, *Oertliella*.

Oertliella tubra (REYMENT, 1981)

Plate 6, Fig. 15.

1981 *Phalcocythere tubra* REYMENT. Reyment, p. 61, pl. 5, figs 1, 4.
1990 *Phalcocythere tubra* REYMENT. Carbonnel *et al.*, p. 680, pl. 3, figs 16–18.
1990 *Oertliella vesiculosa* (APOSTOLESCU). Bassiouni and Lüger, p. 829, pl. 17, figs 22–23.
1992 *Phalcocythere tubra* REYMENT. Carbonnel, pl. 18, figs 8–10.

Remarks

This species is very close to *Oertliella khargensis* BASSIOUNI and LÜGER, 1990 from the Maastrichtian of Egypt, with its hinge ear less prominent than in the holotype of *Oertliella tubra* as illustrated by Reyment (1981). As stated by Reyment (1981), *Oertliella tubra* differs from the closely related *Oertliella veisiculosa* "in having sparser though coarser lateral tuberculation, a prominent hinge-ear, and a more strongly denticulate and posteroventrally produced posterior".

Dimensions

L = 0.65 mm
h = 0.40 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (Agamor).

Egypt: Late Paleocene.

Libya: Paleocene.

North-western. Nigeria: Late Paleocene (Kalambaina Formation).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, fig. 15.

15 — Left view, × 65, Agamor, N35, Horizon III.

Oertliella vesiculosa (APOSTOLESCU, 1961)

Plate 6, Figs 12, 16–20.

1961 *Bradleya vesiculosa* APOSTOLESCU. Apostolescu, p. 820, pl. 12, figs 246–249.
1963 *Bradleya vesiculosa* APOSTOLESCU. Barsotti, pl. 1, fig. 10.
1966 *Acanthocythereis* ? n sp. 2 SALAHI. Salahi, p. 21, pl. 5, fig. 8–10.
1981 *Phalcocythere vesiculosa* (APOSTOLESCU). Reyment, p. 60, pl. 5, fig. 2 non 3, 5, 6, pl. 10, fig. 5.
1981 *Phalcocythere vesiculosa* (APOSTOLESCU). Krstic, p. 122, pl. 1, fig. 4.
non 1982 *Martinicythere* cf. *vesiculosa* (APOSTOLESCU). Donze *et al.*, p. 287, pl. 5, figs 9–10, pl. 14, figs 4–5.
1983 *Bradleya vesiculosa* APOSTOLESCU. Foster *et al.*, p. 118–119, pl. 8, fig. 6, pl. 9, figs 2–5.
non 1986 *Phalcocythere vesiculosa* (APOSTOLESCU). Carbonnel, p. 107, pl. 9, fig. 4–6.
non 1986 *Martinicythere* cf. *vesiculosa* (APOSTOLESCU). Damotte, p. 163, pl. 2, fig. 10.
non 1988 *Martinicythere* cf. *vesiculosa* (APOSTOLESCU). Damotte and Fleury, p. 95, pl. 2, figs 20–21.
non 1990 *Oertliella vesiculosa* (APOSTOLESCU). Bassiouni and Lüger, p. 829, pl. 17, figs 22–23.
1990 *Phalcocythere vesiculosa* (APOSTOLESCU). Carbonnel *et al.*, p. 681, pl. 3, figs 8–12.
1992 *Phalcocythere vesiculosa* (APOSTOLESCU). Carbonnel, pl. 18, figs 3–7, non 1–2, 16.
1992 *Phalcocythere cultrata* (APOSTOLESCU). Carbonnel, pl. 18, figs 11, 14 non 12–13, 15–17.
1993 *Phalcocythere vesiculosa* (APOSTOLESCU). Carbonnel and Reyment, figs 2, 3.
1995 *Phalcocythere vesiculosa* (APOSTOLESCU). Carbonnel and Monciardini, p. 41, pl. 3, fig. 19.
non 1996 *Oertliella vesiculosa* (APOSTOLESCU). Ismail, p. 45, pl. 3, figs 9–10.

Remarks

Martinicythere praesamalutensis BASSIOUNI and LÜGER, 1990 from the Late Paleocene-Early Eocene of Egypt is most likely to be conspecific with *Oertliella vesiculosa*. The species called *Oertliella vesiculosa* by the same author is here considered as being *Oertliella tuberata* Reyment. Another closely related species is *Phalcocythere improcera* SIDDIQUI, 1971 from the Late Paleocene of Pakistan.

Dimension

L = 0.58–0.70 mm
h = 0.38–0.40 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene, Horizon I–IV (In Talack, Agamor; Takhabanat, Ibegan).

— previous studies: found by Carbonnel and Monciardini (1995) in Horizons I–IV (Ekkineouan, Fogha, In Araber, Ouarassibilt).

Libya: Late Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Senegal: Early Paleocene ("Zone à Globigérines" = Danian).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, figs 12, 16–20.

12 — Left view, × 65, Creb d'Aginger, N77, Horizon II. **16** — Left view, × 65, Agamor, N56, Horizon IV. **17** — Right view, × 65, In Talack, N17, Horizon. II. **18** — Left view, In Talack, N24, Horizon. III. **19** — Left view, × 65, Takhabanat, N, Horizon II. **20** — Right view, × 65, Ibegan, N92, Horizon II.

Genus *Dameriacella* Liebau, 1991

Dameriacella kaoensis (Carbonnel, Alzouma and Dikouma, 1990)

Plate 6, Figs 8–9.

1990 *Quadracythere kaoensis* Carbonnel, Alzouma and Dikouma. Carbonnel, Alzouma and Dikouma, p. 677–678, pl. 3, fig. 13.

1990 *Schizocythere* sp. 1 Bassiouni and Lüger. Bassiouni and Lüger, p. 815, pl. 12, figs 9–11, 14–15.

1992 *Quadracythere kaoensis* Carbonnel, Alzouma and Dikouma. Carbonnel, pl. 2, fig. 11.

Remarks

This species possesses all the characters of the genus *Dameriacella* recently erected by Liebau (1991) and is very close to *Dameriacella volpensis* (Tambareau, 1972) from the Paleocene of southern France.

Dimensions

L = 0.64 mm
h = 0.39 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (Agamor)

Egypt: Late Paleocene-Early Eocene;

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, figs 8–9.

8 — Left view, × 65. **9** — Right view, × 65, Agamor, N38, Horizon. III

Dameriacella ? tessalitensis (Apostolescu, 1961)

Plate 7, Figs 23–24.

1961 *Bradleya tessalitensis* Apostolescu. Apostolescu, p. 819, pl. 12, figs 8, 12–14.

1981 *"Braleya" tessalitensis* Apostolescu. Krstic, p. 122, pl. 1, fig. 7.

non 1983 *Bradleya ? tessalitensis* Apostolescu. Foster *et al.*, p. 118, pl. 9, figs 8, 12, pl. 10, figs 8, 12–14.

non 1995 *Phalcocythere tessalitensis* (Apostolescu). Carbonnel and Monciardini, p. 40, pl. 3, fig. 18, pl. 4, figs 1–2, pl. 7, fig. 19.

Remarks

This species described by Apostolescu in the Maastrichtian (Danian auct.) of Ait Nafa seems restricted to the Horizon I in Mali. The Late Paleocene Nigerian specimens assigned to this species by Foster *et al.* seem to be somewhat different with their lateral margins less parallel and their less differentiated ends and more pronounced sexual dimorphism. They could in fact (as *P. tessalitensis* in Carbonnel and Monciardini, 1995) belong to *Paragrenocythere praecrassa* (Apostolescu).

Dimensions

L = 0.86–0.87 mm
h = 0.44–0.45 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (In Talack, Ait Nafa).

Figured specimens

Pl. 7, figs 23–24.

23 — Left view, × 65, In Talack, N11, Horizon I. **24** — Left view, × 65, Ait Nafa, N84, Horizon I.

Genus *Hermanites* Puri, 1955

Hermanites ? sp. 1

Plate 7, Fig. 22.

Remarks

Small *Hermanites*-like carapace, with the ventral ridge ending in a well developed node or spine. Less elongate than *Hermanites bireticulata* Al-Furaih, 1980 from the Late Cretaceous and Early Eocene of Saudi Arabia from which it is closely related.

Dimensions

L = 0.67 mm
h = 0.34 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon II (Takhabanat, Creb d'Aginger).

Figured specimens

Pl. 7, fig. 22.

22 — Left view, × 76, Creb d'Aginger, N75, Horizon II.

Genus *Pataviella* Liebau, 1991

Pataviella digidaensis (Carbonnel and Monciardini, 1995).

Plate 7, Figs 1–4.

1995 *Tenedocythere digidaensis* Carbonnel and Monciardini. Carbonnel and Monciardini, p. 64–66, pl. 7, fig. 8.

Remarks

On the basis of the ornamentation this species has been assigned by Carbonnel and Monciardini (1995) to the Neogene genus *Tenedocythere* Sissingh. It shows strong affinities with forms assigned by various authors to *Quadracythere lagaghiroboensis* (Apostolescu, 1961) from the Paleocene of North and West Africa. *Alocopocythere elhuseini* Bassiouni and Lüger from the Late Paleocene or basal Eocene of Egypt seems very closely related but differs by the total absence of muscle node. Another closely related species is *Hornibrookella episcelis* Al-Furaih, 1977 from the Early Paleocene of Saudi Arabia. Overall shape and ornamentation lead us to assign Carbonnel and Monciardini's species to the genus *Pataviella* recently created by Liebau (1991).

Dimensions

L = 0.73 mm
h = 0.40 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (Agamor, Ibegan).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 7, figs 1–4.

1 — Left view, × 76. **2** — Right valve, internal view, × 125. **3** — Right valve, × 76. **4** — Left valve, × 76, N38, Agamor, Horizon III.

Genus *Hornibrookella* Moos, 1952

Hornibrookella apostolescui sp. nov.

Plate 7, Figs 5–9.

Derivation of name: In honour of Dr. V. Apostolescu who first described the ostracode faunas from Mali.

Holotype: Male carapace (pl. 7, fig. 9).

Paratypes: 19 carapaces.

Type-locality: Late Maastrichtian, Horizon I, In Talack, Mali.

Diagnosis

Large, subrectangular species of *Hornibrookella* with a regular reticulation and strong sexual dimorphism.

