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DEPTH GRADIENT PROXIES: PALAEOECOLOGY VERSUS SEDIMENTOLOGY. CASE STUDY FROM THE TUREA GROUP DEPOSITS OF THE PALEOGENE TRANSYLVANIAN BASIN

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Abstract. We approached problems of paleobathymetry from two different, but interconnected directions: from a paleoecological point of view and from a sedimentological one.

To approximate from paleoecology, in our preliminary study (Kovács and Arnaud-Vanneau, 2004), we defined 6 paleoecological assemblages focusing solely on the Pleşca Valley 2 outcrop. After analyzing correlative sections, as we had actually forecast, it raised the demand of restructuring previous working assemblages into new ones, built up from sub-assemblages reflecting more restrictive ecological conditions.

The reasons for this complementation are that several depositional profiles replace each other during basin morphology evolution, and secondly, substrate and trophic conditions also might change from one paleogeographic location to other.

Initial strandplain carbonate ramp (Pleşca Valley 1) evolves to a beach barrier carbonate ramp (Cheile Baciului), locally to a reef-mound beach barrier ramp (Pleşca Valley 2, Turea) and finally to a siliciclastic delta profile (Mera). Each profile from the above is holding its own particular facies zones, reflected by particular paleoecological assemblages and typical sedimentary structures.

Considering a shallowing depth gradient, depositional environments and their dominant IDRA assemblages will align one after other as follows: I. offshore basin; IIa. Proximal outer ramp-outer middle ramp – muddy substrate, oligophotic, oligotrophic; IIb. Outer middle ramp shoals – mezophotic; IIc. Outer middle ramp – probably eutrophic; IIIa. Middle ramp – reef mounds; IIIb. Middle ramp – sandy substrate; IVa Inner middle ramp bioherms; IVb Inner middle ramp – sandy substrate; IVc. Inner middle ramp – probably eutrophic; Va. Outer inner ramp shoals – euphotic; Vb. Inner ramp – lagoon; VI. Proximal inner ramp; VII Nearshore.

Keywords: depth related assemblages, paleobathymetry, Late Eocene, Paleogene Transylvanian Basin

INTRODUCTION

Problems of paleobathymetry might be approached from two different directions: from a paleoecological point of view and from a sedimentological one. In ideal conditions these two approaches support each other's findings. Turea Group deposits are nicely reflecting and validating this perception.

However, the main outcome of this study consists in defining seven Idealized Depth Related Assemblages (IDRA), including ten sub-assemblages that are tuned for paleobathymetrical estimations within the Turea Group sedimentary sequence.

In this purpose, four outcrops have been selected along a 40 km long transect through the Late Eocene\ earliest Oligocene carbonate-siliciclastic shelf in the southern part of the Paleogene Transylvanian Basin (PTB).

In a preliminary report, Kovács and Arnaud-Vanneau (2004a) defined as a first approximation 6 paleoecological working-assemblages belonging to the Late Eocene – earliest Oligocene interval and one group made of echinoderm fragments. Biota, part of these assemblages (i.e. census assemblages), lived more or less in the same paleoecological environments and were deposited at similar depth during that same time.

As it could be predicted, processing new data from additional outcrops, assemblages could be further refined as it will be presented below.

Possibilities and limitations in depth estimation using paleoecological data

Unfortunately, changes in depth, although very commonly discussed, are inevitably accompanied by changes in several other inextricably and intricately interrelated parameters (such as temperature, pressure, dissolved oxygen, or "water mass" characteristics) and depth itself is probably of little consequence (Reiss and Hottinger, 1984 in Boltovskoy et al., 1991). Hence, depth cannot really be considered an "environmental" parameter.

However, many of the other ecological factors, such as temperature, substrate, turbulence, light, oxygen, nutrients and salinity are depth related and are commonly used to infer relative depth in environmental reconstructions (Arnaud-Vanneau, 2005)

According to Van der Zwaan (1999), using modern foraminifera faunas as an analogue, relative proportion of the morphogroups present in an assemblage may be used to interpret changes in environmental parameters, such as water depth, current strength and organic flux to the sea floor. Morphogroups are defined on basis of the external morphology of the foraminiferal test.

For the other groups of organisms, such as red algae, bryozoans or corals, growth forms are

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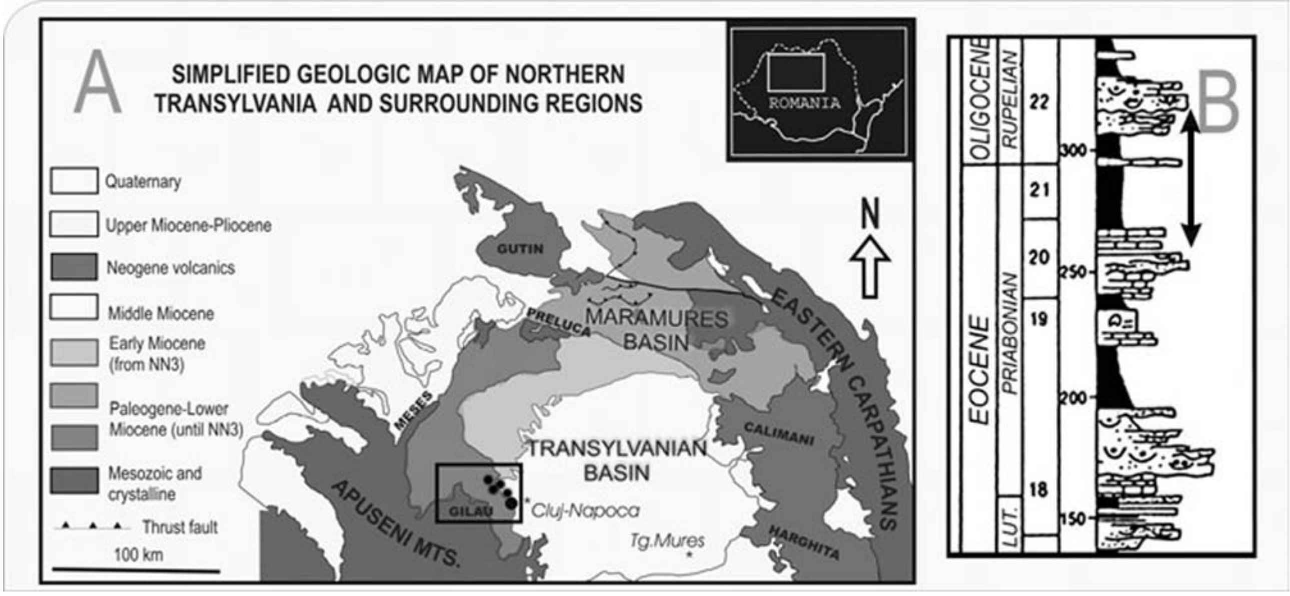