Description

Large subrectangular carapace with a pronounced sexual dimorphism, the presumed males being more elongate and less high than the presumed females. Dorsal and ventral margins slightly converging. Ventral margin straight. Anterior margin very broadly ventrally rounded ornamented of a denticulate rim; posterior margin weakly acuminate about mid-height with three more or less developed spines in its ventral part. Carapace coarsely reticulate with a distinct sub central tubercle, a prominent conve× dorsal ridge and a strong straight ventral ridge, both ending in at an angular posterior (spine or) node more or less well preserved. Large prominent eye tubercle.

Remarks

This species seems related to *Hornibrookella posterisella* Al-Furaih, 1977 from the Lower Paleocene of Saudi Arabia from which it essentially differs by better defined dorsal and ventral ridges and pronounced ocular tubercles.

Dimensions

Holotype:
L = 0.90 mm
h = 0.51 mm
Paratypes:
L = 0.85 (female) – 0.90 mm (male)
h = 0.51 mm
w = 0.42 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (In Talack, Tackhabanat, Ait Nafa)

Figured specimens

Pl. 7, figs 5–9.

5 — Right view, × 76, Takhabanat, N63, Horizon I. **6, 8** — Left views, × 76, In Talack, N11, Horizon I. **7** — Right view, × 65, Ait Nafa, N85, Horizon I. **9** — Left view, holotype, In Talack, N8, Horizon I.

Hornibrookella bellioni n. sp.

Plate 7, Figs 12–13.

Name derivation: dedicated to Dr. J.-C. Bellion, Avignon for his work on the stratigraphy of West African basins.

Holotype: male carapace (Pl. 7, fig. 12).

Paratypes: 5 carapaces

Type-locality: Late Paleocene, Horizon IV, In Talack, Mali.

Diagnosis

Large species of *Hornibrookella* characterised by a thick convex dorsal ridge, and a coarse reticulation.

Description

Large, thick and heavily calcified carapace with a subovate lateral outline. Greatest height at the antero-

dorsal angle; greatest width at the posterior end of the ventral ridge. High anterior margin broadly rounded. A narrow denticulate anterior marginal rib runs from behind the well developed eye tubercle and reaches the ventral margin at about the anterior third of the valve. Spinose posterior margin, slightly acuminate in its dorsal third. Ventral margin anteriorly and posteriorly curved upwards. Dorsal margin hidden by a thick convex dorsal ridge. Coarse and straight latero-ventral rib forming a kind of wing ornamented in its posterior flattened ventral face with a weaker longitudinal rib. Coarse reticulation with large fossae and thickened horizontal muri. Very weakly developed muscle (sub central) tubercle. Obvious sexual dimorphism with males longer than females.

Remarks

Differs from *Hornibrookella apostolescui* n. sp. by its lateral outline more ovate. It resembles *Hornibrookella cyclopea* Al-Furaih, 1977 from the Early Paleocene of Saudi Arabia, by its general shape and ornamentation pattern but it has a higher anterior margin and a posterior end more dorsally acuminate and more compressed.

Dimensions

Holotype:

L = 0.89 mm

h = 0.50 mm

Paratypes:

L = 0.88 mm (female) – 0.90 mm (male)

h = 0.40 (female) – 0.54 (male)

w = 0.66 (female)

Age and distribution

Mali: Late Paleocene (Thanetian), Horizons III–IV (In Talack, In Ori).

Figured specimens

Pl. 7, figs 12–13.

12 — Left view, holotype, × 65, In Talack, N31, Horizon IV. **13** — Left view, × 65, In Talack, N27, Horizon IV.

Genus *Paragrenocythere* Al-Furaih, 1975
Paragrenocythere cultrata (Apostolescu, 1961)

Plate 8, Figs 1–6.

1961 *Bradleya cultrata* Apostolescu. Apostolescu, p. 816, pl. 12, fig. 238–240

1963 *Bradleya cultrata* Apostolescu. Barsotti, p. 1527, pl. 2, fig. 17.

1966 *Bradleya* aff. *cultrata* Apostolescu. Salahi, p. 22, pl. 4, fig. 20

1981 *Phalcocythere cultrata* (Apostolescu). Reyment, p. 61, pl. 5, figs 7–9, pl. 6, figs, 1L, 1R.

1981 *Quadracythere ? praecrassa* (Apostolescu). Foster *et al.*, pl. 9, figs 13, 14, pl. 11, figs 1–4.

1981 *Phalcocythere* aff. *dissentea* Siddiqui. Reyment, pl. 5, fig. 10.

1983 *Bradleya ?* sp. aff. *Bradleya cultrata* Apostolescu. Foster *et al.*, p. 117, pl. 9, figs 7, 9, 10, 13, 14.

1986 *Phalcocythere cultrata* (Apostolescu). Carbonnel, p. 107, pl. 9, figs 4–6.

1987 *Phalcocythere cultrata* (Apostolescu). Okosun, p. 34–35, pl. 12, figs 9–10, 13.

1990 *Phalcocythere cultrata* (Apostolescu). Carbonnel *et al.*, p. 679–680, pl. 3, figs 1–2, non figs 3, 4.

1990 *Phalcocythere cultrata* (Apostolescu). Bassiouni and Lüger, p. 806, pl. 9, figs 13–20.

1991 *Limburgina praecrassa* (Apostolescu). Damotte, p. 8, pl. 1, figs 13–14.

1991 *Phalcocythere cultrata* (Apostolescu). Damotte, p. 11, pl. 2, figs 15–16.

1992 *Phalcocythere cultrata* (Apostolescu). Carbonnel, pl. 18, figs 12–16, non figs 11, 14, 17.

1993 *Phalcocythere cultrata* (Apostolescu). Carbonnel and Reyment, p. 83, fig. 2, p. 84, fig. 3.

1995 *Phalcocythere cultrata* (Apostolescu). Carbonnel and Monciardini, p. 39–40, pl. 3, figs 16–17.

1995 *Limburgina* sp. aff. *praecrassa* (Apostolescu). Swain *et al.*, p. 57–58, pl. 2, figs 21–22.

Remarks

The assignment of this species to the genus *Paragrenocythere* has been previously suggested and argued by Al-Furaih (1980) on the basis of well developed clavae on the dorsal margin. It differs from *Paragrenocythere biclavata* Al-Furaih, 1975 and *Paragrenocythere gravis* Al-Furaih, 1980 from the Late Maastrichtian and Early Paleocene of Saudi Arabia by its posteroventral margin more strongly curved upwards with a more dorsal acuminate posterior end, especially in the older specimens, and by its higher anterior margin. Reyment suggested that a species from the Late Paleocene of Pakistan and India, *Paragrenocythere reticulospinosa* (Sohn, 1970) could be conspecific (see also illustrations *in* Bhandari, 1995, 1996).

Dimensions

L = 0.70–0.87 mm

h = 0.42–0.52 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–IV (In Talack, Agamor, Takhabanat, Creb d'Aginger, In Ori, Ibegan).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizon II of the Tilemsi Valley. Also reported by Carbonnel and Monciardini (1995) from Horizons I–IV (Ouarassibilt, In Araber, Ekkineouan, Fogha).

Egypt: Late Paleocene (*velascoensis* Zone)-Early Eocene.

Ivory Coast: Late Paleocene.

Libya: Late Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Dukamaje Formation)-Late Paleocene (Kalambaina Formation).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 8, figs 1–6.

1, 5 — Left views, × 65, Takhabanat, N64, Horizon II. **2** — Left view, In Talack, N10, Horizon I. **3** — Right view, × 65, Agamor, N34, Horizon III. **4** — Left view, In Talack, N24, Horizon III. **6** — Right view, Agamor, N49, Horizon IV.

Paragrenocythere aff. *P. mudhensis* (KHOSLA, 1972)

Plate 8, Fig. 7.

aff. 1972 *Anticythereis memorans mudhensis* KHOSLA. Khosla, p. 487, pl. 2, figs 5–6.

Remarks

This species is closely related to *Anticythereis memorans mudhensis* KHOSLA, 1972 from the Early Eocene of India from which it essentially differs by a much coarser reticulation. Both species have very reduced clavae on the dorsal margin.

Dimensions

L = 0.80 mm
h = 0.50 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon III (Agamor).

Figured specimens

Pl. 8, fig. 7.

7 — Left view, Agamor, N38, Horizon III.

Paragrenocythere sehouensis (APOSTOLESCU, 1961)

Plate 8, Figs 8–11.

1961 *Bradleya sehouensis* APOSTOLESCU. Apostolescu, p. 818, pl. 9, figs 233–234.

1980 *Bradleya* ? *praecrassa* APOSTOLESCU. Reyment, fig. 8l.

1980 *Bradleya* ? *praecrassa* APOSTOLESCU. 1, pl. 1, fig. 11.

1981 *Bradleya* ? *praecrassa* APOSTOLESCU. Reyment and Reyment, pl; 1, fig. 11.

1981 *Limburgina praecrassa* (APOSTOLESCU). Reyment, p. 59–60, pl. 4, figs 7–40.

1981 *Limburgina sehouensis* (APOSTOLESCU). Reyment, p. 60, pl. 2, fig. 4, pl. 4, fig. 11.

1983 *Bradleya* ? *tessalitensis* APOSTOLESCU. Foster *et al.*, pl. 9, figs 8–12.

1983 *Bradleya* ? *sehouensis* APOSTOLESCU. Foster *et al.*, p. 135, pl. 10, figs 13–14.

non 1991 *Gyrocythere sehouensis* (APOSTOLESCU). Carbonnel and Oyédé, p. 79, pl. 3, fig. 9.

1995 *Phalcocythere tessalitensis* (APOSTOLESCU). Carbonnel and Monciardini, p. 40, pl. 3, fig. 18, pl. 4, figs 1–2.

1995 *Hermanites* sp. 2, p. 64, CARBONNEL and MONCIARDINI. Carbonnel and Monciardini, p. pl. 6, fig. 19.

non 1995 *Benina sehouensis* (APOSTOLESCU). Carbonnel and Monciardini, p. 31–32, pl. 2, figs 14–15.

Remarks

Carbonnel (*in* Carbonnel *et al.* 1996) erected a new genus *Benina* with *Benina postesehouensis* Carbonnel from the Oligocene of Benin. He included in this new genus Apostolecu's species *sehouensis* which is in our opinion not even related to *postsehouensis*, but possesses all the characteristics of the genus *Paragrenocythere* (dorsal clavae) as already suggested by Al-Furaih (1980). *Bradleya*? *praecrassa* (APOSTOLESCU, 1961) with which this species has been often mistaken does not possess the dorsal projections (clavae) typical of the genus *Paragrenocythere*.

Dimensions

L = 0.60–0.72 mm
h = 0.37–0.44 mm

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene, Horizons I–III (In Talack, Takhabanat, Ibegan).

— previous studies: found by Apostolescu (1961) in the Late Paleocene of Sarariguida, north-west of Gao. Also reported by Carbonnel and Monciardini (1995), as *Hermanites* sp. 2, from Horizons II–IV (Fogha, Agamor).

Libya: Late Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina and Dange Formations).

Senegal: Paleocene-Early Eocene (Sarr, 1992).

Western Niger: Late Paleocene (Garaouda Formation).

Figured specimens

Pl. 8, figs 8–11.

8 — Left view, × 65, In Talack, N5, Horizon I. **9** — Left view, × 65, Ibegan, N92, Horizon II. **10, 11** — Left and Right views, × 65, In Talack, N25, Horizon III.

Subfamily ORIONININAE Puri, 1973

Genus *Occultocythereis* HOWE, 1951

Occultocythereis confirmatus EL SWEIFY, 1984

Plate 6, Figs 13, 21.

1966 *"Caudites"* n. sp. 1 SALAHI. Salahi, p. 15, pl. 4, figs 6–8.

1984 *Occultocythereis confirmatus* EL SWEIFY. El Sweify, p. 49, pl. 3, figs 6–8.

1990 *Occultocythereis confirmatus* EL SWEIFY. Bassiouni and Lüger, p. 828, pl. 17, figs 8–14.
1991 *Occultocythereis* cf. *confirmatus* EL SWEIFY. Damotte, p. 8, pl. 1, figs 15–16.
1995 *Occultocythereis confirmatus* EL SWEIFY. Carbonnel and Monciardini, p. 35, pl. 3, fig. 4.

Remarks

Only two carapaces of this species have been found in our material from Mali. The older (fig. 13) which is probably a female specimen (cf. fig. 12 in Bassiouni and Lüger, 1990) and the younger which seems to be a juvenile (fig. 21). Several closely related species of *Occultocythereis* have been described by Al-Sheikly (1982) in the Maastrichtian to Eocene of Iraq. The morphologically closest species are *Occultocythereis harthaensis* AL-SHEIKLY and *Occultocythereis namrudia* AL-SHEIKLY, both from the Maastrichtian. *Clinocypris celata* AL-FURAIH, 1984b from the Maastrichtian of Saudi Arabia is also very similar but possesses a thin oblique median ridge.

Dimensions

L = 0.35 mm
h = 0.24 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons III–IV (Agamor).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizons I and II of the Tilemsi Valley. Found in Horizons II and IV (Fogha, Ekkineouan) by Carbonnel and Monciardini (1995).

Egypt: Late Paleocene-Early Eocene.

Libya: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 6, figs 13, 21.

13 — Right view, × 65, Agamor, N39, Horizon III. **21** — Right view, Agamor, N57, Horizon. IV.

Family PARACYTHERIDEIDAE Puri, 1957

Genus *Paracytheridea* G.W. MÜLLER, 1894

***Paracytheridea ? talackensis* sp. nov.**

Plate 7, Figs 10–11, 21.

Derivation of name: from the type-locality, In Talack.

Holotype: one carapace (Pl. 7, fig. 10).

Paratypes: 2 carapaces (Pl. 7, figs 11, 21).

Type-locality: Late Maastrichtian, Horizon I, In Talack, Mali.

Diagnosis

Species tentatively assigned to the genus *Paracytheridea* with a small carapace, deeply reticulate, subtriangular in lateral view with greatest height at anterior cardinal angle.

Description

Anterior margin almost symmetrically rounded; posterior extremity forming a sub-dorsal caudal process. Dorsal and ventral margins hidden by lateral ridges converging posteriorly. Convex short dorsal ridge separated by a sulcus of an oblique anterior ridge running from the anterior cardinal angle to the antero ventral part. There, it branches to form a little ridge reaching the anterior margin and it curves backwards forming a straight wing-like ventral ridge. Coarse reticulation irregular in the media-posterior part of the valves.

Remarks

It resembles the broken juvenile *Schizocythere* sp. CARBONNEL and OYÉDÉ, 1991, and *in* Carbonnel (1992) from the Late Paleocene of Benin which is smaller and less strongly ornamented.

Dimensions

L = 0.54 mm
h = 0.29 mm
w = 0.28 mm

Age and distribution

Mali: Late Maastrichtian, Horizon I (In Talack)

Figured specimens

Pl. 7, figs 10–11, 21.

10 — Left view, holotype, × 65, In Talack, N9, Horizon I. **11, 21** — Right and dorsal views, × 65, In Talack, N5, Horizon I.

Family CYTHERURIDAE G.W. Müller, 1894

Subfamily CYTHERURINAE G.W. Müller, 1894

Genus *Evisceratocythere* APOSTOLESCU, 1961

***Evisceratocythere* ? sp. 1**

Plate 7, Fig. 20.

Remarks

The specimen found in our Malian material is closely related to *Schizocythere* ? aff. *musculoides* REYMENT, 1963 *in* Carbonnel and Oyédé (1991) from the Late Paleocene of Benin which could be a juvenile instar but is more elongated and posteriorly acuminate. It lacks the three or four ribs in the posterior half of the carapace characteristic of the Paleocene Nigerian forms illustrated by Reyment (1963) and by Foster *et al.*, 1983. With its ovoid shape, its median sulcus and its ornamentation of concentric fossae, it resembles *Evisceratocythere glabella* APOSTOLESCU, 1961, ornate morph in Carbonnel (1992), but its posterior end is symmetrically acuminate without the sub dorsal process of the Early Eocene species from Senegal.

Dimensions

L = 0.43 mm
h = 0.21 mm

Age and distribution

Mali: Late Paleocene (Thanetian), Horizon II (In Talack).

Figured specimens

Pl. 7, fig. 20.

20 — Left view; × 65, In Talack, N17, Horizon II.

Family XESTOLEBERIDIDAE Sars, 1928

Genus *Uroleberis* TRIEBEL, 1958

***Uroleberis glabella* APOSTOLESCU 1961**

Plate 8, Figs 12–13, 21–22.

1961 *Uroleberis glabella* APOSTOLESCU. Apostolescu, p. 798, pl. 2, figs 32–34.
1966 *Xestoleberis* n. sp. 1 SALAHI. Salahi, p. 27–28, pl. 2, figs 4–5.
1976 *Uroleberis glabella* APOSTOLESCU. Ficcarelli, p. 737, pl. 91, fig. 9.
1981 *Uroleberis* aff. *glabella* APOSTOLESCU. Reyment, p. 58–59, pl. 3, figs 4–5.
1984 *Foveoleberis trapezium* AL-FURAIH. Al-Furaih, p. 164, 167–168, pl. 1, figs 1–5.
1990 *Uroleberis triebeli* BASSIOUNI and LÜGER. Bassiouni and Lüger, pl. 25, figs 13–17.
1990 *Uroleberis uppsalaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 685, pl. 4. figs 7–9.
1991 *Uroleberis glabella* APOSTOLESCU. Damotte, p. 11–12, pl. 2, fig. 17.
1992 *Uroleberis uppsalaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel, pl. 23, figs 7–9.
1993 *Uroleberis* cf. *glabella* APOSTOLESCU. Neale and Huang, pl. 10, fig. 3, 4.
1995 *Uroleberis uppsalaensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel and Monciardini, p. 68.

Remarks

This very characteristic species, although having its surface very finely pitted (only visible on SEM micrographs), belongs to the Group II defined by Neale and Singh (1988): "smooth forms with a typical caudal process". The species *trapezium* AL-FURAIH, *triebeli* BASSIOUNI and LÜGER and *uppsalaensis* CARBONNEL *et al.* are here considered as junior synonyms. It is possible that *Uroleberis ranikothania* (LATHAM, 1938) from the Paleocene of Pakistan and Tibet (see illustrations *in* Neale and Singh, 1988 and Neale and Huang, 1983) and possibly Eocene of Guatemala (van den Bold, 1948), *Uroleberis chamberlaini* SOHN, 1970 from the Early Eocene of Pakistan and *Uroleberis gopuramensis* Guha and Shukla, 1973 from the Paleocene of India are conspecific with the African species *Uroleberis glabella* APOSTOLESCU. According to Reyment (1981) there is also very close relationship with *Uroleberis stagnosa* AL-FURAIH, 1980 from the Lower Paleocene of Saudi Arabia.

Dimensions

L = 0.69–0.71 mm
h = 0.48 mm
w = 0.37 mm (male) – 0.50 mm (female)

Age and distribution

Mali:

— this study: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I–III (In Talack, Agamor, Takhabanat, Ibegan, Asselar).

— previous studies: reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizons I and II of the Tilemsi Valley. Originally described by Apostolescu (1961) from the Late Paleocene of the Tilemsi valley (Sagarariguida section). Also reported by Carbonnel and Monciardini from Horizon III (Ekkineouan, Fogha, In Araber).

Egypt: latest Paleocene or basal Eocene.

Libya: Paleocene.

North-western Nigeria (Iullemmeden Basin): Late Paleocene (Kalambaina Formation).

Saudi Arabia: Maastrichtian.

Senegal: Paleocene-Early Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 8, figs 12–13, 21–22.

12, 21 — Female left and dorsal views, × 65, Agamor, N34, Horizon III. **13** — Juvenile, right view, × 65, Asselar, N80, Horizon I. **22** — Male, dorsal view, In Talack, N20, Horizon III.

Genus *Foveoleberis* MALZ, 1980

***Foveoleberis teiskotensis* (APOSTOLESCU, 1961)**

Plate 8, Figs 14–20.

1961 *Uroleberis teiskotensis* APOSTOLESCU. Apostolescu, p. 798, pl. 2, figs 29–31.
1963 *Uroleberis teiskotensis* APOSTOLESCU. Barsotti p. 1525, pl. 1, fig. 5.
1966 *Xestoleberis* n. sp. 3 SALAHI. Salahi, p. 28, pl. 2, fig. 7.
1980 *Uroleberis oculata* sp. nov. AL-FURAIH. Al-Furaih, p. 71–72, pl. 63. figs 1–4.
1984 *Foveoleberis oculata* (AL-FURAIH). Al-Furaih, p. 162–163, pl. 2, fig. 3.
1988 *Uroleberis oculata* AL-FURAIH. Neale and Singh, pl. 2, figs 6, 10.
1990 *Uroleberis oculata* AL-FURAIH. Carbonnel *et al.*, p. 684–685, pl. 4, figs 4–6.