Fig. 1 Localization of sampled profiles within the Gilău depocenter

Geologic map A, after Györfi et al. 1999;

Section B - sedimentary succession of the Paleogene Transylvanian Basin (from Proust & Hosu, 1996) - arrow shows the stratigraphic range of the studied sections.

considered to supply useful information that are related to environmental parameters.

For our Paleogene associations, we kept in mind Hottinger's (1997) way of thinking too, who argues that neritic foraminiferal associations prior to the last biological revolution in Mid-Miocene, must be interpreted as to their depth of habitat, not according to their closeness to their extant relatives in the taxonomic system, but according to the presence of morphological elements in their shell reflecting vital functions related to depth of habitat.

Autecological functions of shell structures are more clearly expressed at the K-strategy pole of the K-r strategy[2] gradient. Consequently, an interpretation of depth of habitat is much favoured in, if not limited to oligotrophic and warm environments.

As emphasized by Van der Zwaan (1999), organic flux causes decreasing oxygen contents deeper into the water column, due to oxygen consumption. Depending on the oxygen supply, various combinations of oxygen and flux are possible at a given depth going from basin to basin. Therefore, at a given depth various combinations of species will occur, depending on the oxygen/organic supply combination. With depth, organic flux always regularly decreases, leading to a regular succession of species. The bathymetric position of the succession is different from place to place dependent on the level of organic flux.

By this reasoning, Van der Zwaan (1999) argues that individual species are never good markers of paleodepth although we know that some species are typically deep water ones i.e., adapted to low organic flux and others proliferate at the shelf margin i.e., require a high organic load in order to flourish. He also concludes that it would be preferable to reconstruct depth with faunal characteristics independent of organic flux.

In contrast, Hottinger (1997) states that significant depth ranges must reflect the depth dependent limits of the area inhabited by a population of individuals having genetic exchange in sequential generations. So far, the closest practicable approach to this would be to operate with species, not genera.

GEOLOGICAL BACKGROUND

All the investigated sedimentary successions are situated within the Gilău area (fig.1). Topics of sedimentary infill have been reviewed in several studies (Popescu, 1984; Hosu, 1996, 1999; Rusu, 1995; Filipescu, 2001; Kovács, 2005).

Seven outcrops were sampled at a high resolution in the neighbourhood of Cluj-Napoca. These are the following: two outcrops in the Pleşca Valley of Cluj-Napoca (section PV1 and PV2), one outcrop in the Someş Valley (section SZP), the famous succession from the Cheile Baciului (section BT), two very closely spaced outcrops from Mera (section M1 and M2), and the others from Viştea (section V) and Turea (section T). Among these sections, those from Mera and Viştea are mainly siliciclastic. Here, our methods based on thin-section studies had less success.

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[2] It is a common usage to classify organisms according to their life-history strategies. At one extreme are the r-mode opportunists which rapidly increase their population densities, usually by early maturation and reproduction, and which proliferate in nutrient-rich ephemeral or stressed habitats. At the other extreme are the K-mode biotically competent species, characterized by long individual life and low reproduction potential (Geel, 2000).

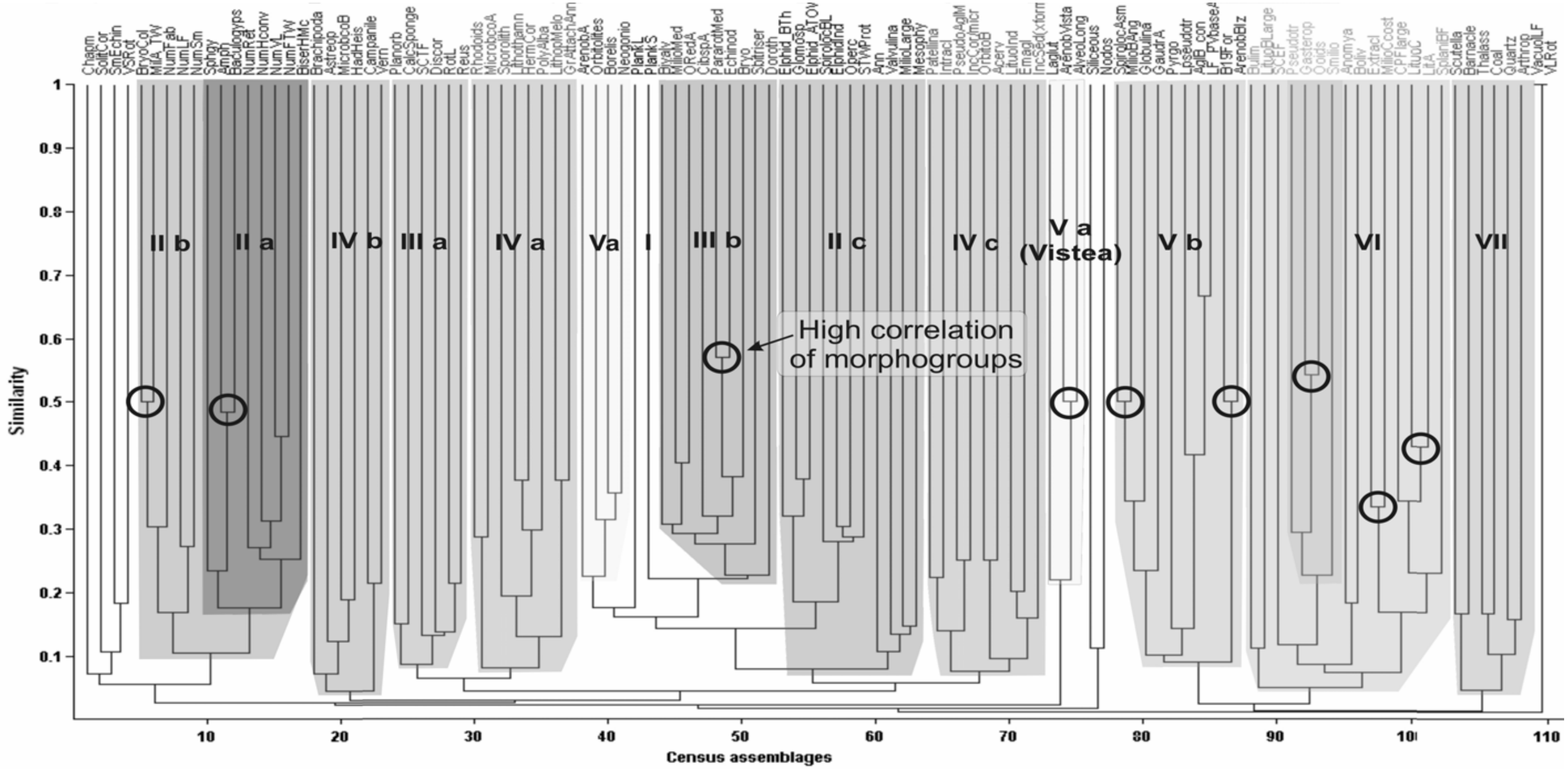

Fig. 2 Census assemblages of the Turea Group deposits. Explanation of acronyms: *I. Basin:* PlankL (Large planktonic forams), PlankS (Small planktonic forams). *IIa. Transition from proximal outer ramp to outer middle ramp – muddy substrate, oligophotic, oligotrophic:* NumVL (Very Large *Nummulites*), Bryo (Bryozoan), Siliceous (Siliceous allochems), Nodos (Nodosariids), BiserHMc (Biserial high-magnezian calcite walled forams), NumFTW (Thick-walled *Nummulites*), Baculogyps (*Baculogypsinoides*), NumRet (*Nummulites cf. retiatus*). *IIb. Outer middle ramp – shoals:* VSRot (Very small *Pararotalia*), SolitCor (Solitary corals), SmEchin (Small echinoids), Amph (Amphisteginid forams), Sphgy (*Sphaerogypsina*), BryoCol (Colonial bryozoans), MilA_ TW (thick-walled miliolids, type A), NumFab (*Nummulites fabianii*), NumLF (Large and flat *Nummulites*), NumSm (Small, macrospheric *Nummulites*), NumHconv (High convex *Nummulites*). *IIc. Outer middle ramp – probably eutrophic:* Elphid_BTh (Thin-walled Elphidiids, type B), Glomosp (*Glomospira*), Elphid_ATOW (Elphidiids with thicker outer wall, type A), SpirolocBL (Large *Spiroloculina*, type B), ElphidInd (Elphidiidae indet.), Operc (*Operculina alpina*), Ann (annelids), Valvulina, MilioLarge (large miliolids), Mesophy (Mesophyllum). *IIIa. Middle ramp – reef mounds:* Planorb (*Planorbulina*), CalcSponge (Calcareous sponge), SCTF (Small, calcitic trochospiral forams), Discor (Discorbidae), RotL (Large *Pararotalia*), Reus (*Reussella*). *IIIb. Middle ramp – sandy substrate:* Bivalv (Bivalves), MilioMed (Medium sized miliolids), ORedA (Other red algae), CibspA (Cibicides), PararotMed (Medium sized *Pararotalia*), Echinod (echinoderm fragments), Sbitriser (Small biserial-triserial forams), Marssonella. *IVa Inner middle ramp – bioherms*: MicrobcoA (microbial construction, type A), Sporolith (*Sporolithon*), Lithothamn (*Lithothamnion*), HermCor (Hermatypic corals), PolyAlba (*Polystrata alba*), LithopMelo (*Lithoporella melobesioides*), GrAttachAnn (Large attached annelids), rhodoids (facies marker). *IVb. Inner middle ramp – sandy substrate:* Brach (Brachiopoda), Astreop (*Astreopora*), HadHeis (*Haddonia heisinghi*), Vern (*Verneuilina*), MicrobcoB (Microbial construction, type B), Campanile (facies marker). *IVc Inner middle ramp – probably eutrophic:* Patellina, PseudoAglM ('Pseudoagglutinated' thick-walled miliolids), IncCor/micr (Incertae sedis, coral or microbial construction), Acerv (*Acervulina*), LituoInd (Lituolid indet.), Emagl (Elongated, medium sized agglutinated foram), IncSed(xform) (incertae sedis showing X pattern). *Va. Outer inner ramp – shoals, euphotic zone:* ArenobA (*Arenobulimina*, type A), Orbitolites, Borelis, Neogonio (*Neogoniolithon*), AlveoLong (*Alveolina elongata*), ArenobVista (*Arenobulimina* of the Vistea outcrop), OrbitoB (*Orbitolites*, type B), GaudrA (*Gaudryina*, type A), AglB_con (conical agglutinated foram, type B). *Vb. Inner ramp – lagoon:* SpirolocAsm (Small *Spiroloculina*, type A), MilioBAng (Angular miliolid), Globulina, Pyrgo, Lpseudotr (Large *Pseudotriloculina*), LF_PV baseA (large foram found in the base of the PV2 section, type A), Bt19For (foraminifera from sample Bt19), ArenobBlz (*Arenobulimina*, type B, with izometric chambers).*VI. Proximal inner ramp*: LituoBLarge (Large lituoid, type B), SCEF (small, erected calcitic foram), Boliv (Bolivinids), Anomya, MilioCcost (costulated miliolids), LituoC (lituolid, type C) LitA (lituolid, type A), CPFlarge (Large calcitic planispiral foram). *VII. Nearshore:* Pseudotr (*Pseudotriloculina*), Smilio (Small miliolids), Gasterop (Gastropoda), Arthrop (Arthropoda), Coal (facies marker), Thalass (*Thalssinoides*, facies marker), Scutella, Barnacle.