1991 *Uroleberis teiskotensis* APOSTOLESCU. Damotte, p. 12, pl. 2, figs 18–19.
1992 *Uroleberis oculata* AL-FURAIH. Carbonnel, pl. 23, figs 10–12.
1995 *Uroleberis teiskotensis* APOSTOLESCU. Carbonnel and Monciardini, p. 67–68, pl. 7, figs 13–14.

Remarks

We follow Al-Furaih's (1984) concept of *Foveoleberis* for reticulate *Uroleberis*-type Xestoleberididae, foveolate-reticulate and without caudal process. They fit into the Group IV defined by Neale and Singh (1988): "foveolate-reticulate species with or without eye tubercle". For Malz (1981) the hinge of the genus *Foveoleberis* is also characterised by a crenulate median ridge. Carbonnel *et al.* (1990) considered Apostolescu's species *Uroleberis teiskotensis* as conspecific with Al-Furaih's species *Uroleberis oculata*; since Apostolescu's species was created in 1961 there is no reason to use Al-Furaih's species which is considered as an aggraded morph of *Foveoleberis teiskotensis*. *Uroleberis reticulata* GUHA and SHUKLA, 1973, from the Paleocene-Early Eocene of India could belong to this group.

Dimensions

L = 0.54–0.67 mm
h = 0.38–0.44 mm
w = 0.44 mm (male) – 0.55 mm (female)

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons III–IV (In Talack, Agamor, In Ori).

— previous studies: originally described by Apostolescu from the Late Paleocene of Teiskot; reported by Bellion *et al.* (1989) and Damotte (1991) from the Horizons II and III of the Tilemsi Valley. Also found by Carbonnel and Monciardini (1995) in Horizons III–IV (Fogha, Ekkineouan, In Araber).

Congo: Paleocene (Damotte and Massala, 1996).
Egypt: latest Paleocene-earliest Eocene.
Libya: Paleocene (since the Danian).
Saudi Arabia: Paleocene.
Western. Niger (Garadoua Formation): Late Paleocene.

Figured specimens

Pl. 8, figs 14–20.

14 — Female, left view, × 65, Agamor, N49, Horizon IV. **15, 19** — Female, right and ventral views. **16, 18** — Male, right and ventral views, × 65, In Ori, N86, Horizon II. **17** — Male, right view, × 65, In Talack, N27, Horizon IV. **20** — Male, dorsal view, × 65, In Talack, N25, Horizon III.

Genus *Xestoleberis* SARS, 1866

***Xestoleberis* sp. 1**
Plate 7, Figs 18–19.

Remarks

This species differs from *Xestoleberis kekere* REYMENT, 1960 from the Paleocene of Nigeria by its lateral outline, this last species being more bean-shaped.

Dimensions

L = 0.55–0.65 mm
h = 0.35–0.40 mm

Age and distribution

Mali: Late Maastrichtian-Late Paleocene (Thanetian), Horizons I, III (In Talack; Agamor).

Figured specimens

Pl. 7, figs 18–19.

18 — Dorsal view, × 65, In Talack, N 11, Horizon. I. **19** — Right view, × 65, In Talack, N8, Horizon I.

Superfamily CYPRIDACEA Baird, 1845
Family PONTOCYPRIDIDAE Müller, 1894

Genus *Propontocypris* SYLVESTER-BRADLEY, 1947

***Propontocypris ? mentesensis* (CARBONNEL, ALZOUMA and DIKOUMA, 1990)**
Plate 1, Fig. 10.

1990 *Argilloecia ? mentesensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel *et al.*, p. 678, pl. 1, fig. 3.
1992 *Argilloecia mentesensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel, pl. 7, fig. 7.
1995 *Argilloecia mentesensis* CARBONNEL, ALZOUMA and DIKOUMA. Carbonnel and Monciardini, p. 27.

Remarks

The straight posterior segment of the dorsal margin is longer and more gently sloping down toward the posterior extremity than in the figured type of the species.

Dimensions

L = 0.68 mm
h = 0.44 mm

Age and distribution

Mali:

— this study: Late Paleocene (Thanetian), Horizons II, III (Takhabanat, In Talack, Creb d'Aginger).

— previous studies: found by Carbonnel and Monciardini (1995) in Horizons II–IV (Fogha, Ouarassibilt).

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, fig. 10.

10 Right view, × 65, Takhabanat, N64, Horizon II.

***Propontocypris nigeriensis* (REYMENT, 1960)**
Plate 2, Fig. 16.

1960 *Paracypris nigeriensis* REYMENT. Reyment, p. 66–68, pl. 4, figs 2a–b.
1963 *Paracypris nigeriensis* REYMENT. Reyment, p. 68–71, pl. 5, fig. 10.

non 1976 *Paracypris nigeriensis* REYMENT. Ficcarelli, p. 734, pl. 90, fig. 7.
1981 *Paracypris nigeriensis* REYMENT. Reyment, pl. 1, fig. 6.
1987 *Paracypris nigeriensis* REYMENT. Okosun, p. 26–27, pl. 15, figs 16, 23.
1989 *Propontocypris nigeriensis* (REYMENT). Carbonnel and Johnson, pl. 4, fig. 2.
1990 *Propontocypris nigeriensis* (REYMENT). Carbonnel *et al.*, p. 678, pl. 2, fig. 15.
1990 *"Paracypris" ? nigeriensis* REYMENT. Bassiouni and Lüger, p. 783–784, pl. 2, figs 13–18.
1992 *Propontocypris nigeriensis* (REYMENT). Carbonnel, pl. 7, fig. 11–12.
1995 *Propontocypris nigeriensis* (REYMENT). Carbonnel and Monciardini, p. 27, 28, pl. 1, fig. 6.
1995 *Paracypris nigeriensis* REYMENT. Swain *et al.*, pl. 1, figs 20–22
non 1996 *Paracypris nigeriensis* REYMENT. Ismail, p. 43, pl. 1, fig. 14.

Remarks

In our material, the posterior part of the ventral margin is gently convex and not sloping upwards as in the type-species, and the ventral posterior extremity is blunt.

Dimensions

L = 0.80 mm
h = 0.40 mm

Age and distribution

Mali:

— this study: restricted to the Late Maastrichtian, Horizon I (In Talack, Takhabanat, Creb d'Aginger, Ait Nafa).

— previous studies: reported by Carbonnel and Monciardini (1995) from Horizons I–IV (Fogha, In Araber).

Egypt: Early Eocene.

Ghana: Campanian-Maastrichtian (Khan, 1970; Kogbe and Me'hes, 1986).

Libya: Paleocene.

Nigerian coastal basin: Early Paleocene (Danian)-Eocene;

North-western Nigeria (Iullemmeden Basin): Late Maastrichtian (Dukamaje Formation) -Late Paleocene (Kalambaina Formation).

Togo: Paleocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 2, fig. 16.
16 Right view, × 65, In Talack, N9, Horizon I.

Family CANDONIDAE Kaufmann, 1900
Subfamily PARACYPRIDINAE Sars, 1923

Genus *Paracypris* SARS, 1866

Paracypris sokotoensis REYMENT, 1981

Plate 1, Fig. 13.

1981 *Paracypris sokotoensis* REYMENT. Reyment, p. 56, pl. 1, figs 7–10, pl. 2, fig. 2.
?1983 *Paracypris* sp. 1 FOSTER, SWAIN and PETTERS. Foster *et al.*, p. 111, pl. 2, figs 3–4.
1983 *Paracypris sapperi* VAN DEN BOLD. Foster *et al.*, p. 111–112, pl. 2, figs 1, 2.
1986 *Paracypris sokotoensis* REYMENT. Carbonnel, p. 104, pl. 10, fig. 16.
1990 *"Paracypris" ? sokotoensis* REYMENT. Bassiouni and Lüger, p. 784, pl. 2, figs 6–8.
1990 *Paracypris sokotoensis* REYMENT. Carbonnel, pl. 7, fig. 16.
1995 *Paracypris sokotoensis* REYMENT. Carbonnel and Monciardini, p. 25.

Remarks

The specimens from our Malian material are much more similar in outline to the Nigerian forms illustrated by Reyment (1981) than to the Egyptian specimens of Bassiouni and Lüger (1990). *Paracypris* sp. ANDREU, 1996 from the Coniacian-Campanian of Morocco show strong similarities with Reyment's species.

Dimensions

L = 1.03–1.06 mm
h = 0.53–0.55 mm

Age and distribution

Mali:

— this study: Late Maastrichtian, Horizon I (In Talack, Takhabanat, Creb d'Aginger), Late Paleocene (Thanetian), Horizon IV (Agamor).

— previous studies: reported by Carbonnel and Monciardini (1995) from Horizons III and IV (Agamor).

Egypt: Late Paleocene-basal Eocene (*pesudomenardii* to *edgari* Zone).

North-western Nigeria: Late Paleocene.

Senegal: Early Paleocene-Middle Eocene.

Western Niger: Late Paleocene (Garadoua Formation).

Figured specimens

Pl. 1, fig. 13.
13 Right view, × 65, Takhabanat, N67, Horizon III

Paracypris gr. *jonesi* BONNEMA, 1941

Plate 1, Fig. 11.

gr. 1941 *Paracypris jonesi* BONNEMA. Bonnema p. 115, pl. 3, figs 24–28.
1966 *Paracypris* n. sp. 1 SALAHI. Salahi, p. 7, pl. 1, figs 29, 30, 34.
1968 *Paracypris jonesi* BONNEMA. Esker, pl. 1, fig. 13.
1982 *Paracypris* cf. *jonesi* BONNEMA. Diop *et al.*, p. 25, pl. 1, fig. 6.

1983 *Paracypris* sp. DONZE, COLIN, DAMOTTE, OERTLI, PEYPOUQUET and SAID. Donze *et al.*, p. 282, pl. 2, fig. 7.
1986 *Paracypris* cf. *jonesi* BONNEMA. Carbonnel, p. 103, pl. 3, fig. 6.
1989 *Paracypris* cf. *jonesi* BONNEMA. Carbonnel and Johnson, p. 420, pl. 4, fig. 3.
1990 *Paracypris jonesi* BONNEMA. Bassiouni and Lüger, p. 783, pl. 2, figs 9, 11.
1990 *Paracypris* cf. *jonesi* BONNEMA. Carbonnel, pl. 7, figs 8–9.
1992 *Paracypris* NC 206 COLIN and HOCHULI. Colin and Hochuli, pl. 4, fig. 7.
1995 *Paracypris* cf. *jonesi* BONNEMA. Carbonnel and Monciardini, p. 13.