For this reason, the greatest part of the studied thin-sections belongs to the Cluj Limestone. However, thin-sections were prepared from each stratigraphical body across the whole thickness of the Turea Group when possible.

The idealized succession of the Turea Group is roughly composed of lagoonal, bioclastic shoal and open carbonate platform deposits (Proust & Hosu, 1996).

METHODS

We applied the following workflow in data acquisition and data interpretation of thin-sections:

1) *Biota recognition* All possible appearances of any organisms have been discriminated in thin-sections, washed materials or embedded artificial microfacies.

2) *Biota description and morphogroup delineation*. Involved to group together and label with a name all the specimens belonging to a given taxon or morphotype. We used two types of morphogroups (see fig.2): *restrictive* morpho-groups, that contain more taxonomically constrained members (e.g. *Operculina* morphogroup), and play the role of marker categories in cluster analysis, (2) *permissive* morphogroups, having broader definitions (e.g. Morphogroup of medium-sized miliolids). Grouping criteria consisted of wall-structure features, spatial disposition of chambers and test size and morphology. Morphogroups are presented in detail in the forthcoming section.

3*) Counting phase*. Counted data were acquired from thin-sections of carbonates and siliciclastics (average size of utile surface: 4cm x 6cm) and embedded artificial microfacies (average size of utile surface: 2cm x 2cm).

4) Creating 'Idealized Depth Reference Assemblages' (IDRA). We achieved seven IDRAs by classifying previously identified morphogroups according to a depth zonation of their niche, ranging from outer marine to littoral environments. IDRA assemblages, by definition, comprise and are valid to the whole time-span of the studied sections. IDRAs were further refined into sub-assemblages when needed, taking into account different substrates or trophic conditions.

The ordination principle of morphogroups, and their grouping into assemblages, usually followed ecological analogies encountered in ancient and actual environments for the major part of organisms. The rest of morphogroups were included into assemblages when their abundance showed a systematic positive correlation with those already recognized. Meanwhile ordination, we assumed restrictions pointed out by Boltovskoy et al. (1991), Hottinger (1997) and Van der Zwaan (1999).

IDRAs were tested, and outliers removed, applying R-mode unweightened pair-group cluster analysis (fig. 2) on presence/absence data matrices, constructed from foraminifera morphogroups, red algal, coral and bryozoan growth forms. Presence/absence data were acquired from the whole thin-section surface.

5) Abundance Calculations of the 'Real Depth Related Assemblages' (RDRA). We define here as 'Real Depth Related Assemblages' those preserved individuals of an initially living population that can be identified in one single thin-section/sample, and which can be assigned to any of the morphogroups defining an IDRA assemblage. As a consequence, each RDRA assemblage will belong to a particular IDRA assemblage. RDRA mean only an approximation to ancient populations, which, as we know, were subject to diagenetic processes. They are described with their sample number and the depth interval they refer to.

6) Graphical selection of dominant RDRA. RDRA percentages are represented as peak signals. Dominant RDRA are assemblages showing the greatest abundance (highest peak) in one sample. It is assumed, that optimum life-condition of species and assemblages is bell-shaped, as well.

7) Graphical Calculation of Minimum and Maximum Paleobathymetrical values

To enhance working with the graphical method, relevant peaks (abundances) were emphasized by converting to their squares. IDRAs and their minimum/maximum depth limits were designed to cover the whole possible depth domain. As a consequence, with changing habitat depth/ sea-level peaks of dominant RDRAs are able to shift almost continuously from deep to shallow domains in a vertical section.

Building depositional model for the Turea Group deposits

Facies zones have been defined looking for real oceanographic limitative conditions. They are presented in more detail in the following sections.

Nevertheless actual oceanographic limitative conditions (i.e. tide heights, storm weather wave base) are changing from basin to basin, and so it was in the Paleogene too, available sedimentological and micropaleontological data from the Paleogene Transylvanian Basin made possible to reconstruct the following plausible scenario (fig. 3): fair weather wave base placed at 14m depth, ramp profile breaking point round 30m, and storm weather wave base at 50m depth.