Remarks

The synonymy list is restricted to African occurrences of this species originally described from the Late Cretaceous of the Netherlands by Bonnema (1941). *Paracypris siddiquii* BHANDARI, 1992 from the Late Paleocene of Rajasthan (India) could belong to this group.

Dimensions

L = 0.730 mm
h = 0.27 mm

Age and distribution

Mali:
— this study: Late Paleocene (Thanetian), Horizon II (In Talack, Creb d'Aginger, Ibegan).
— previous studies: reported by Carbonel and Monciardini (1995) from Horizon III (Galmi).
Egypt: Middle Paleocene-earliest Eocene (*praecursoria* to *edgari* Zone).
Libya: Paleocene.
Senegal: Late Paleocene.
Togo: Late Paleocene.
Western Niger: Late Paleocene (Garadoua Formation).
Tunisia: Late Maastrichtian-Early Paleocene (Danian).

Figured specimens

Pl. 1, fig. 11.
11 Right view, × 65, In Talack, N17, Horizon II.

Paracypris sp. A ESKER, 1968

Plate 2., Fig. 18.

1968 *Paracypris* sp. A ESKER. Esker, p. 322, pl. 3, fig. 9.
1982 *Paracypris* sp. A ESKER. Donze *et al.*, p. 282, pl. 2, fig. 8.
1998 *Paracypris* sp. A ESKER. Damotte and Fleury, p. 94, pl. 1, fig. 13.
?1992 *Paracypris* NC 113 COLIN and HOCHULI. Colin and Hochuli, pl. 4, fig. 9.

Remarks

The specimens from our Malian material are smaller than the Tunisian and the Argentinean related forms (*Paracypris* sp. BERTELS, 1973), but with a ventral margin straighter in its posterior part than in the first form and an anterior margin more largely rounded than in the second and than in *Paracypris* NC113 COLIN and HOCHULI from the Campanian of eastern Niger whose dorsal margin is slightly more strongly arched.

Dimensions

L = 0.80 mm
h = 0.38 mm

Age and distribution

Mali: Late Maastrichtian-Late Paleocene, Horizons I–II (In Talack, Ibegan).
Algeria: Late Maastrichtian.
Eastern Niger: Campanian (Aschia-Tinamou Formation).
Tunisia: Late Maastrichtian-Early Paleocene (Danian).

Figured specimens

Pl. 2, fig. 18.
22 Right view, × 65, In Talack, N12, Horizon I.

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Appendix

After completition of this paper we had knowlidge of a very interesting paper by A. El Sogher (Late Cretaceous and Paleocene ostracods from the Waha Limestone and Hagfa Shale formations of the Sirt Basin, Libya. In: SALEM M.J. *et al.* (eds.): The Geology of Sirt Basin, Elsevier, Amsterdam, vol. 1: 287–367). Several species known from Mali are reported by the author from the Lata Maastrichtian and Paleocene of Libya.

ALPHABETICAL INDEX TO GENERA

Ovocytheridea pulchra Reyment,
Paijenborchellina sp. 1,
Paracosta warriensis (Reyment),
Paracypris gr. *jonesi* Bonnema,
Paracypris sokotoensis Reyment,
Paracypris sp. A Esker,
Paracytheridea ? *talackensis* sp. nov.,
Paragrenocythere aff. *P. mudhensis* (Khosla),
Paragrenocythere cultrata (Apostolescu),
Paragrenocythere sehouensis (Apostolescu),
Parakrithe ? *kalambainensis* (Reyment),
Parakrithe ? sp. 1,
Pataviella digidaensis (Carbonnel and Monciardini),
Patrizia ? *lagaghiroboensis* (Apostolescu),
Ponticulocythere cf. *P. austraegyptiaca* (Bassiouni and Lüger),
Propontocypris nigeriensis (Reyment),
Propontocypris ? mentesensis (Carbonnel, Alzouma and Dikouma),
Rayneria tilemsiensis (Apostolescu),
Schizocythere salahii Bassiouni and Lüger,
Schizoptocythere usmandanfodioi (Reyment),
Soudanella cf. *S. laciniosa laciniosa* Apostolescu,
Stigmatocythere brgmensis (Carbonnel and Monciardini),
Teiskotella teiskotensis (Apostolescu),
Trachyleberis teiskotensis (Apostolescu),
Uroleberis glabella Apostolescu,
Xestoleberis sp. 1.

ALPHABETICAL INDEX TO SPECIES

PLATE 1

Figs 1–3: *Bairdoppilata nafaensis* sp. nov.