For tracking facies zones over a depositional profile, we followed and adapted the terminology of Burchette and Wright (1992), Pomar (2001) for ramp sectors. The ramp depositional profile can be reconstructed by using bedding geometries, relative position of facies belts, sedimentary structures and the dependence of some skeletal components upon light penetration (Pomar, 2001).

Considering a shallowing depth gradient, depositional environments will align one after other as follows 1. Offshore basin, 2. Outer ramp, 3. Outer middle ramp shoals and reef mounds, 4. Middle ramp coralline sands, 5. Inner middle ramp bioherms and ‘patch-reefs’, 6. Inner ramp shoals, 7. Restricted inner ramp or shallow lagoon/ Flooded strandplain, 8. Nearshore. In our model, the ramp-slope steepens at the transition between the middle and outer ramp.

These eight depositional environments and their particular IDRAs not necessarily occur together at the same time on the same depositional profile. Some of them are replaced during basin morphology evolution, while some may appear simultaneously, but in different paleogeographical positions of the basin.

In this respect we found that the initial strandplain carbonate ramp (Pleşca Valley 1 section) evolves to a beach barrier carbonate ramp (Cheile Baciului section), after that locally to a reef-mound beach barrier ramp (Pleşca Valley 2 section) and finally to a siliciclastic delta profile (Mera section).

IDEALIZED DEPTH RELATED PALEO-ECOLOGICAL ASSEMBLAGES (IDRA)

The distribution of paleoecological assemblages across a carbonate platform has been outlined by Arnaud-Vanneau (1980). The study proposed a faunal and floral distribution over urgonian–type platform and described characteristic of paleoecological assemblages for different environments. Transposing these results, just as others from the Cretaceous and Miocene (see Kovács and Arnaud-Vanneau, 2004a for references) seven paleoecological assemblages were identified that are showing maximum abundance in different successive bathymetrical intervals.

Depth zone values assigned to IDRA assemblages are considered to delimit in space habitats of optimum life-conditions, and thereby might be almost always translated into statistically meaningful abundance values. While executing depth zonation of assemblages, we assumed that assigned depth values may differ from the most optimistic possible, and we tried to be very accurate at least in the ordination procedure, to obtain a real depth related arithmetic progression of depth values.

Given the limited extension of this volume and the large number of working morphogroups, only the most significant morphogroups will receive a brief description herein.

Metazoa ‘morphogroups’ were not classified as rigorously as foraminifera morphogroups. They are in fact classes of organisms with distinct habitus or growth form.

IDRA Assemblage I – Basin

Depth zone assigned: 80m - 40m.

Group of planktonic foraminifera (Plate I, fig.1-3)

Test is trochospiral to planispiral, wall-structure calcitic and perforated. Chambers of the last spire are greatly increased in size in comparison to the initial spire.

IDRA Assemblage I behaves in most cases as an accessory assemblage to other deeper ones. In fact, it is the most important denouncer of deepening events. There are no facies showing absolute dominancy of IDRA Assemblage I. Their absolute abundance never passes 10 specimens within the counting frame (10mm X 15mm).

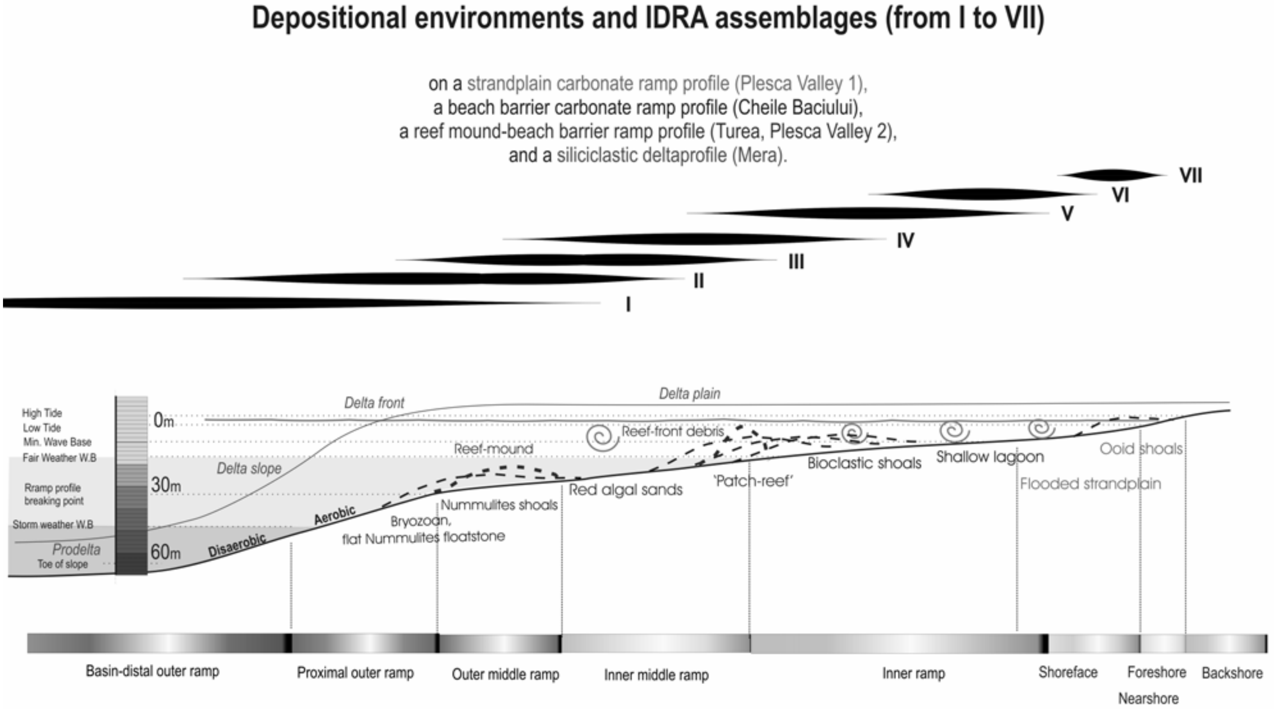

Fig. 3 Relationship of IDRA Assemblages, facies zones and their bounding oceanographic limits to depositional profiles.

IDRA Assemblage II – Transition from proximal outer ramp to outer middle ramp

Depth zone assigned: 60-30m.

IDRA Assemblage II is dominated by the presence of large foraminifera species. It has the most prominent development in the upper third of Pleşca Valley 2 section and in its correlating part from the Turea section.

Generally speaking, with increasing water-depth (30 - 80m) *Nummulites* become prevalent in world-wide Paleogene basins. *Asterigerina* and great-sized *Rotalia* appear. They are associated with *Nonion commune*, *Lobatula carinata*, *Neoeponides schreibersii*, etc. Between 80 and 130m, great and flat forminifers, as *Assilina*, *Operculina*, Orthophragminae are frequent and the number of small benthic foram species increases (Murray, 1991; Hottinger et al., 1993 in Sztrákos 2003). Paleodepth between 80 and 100 till 130 m should be indicated by the abundance of bryozoans, discocyclinids and *Operculina* sp. (Sztrákos and Castelltort, 2001).

In the case of the Turea Group deposits we faced the complete absence of discocylinids and *Asterigerina* sp. in thin-sections. If they are present, they should be in a very low number.

Sztrákos (2003) states that the association of small benthic foraminifera becomes much diversified at paleodepth of 100-130m. In our material, in comparison to the above situation, the number of small-sized species is quite low in this assemblage.

IDRA Subassemblage IIa – muddy substrate, oligophotic

Morphogroup of nodosariids (Plate I, fig. 4) Test: uniserial. Aperture: terminal. Also includes foraminifera with a great Length/ Diameter of chambers ratio.

Morphogroup of flat nummulitids (Plate IV, fig. 2) Test: lenticular- discoidal- planispiral with an extremely high length to height ratio. Without septula. Channel system with fine embranchments. Aperture: a pore in the central-basal part of the septum.

The great number of axial sections gave us a chance to group together different generations of same *Nummulites* species. *Nummulites* morphogroups were always discriminated on specimens of microspheric generations.

To this first subassemblage usually belong flatter taxa, adapted to low light and/or low water energy condition, while to the second one are enrolled the more convex shaped taxa, adapted to more light, and more energy conditions.

In the proximal sector of the outer ramp and on the outer middle ramp, bryozoans (shade-area biota) were the primary sediment producers together with echinoids, mollusks, subordinately, benthic (medium-sized biserial foraminifera, small to medium-sized *Pararotalia* species), as well as large and flat nummulitids (with H/L ratios up to 1:8 in the Pv 56, 62).

IDRA Subassemblage IIb – Outer middle ramp shoals, mezophotic

Morphogroup of amphistiginid foraminifera (Plate I, fig. 20) Test: lenticular, width/height ratio= 2:1. Involute. Walls have multi-lamellar structure.

Baculogypsinoides (Sylvestriella) morphogroup (Plate I, fig. 21) Test: shows a central globular part with isometric chambers, and radial prolongations, organized in a tetrahedral disposition, and cut through by a channel-like structure.

Sphaerogypsina morphogroup (Plate I, fig. 16) Test: globular. Its numerous chambers are small and flat, with constant chamber-height through the whole life-cycle.

This subassemblage is dominated by various lens-shaped nummulitids (H/L ratio of 2:5), amphisteginid foraminifera (H/L ratio of 4:7), alveolinids, medium to large size rotaliids, elphidiids and few thick walled miliolids. *Sphaerogypsina globula* is restricted to the Pv 49-Pv 57 interval, when especially large sized organisms proliferate, suggesting an increased availability of nutrients.

The bloom of suspension-feeding organisms, mostly bryozoans but also echinoids and pelecypods recorded in the upper third of the Cluj Limestone sequence, should be promoted by a change in trophic conditions (nutrient excess) that was responsible also of the coral demise underlying the *N. fabianii* level.

IDRA Assemblage IIc – Outer middle ramp, probably eutrophic

Clavulina morphogroup (Plate II, fig. 11) Juvenil stage triserial and triangular in transverse section, connected to a long uniserial part. Finely agglutinated with much calcitic cement. Aperture: terminal, round.

Elphidiidae (Plate II, fig. 9) Planspiral - bilaterally symmetric. Complex channel-system broken up and dissolved in septa, and felt into pores. Main aperture: one sole or multiple interiomarginal alignment of pores.

Glomospira morphogroup (Plate II, fig. 18) Proloculus followed by a second tube-shaped, somewhat irregularly coiling streptospiral chamber. Finely agglutinated. Aperture at the open end of the tube.

Operculina morphogroup (Plate I, fig. 13) Test: planspiral, laterally flattened, evolute. Chambers are narrow, septa strongly arcuated to the peripheral margins. They make just a few windings with rapidly growing height. Well defined channel-system (marginal, interseptal, lateral and sutural stolons).

Valvulina morphogroup (Plate I, fig. 11) Test triserial, triangular in transverse section. Aperture: basal, with deeply bulging tooth. Calcitic cement.