Figs 4, 5: *Bairdoppilata ilaroensis*

Fig. 6: *Neonesidea elongatoilaorides*

Fig. 7: *Neonesidea* sp. 1

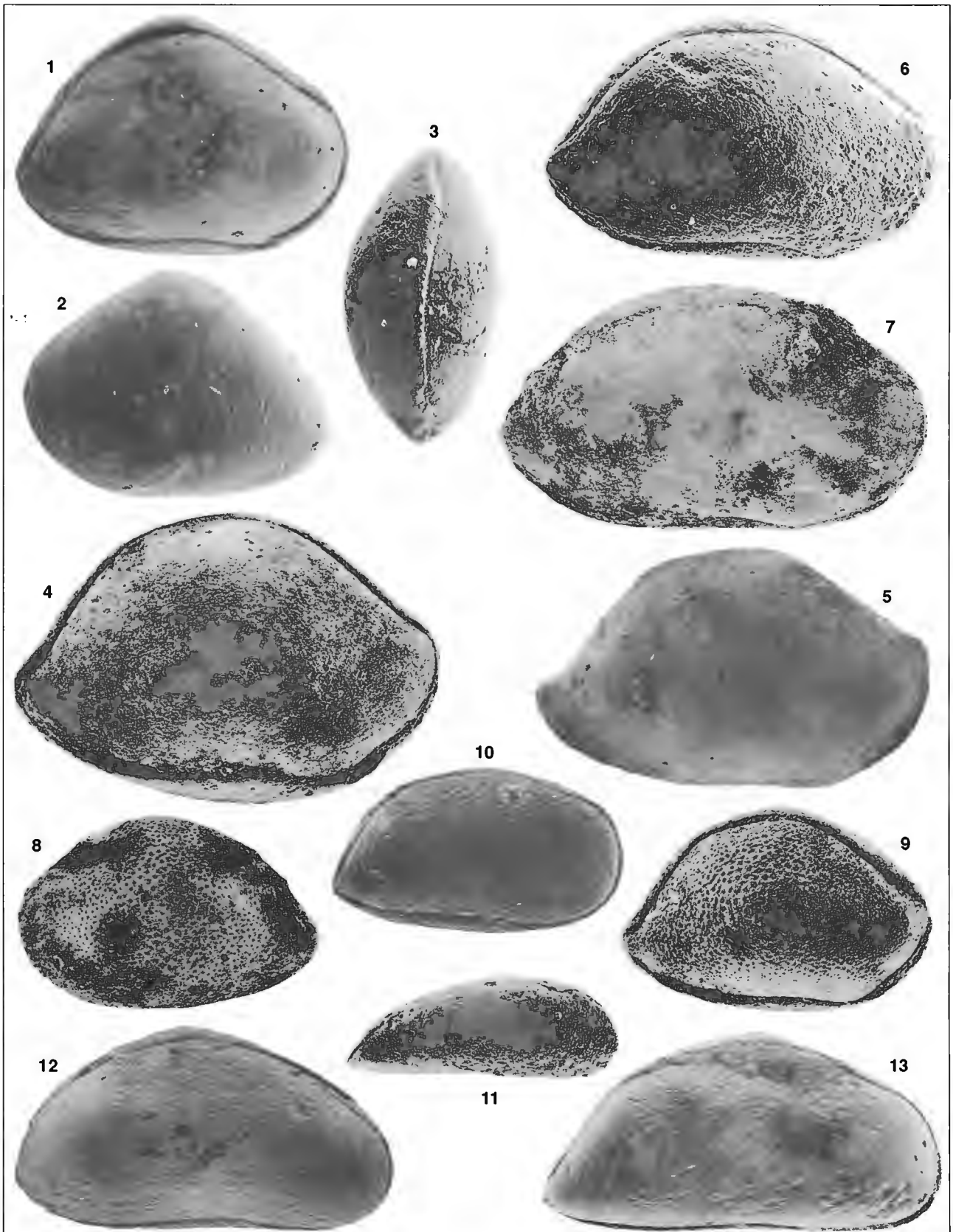
Figs 8, 9: *Neonesidea ilaroides*

Fig. 10: *Propontocypris ? mentesensis*

Fig. 11: *Paracypris* gr. *jonesi*

Fig. 12: *Bythocypris fosteralii*

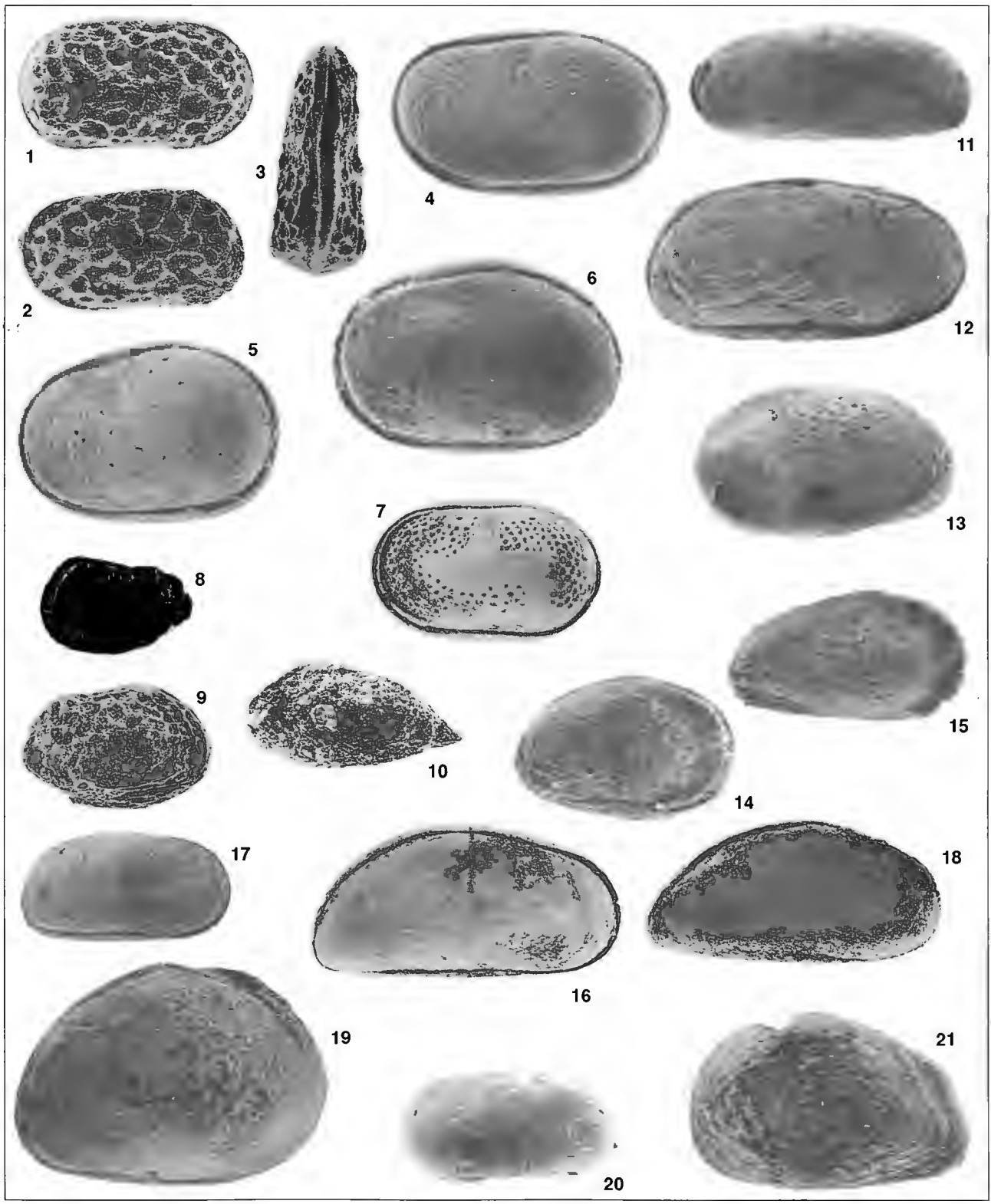
Fig. 13: *Paracypris sokotoensis*



all x 65

PLATE 2

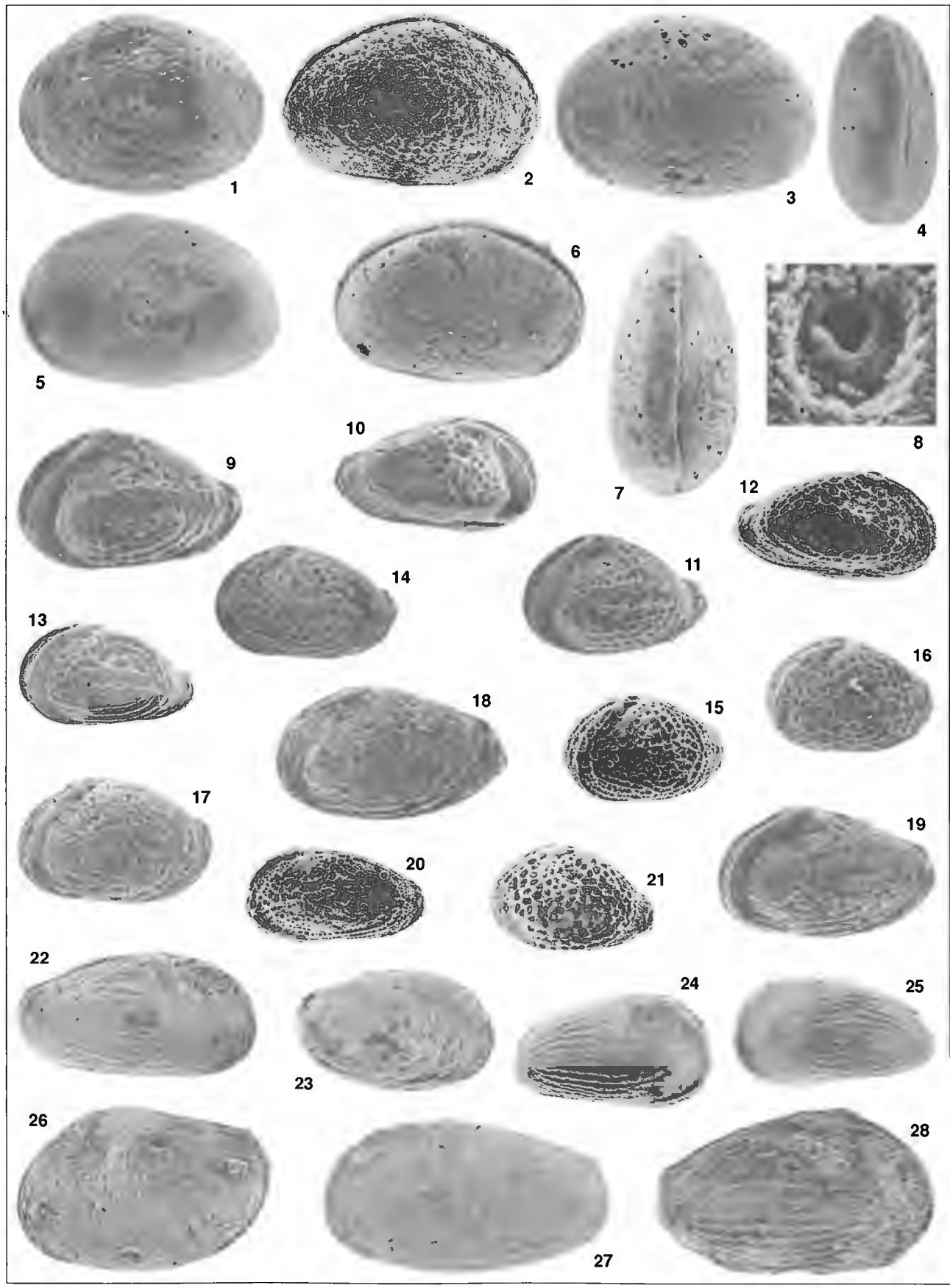
Figs 1–3: *Cytherelloidea christianae* sp. nov.
Fig. 4: *Cytherella* gr. *meijeri*
Fig. 5: *Cytherella* sp. 2
Fig. 6: *Cytherella sylvesterbradleyi*
Fig. 7: *Cytherella* sp. 1.
Figs 8, 9: *Schizocythere salahii*
Fig. 10: *Paijenborchellina* sp.
Figs 11, 12: *Bythocypris olaredodui*
Figs 13–15: *Isohabrocythere teiskotensis*
Fig. 16: *Propontocypris nigeriensis*
Fig. 17: *Parakrithe* ? sp. 1
Fig. 18: *Paracypris* sp. A
Fig. 19: *Ovocytheridea pulchra*
Fig. 20: *Parakrithe kalambainaensis*
Fig. 21: *Patrizia* ? *lagaghiroboensis*



all x 65

PLATE 3

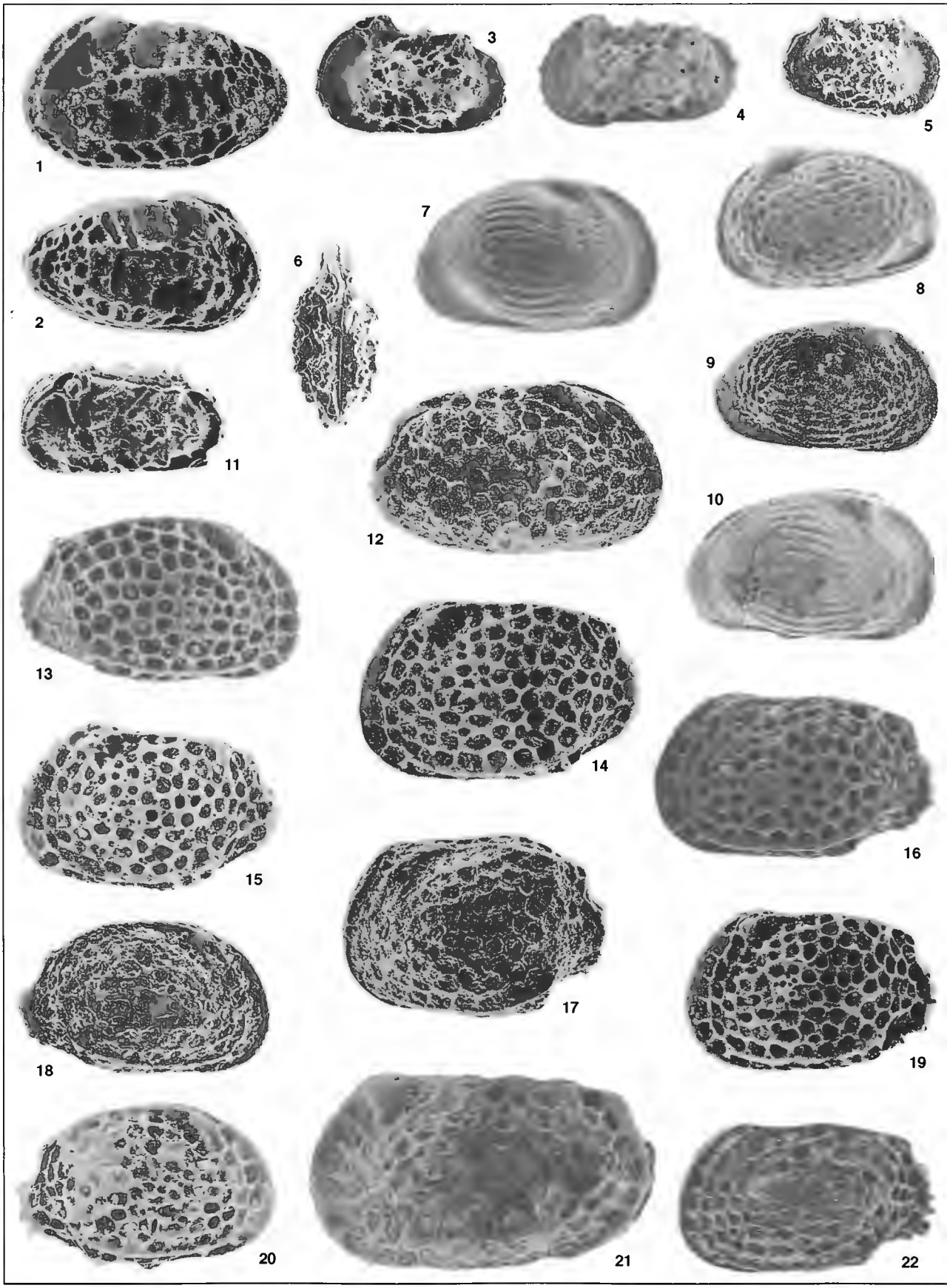
Figs 1–8: *Bopaina hottingeri*
Figs 9–11: *Buntonia apatyerieryii*
Figs 12–13: *Buntonia issabaensis*
Figs 14–16: *Buntonia tichittensis*
Fig. 17: *Buntonia isobopaensis*
Figs 18–19: *Buntonia pyriformis*
Fig. 20: *Buntonia misreia lineata*
Fig. 21: *Buntonia tilemsiensis*
Fig. 22: *Iorubaella virgulata*
Figs 23, 26: *Butonia bopaensis*
Figs 24, 25: *Iorubaella* sp 1
Fig. 27: *Iorubaella ologuni ologuni*
Fig. 28: *Soudanella* cf. *S. laciniosa laciniosa*