This subassemblage is characteristic almost exclusively for the Cheile Baciului section. K-strategist large foraminifera and corals are missing.

Facies containing high abundances of *Operculina* sp. (e.g. BT 28-32) were claimed as being deposited in the deepest part of the basin (Kovács and Arnaud-Vanneau, 2004b).

IDRA Assemblage III Middle ramp

Depth zone assigned: 30-15 m.

Middle ramp subassemblages were found to incorporate the largest abundances of red algal and echinoderm fragments. The identification of red algal taxa requires the consideration of reproductive structures in many cases. By the time these features are almost impossible to figure out on every broken fragment, statistical analysis of red algal data needs a somewhat different approach then working with foraminifera. Only clearly recognizable taxa were counted separately, the rest of fragments were joined into the "other red algae" category.

IDRA Subassemblage IIIa – Middle ramp reef-mounds

Reusella-Clavulinoides morphogroup (Plate I, fig. 12) Test: triserial, trihedral in transection, dull-edged, sometimes killed or spiky.

Calcareous sponge*, Planorbulina* sp*.,* platy frameworks of coral colonies, Discorbidae and large ornamented rotaliid foraminifera were included into this subassemblage, all recorded in the Turea section, found in mud-rich microfacies.

Taking into account the Pleşca Valley 2 coral growth forms and taxonomic composition, just as their positive correlation with increasing plankton content, we inferred that some of coral facies (e.g. Pv 41) could be assigned to relatively deeper-water coral colonies.

IDRA Subassemblage IIIb – Middle ramp, sandy substrate

Cibicides morphogroup (Plate II, fig. 8) Plan-convex, trochospiral on the spiral-side and greatly perforate. High-convex, fine and clearly perforate on the umbilical-side. Aperture: interiomarginal, opened towards the spiral suture.

Gaudryina morphogroup (Plate I, fig. 10) The test is elongate, stout, in its early stage has a triserial and triangular cross-section that becomes biserial and rounded later. The size of the chambers increases very slowly therefore the test has nearly parallel sides. The wall finely is agglutinated, solid, with calcitic cement. The aperture is an arch in the inner margin of the final chamber.

Group of medium-sized Pararotalia (Plate II, fig. 7) Test: flattened trochospiral. Usually keeled. Chamber walls are aragonitic and ornamented on the outer side. They are varied in width from species to species.

As it has already been stated by Popescu et al. (1978), within the Transylvanian Eocene, echinoderms reach their maximum abundance in the Cluj Limestone. In our successions, this level is located around the level of Pv 61 in the Pleşca Valley 2 outcrop, and between Bt36-Bt38 at Cheile Baciului.

Echinoderms were included into this assemblage according the findings of the cluster analysis, notwithstanding the great variability in echinoderm ecomorphotypes (Popescu, 1978, 16 species cited, e.g. large-sized specimens of *Echinolampas* sp. or small forms of *Laganum transsilvanicum* Pávay) that would argue besides portraying them as a distinct unit within the Assemblage Percentage Fluctuation Charts (Kovács and Arnaud-Vanneau, 2004a),

IDRA Assemblage IV – Inner middle ramp

Depth zone assigned: 20-10m.

IDRA Subassemblage IVa – Inner middle ramp bioherms

Bioherms are constructed of hermatypic corals and red algal thalii (*Sporolithon* sp*., Lithoporella melobesioides, Polystrata alba*), approximately in the same amount. Rhodoids are commonly accompanying this assemblage. Large solitaire *Antiguastrea lucasiana* is also found.

IDRA Subassemblage IVb – sandy substrate

Group of large agglutinated foraminifera and Haddonia heisinghi (Plate II, fig. 3) Test: great sized; chamber walls agglutinating relatively coarse calcareous particles, conical in shape or trochospiral, as in the case of incrusting *Haddonia.*

Verneuilina morphogroup (Plate I, fig. 14) Test: triserial, triangular in transverse section. Finely agglutinated, with much cement.

This subassemblage is the topmost element of aggrading patch-reef parasequences and shows a good correlation with the presence of giant *Campanile* gastropods, incorporates thick walled miliolids, ecological successions of *Astreopora* sp., cf. *Porites* and attached foraminifera (*Haddonia heisinghi,* rarely annelids (*Spirobranchus* sp.).

IDRA Subassemblage IVc

Subassemblage designed to group inner middle ramp foraminifera of the Cheile Baciului section, like *Acervulina* sp., cf. *Patellina* sp. (a wide trochospiral, epibenthic foram), accompanied by large agglutinated foraminifera or large miliolids with a 'pseudo-agglutinated' wall-structure (i.e. with partially dissolved chamber-walls, Plate II, fig. 1).

IDRA Assemblage V – Outer inner ramp

Depth zone assigned: 15-6m

IDRA Subassemblage Va – Outer inner ramp shoals, euphotic

Borelis (Neoalveolina) morphogroup (Plate I, fig.17) Their tests are globular with non-alternating septula and one single alignment of apertures.

Arenobulimina morphogroup (Plate II, fig. 13) Trochospiral roll up, four or more chambers per spire. Aperture: arcuate.

Orbitolites morphogroup (Plate II, fig. 17) Test discoidal. Chambers are connected only to the chamber of previous chains. On the peripheries, apertures are rich in teeth.

These morphotypes (see fig. 2) prefer the sandy substrates of shoaling environments. Most of species are suspension feeders.

Considering its contribution to the Pleşca Valley and Turea biofacies, it is an insignificant assemblage. In contrast, it is the most important bioclast contributor of the Cheile Baciului succession. However this assemblage might be reworked at least locally if not regionally (i.e. it is found always in high energy environments, with too much ferruginous pigment, while in situ *Orbitolites complanatus* is found in lagoonal wackestone facies in the Pleşca Valley 2 section).