all x 65, except fig. 8 x 245

PLATE 4

Fig. 1–2: *Paracosta warriensis*
Figs 3–6, 11: *Stigmatocythere brgmensis*
Figs 7–10: *Nucleolina tatteuliensis*
Figs 12–22: *Isalocopocythere teiskotensis*



all x 65

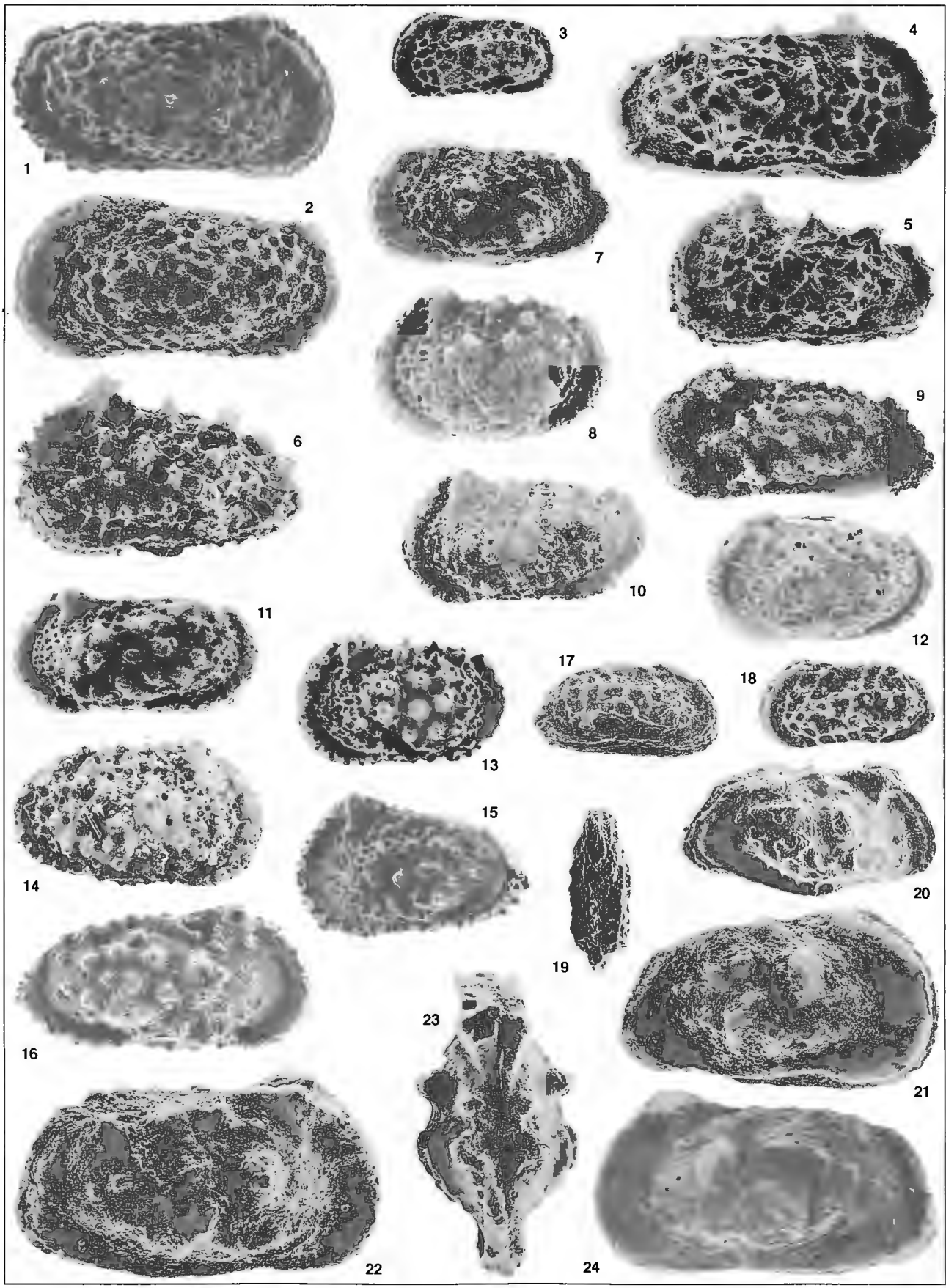
PLATE 5

Figs 1, 2: *Acanthocythereis nyameyiensis*

Figs 3, 17–19: *Moosina terlineata* sp. nov.

Figs 7–15: *Trachyleberis teiskotensis*

Figs 20–24: *Teiskotella teiskotensis*



all x 66

PLATE 6

Fig. 1–6: *Rayneria tilemsiensis*

Fig. 7: *Ponticulocythereis* cf. *P. austraegyptiaca*

Figs 8, 9: *Dameriacella kaoensis*

Figs 10–11: *Schizoptocythere usmandandofioi*

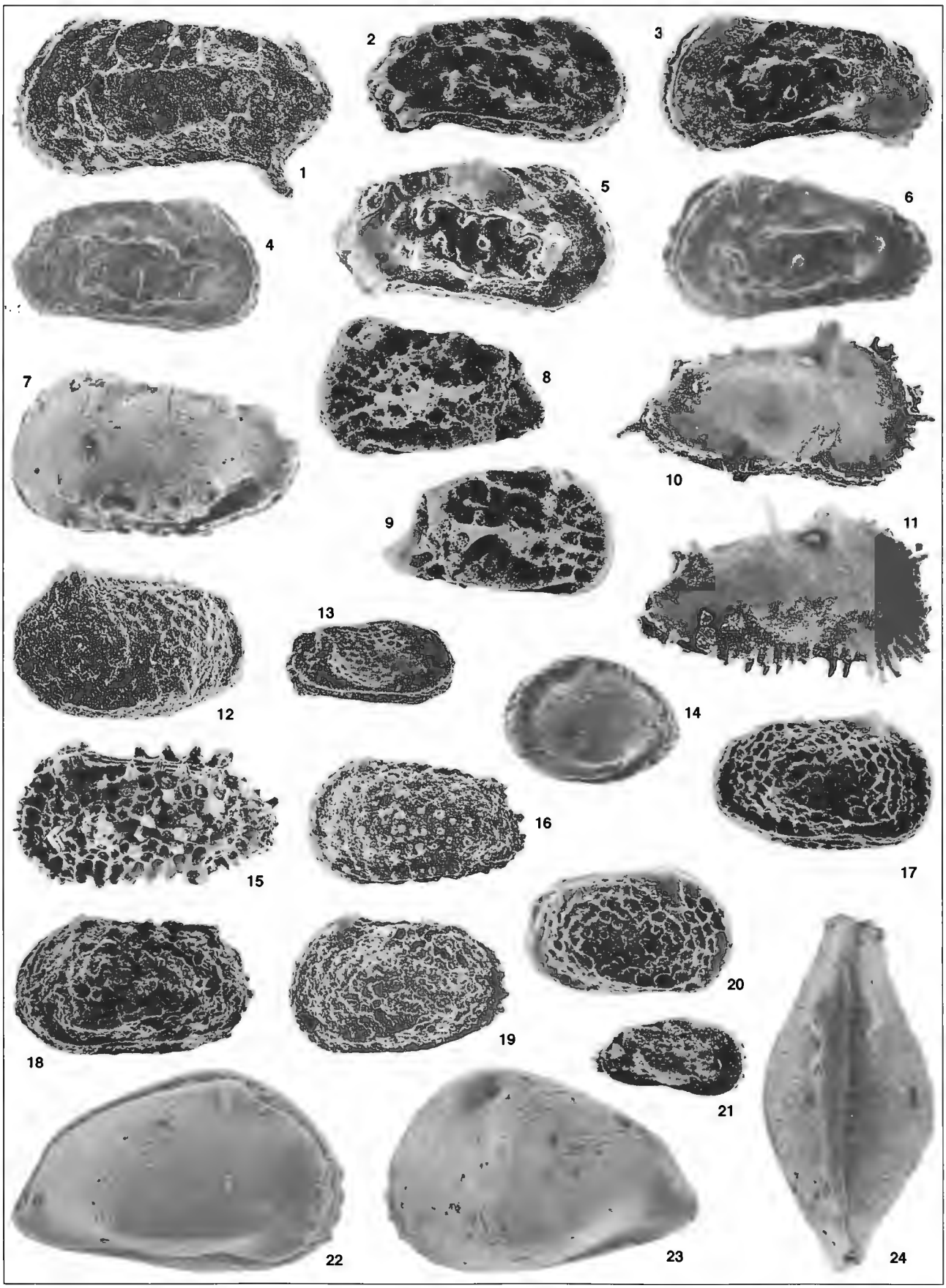
Figs 12, 16–20: *Ortliella vesiculosa*

Figs 13, 21: *Occultocythereis confirmatus*

Fig. 14: *Dahomeya alata*

Fig. 15: *Oertliella tubera*

Figs 22–24: *Brachycythere oguni*



all x 65

PLATE 7

Figs 1–4: *Pataviella digidaensis*

Figs 5–9: *Hornibrookella apostolescui* sp. nov.

Figs 10–11, 21: *Paracytheridea ? talackensis* sp. nov.

Figs 12–13: *Hornibrookella bellioni* sp. nov.

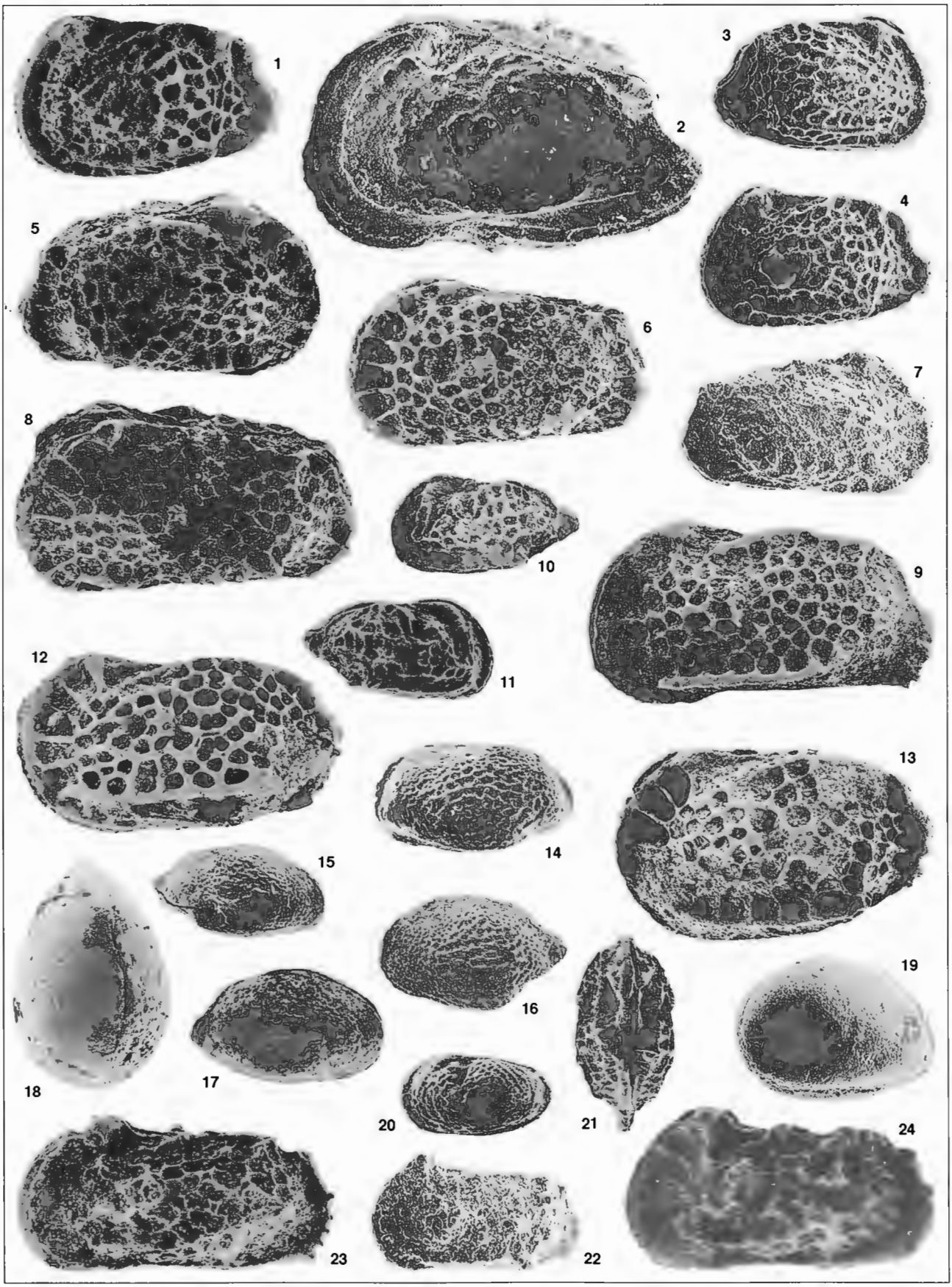
Figs 14–17: *Kroemmelbeinella trapezoidalis*

Figs 18–19: *Xestoleberis* sp. 1

Fig. 20: *Evisceratocythere* aff. *musculoides*

Fig. 22: *Hermanites ?* sp. 1

Fig. 23–24: *Dameriacella ? tessalitensis*



all x 65, except figs 1-4 x 76

PLATE 8

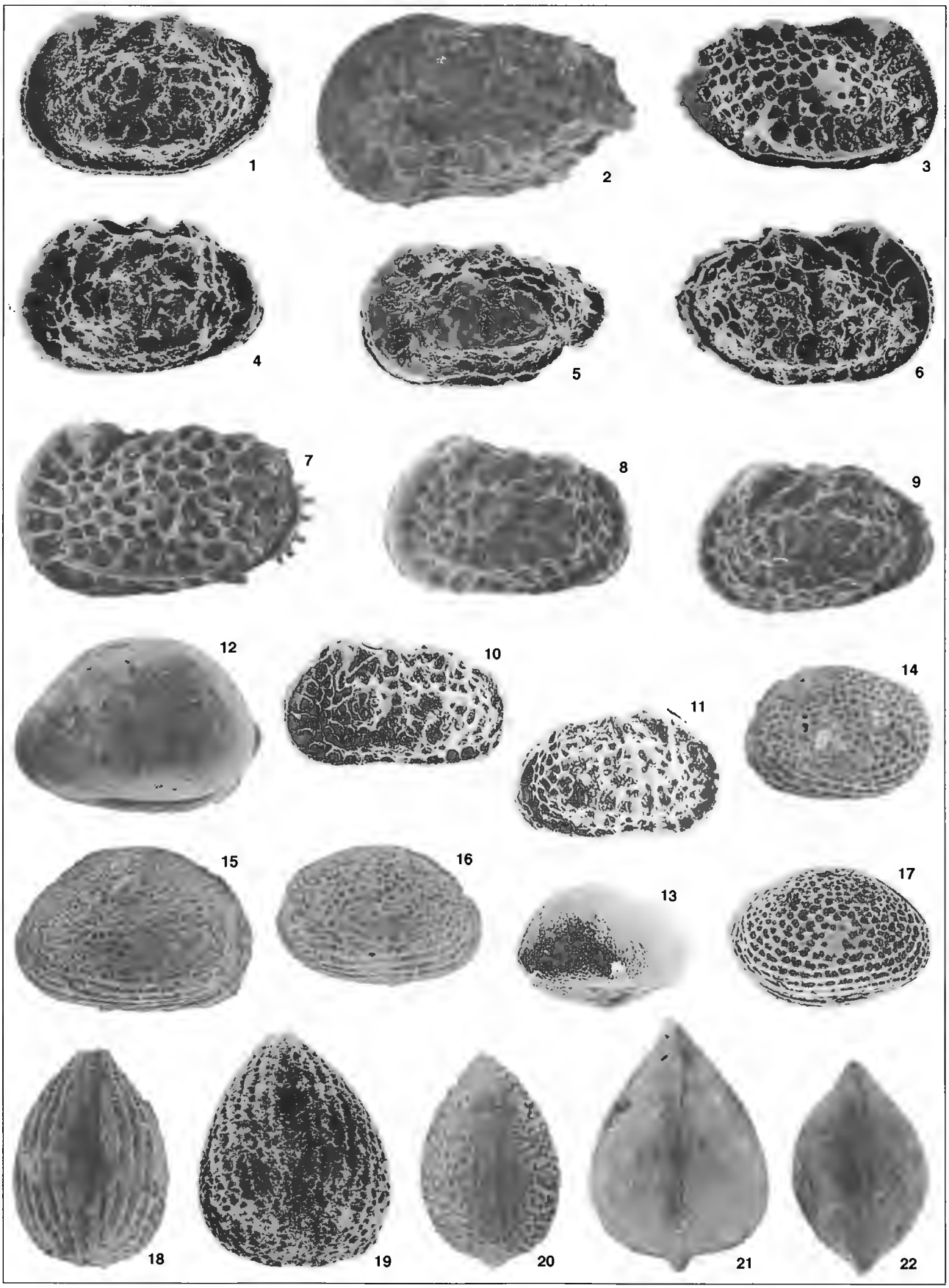
Figs 1–6: Paragrenocythere cultrata

Fig. 7: Paragrenocythere aff. P. mudhensis

Figs 8–11: Paragrenocythere sehouensis

Figs 12–13, 21–22: Uroleberıs glabella

Figs 14–20: Foveoleberis teiskotensis



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PALEOGENE SHALLOW BENTHOS OF THE TETHYS, 2

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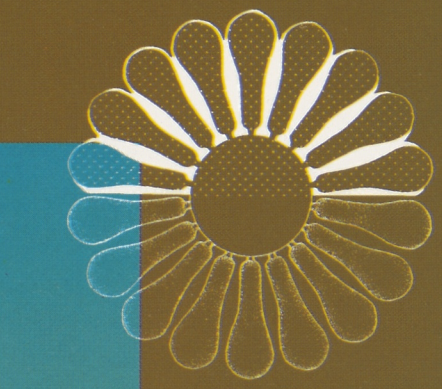

Hommbusella liburnica (Radoičić)

Obdobje 20 milijonov let, ki je sledilo opustošenju po kredno-terciarni meji in izumrtju dinozavrov, ima posebno mesto v zgodovini Zemlje. V tem času se je postopoma obnavljalo življenje z vso pestrostjo svojih oblik. Podrobno proučevanje tega obnavljanja nam daje ključ za razumevanje vzrokov zakaj in kako je vzniknila in napredovala raznovrstnost življenja.

Pričujoči zvezek je zbir zgodovinskih dokumentov, ki ilustrirajo nekatere od mnogih podob obnove. To so dokumenti, ki bi morda lahko pomagali podrobneje razjasniti celotno podobo tega časa, kot jo poznamo doslej. Osvetlijo lahko mračen pogled na katastrofe ob kredno-terciarni meji, kakor jih odseva duh našega časa. Ta zvezek je drugi od treh, pripravljenih pod skupnim naslovom Paleogene Shallow Benthos of the Tethys - ***Plitvomorski bentos v paleogenu Tetide***. Osredotočen je na skupino konservativnih organizmov, kot so dazikladacejske alge ali ostrakodi, medtem ko bo naslednji zvezek posvečen organizmom, ki so se hitreje razvijali.

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Urednika: Lukas Hottinger, Katica Drobne

Oblikovanje:
Romana Lesnika

Drobnella slovenica Barattolo