IDRA Subassemblage Vb – Proximal inner ramp or shallow lagoon.

Group of large miliolids *Quinqueloculina* (Plate II, fig. 14) Chambers are found in five planes. Three chambers can be viewed from on side, and the other two from the other side. Aperture, terminal.

Triloculina The test is ovate in outline and equilaterally triangular in section. The chambers are one to half whorl long. The early growth stages are not preserved the available part is triloculine. Only three chambers are visible from the exterior. The wall is calcareous, porcelaneous and imperforate. The aperture is rounded and having a short bifid tooth at the end of the final chamber.

Group of lituolids and Spirolina (Plate II, fig. 12) Juvenil-stage planspiral, later enrolled. Aperture: multiple as a great number of pores.

Spiroloculina morphogroup (Plate II, fig. 15) Flat test. Chambers are widening, two by two, on every next-following spire. Aperture: terminal, with a single or bifid tooth.

IDRA assemblage V (see fig.2) is dominated by the group of miliolids adapted to significant light exposures, while clinging on sea-grass leaves. An important amount of the other associated foraminifera is mud-dweller.

IDRA Assemblage VI – Proximal inner ramp/ Flooded strandplain

Depth zone assigned: 10-3 m.

Morphogroup of bolivinids (Plate I, fig. 5) Tight and depressed chambers, biserial. Aperture: basal fissure, eventually with tooth.

Morphogroup of small calcitic trochospiral foraminifera (Plate I, fig. 6) Test: trochospiral, Aperture: basal, umbilicus peripheral.

This assemblage is typical almost exclusively for the PV1 section. It may appear as an accessory assemblage in the Turea section. According to its fine laminated sedimentary facies, this assemblage occupied a biotope that was deep enough to get rid of wave actions. The co-occurrence of planktonic foraminifera suggests a regular connectivity with the open shelf, either right over a sub-aquatic barrier, either behind a subaerial barrier by side-channel current activities.

IDRA Assemblage VII – Near shore

Depth zone assigned: 4-1m

Group of Pseudotriloculina and small miliolids Fine-walled infaunal miliolids.

In this assemblage we find biota adapted to the extreme ecological conditions found in intertidal environments: such as small infaunal miliolids, arthropods, microbial constructions, endolithic algae, barnacles, gastropods.

SEDIMENTOLOGY

Our recent results in microfacies analysis enforce previous conclusions made on the sedimentary dynamics of the Paleogene Transylvanian Basin, especially those regarding the tectonically inactive nature of the Gilău basin during Turea Group deposit sedimentation (Proust and Hosu, 1996). At the same time, we stress out the presence of different ecological conditions and different biofacies in the Plesca Valley/Turea section (with reefal elements) and the Cheile Baciului section (typical ramp sequence). Significant patch-reef bodies are developed only in the Preluca area of the Paleogene Transylvanian Basin.

As a consequence, we claim inherited basin topography as being one of the most important factors ruling depositional profile development.

All facies types in the Gilău area are assumed to be deposited on a ramp profile presenting a breaking point. In our opinion, ramp profile breaking point lineaments might be originated in the blind-faulting (i.e. small tectonic reactivations) of previous early Paleogene sedimentary deposits.

Another important controlling factor is supposed to be climate which, by turning into a cooler period, enhanced shutting down the carbonate factory of the Cluj Limestone. Changing climate may also modify continental runoff. By this reason, it's appropriate to link the appearance of nutrient rich facies to changing climate, what denotes by the same time, the end of the *Nummulites fabianii* epibole, and sets the environmental parameters for the proliferation of giant ostreids (*Pycnodonte gigantea* epibole).

In the forthcoming section facies zones continue to be presented as they have been identified by means of microfacies and field sedimentological analysis.

Offshore basin - distal outer ramp

Facies zone upper limit: storm weather wave base. Type facies: bluish shales above sample T73

Offshore basin shales develop as a median lithostratigraphic unit (Brebi Marls) between the Cluj Limestone, a calcareous ramp sequence which may present a rimmed shelf sector locally, at below, and the Mera Fm, a siliciclastic prograding delta sequence, at above. Related to the Mera Fm. this shale sequence might be regarded as the suspension fallout of a prodelta environment, that could be further distributed by axial bottom currents. These are usually present in all the relatively narrow, elongated basins.

According to the Walther's Law, a delta shows comparatively well developed delta plain, delta slope and prodelta architecture simultaneously. By this reasoning, we should find anywhere in the basin contemporaneous sectors of the Brebi Marls and Mera Fm., in a prodelta – delta relationship. The existence or impossibility of this relationship cannot be proved by means of biostratigraphic tools, given the coarse resolution of this timing tool.

We may find almost no sedimentary structures within this facies. However some bivalves may disturb the monotony of the homogenous facies. In particularity, *Pycnodonte gigantea* shells appear in several levels as scattered points, in sequential approximate time-horizons. One of the striking features is a condensed horizon that really pleads for being a major Candidate Maximum Flooding Surface, or at least a time-surface that records a major nutritive event. This condensed horizon is composed of the same *Pycnodonte gigantea* shells, but annelids and solitary corals appear in addition. They show ferruginous pigments.

Proximal outer ramp
Autochthonous facies

Facies zone lower limit: storm weather wave base. Facies zone upper limit: profile breaking point of a distally gently steepened ramp. Type microfacies (thin-section nr.): Pv 59 (Pl.III/3), T24, T72 (Pl. III/2)

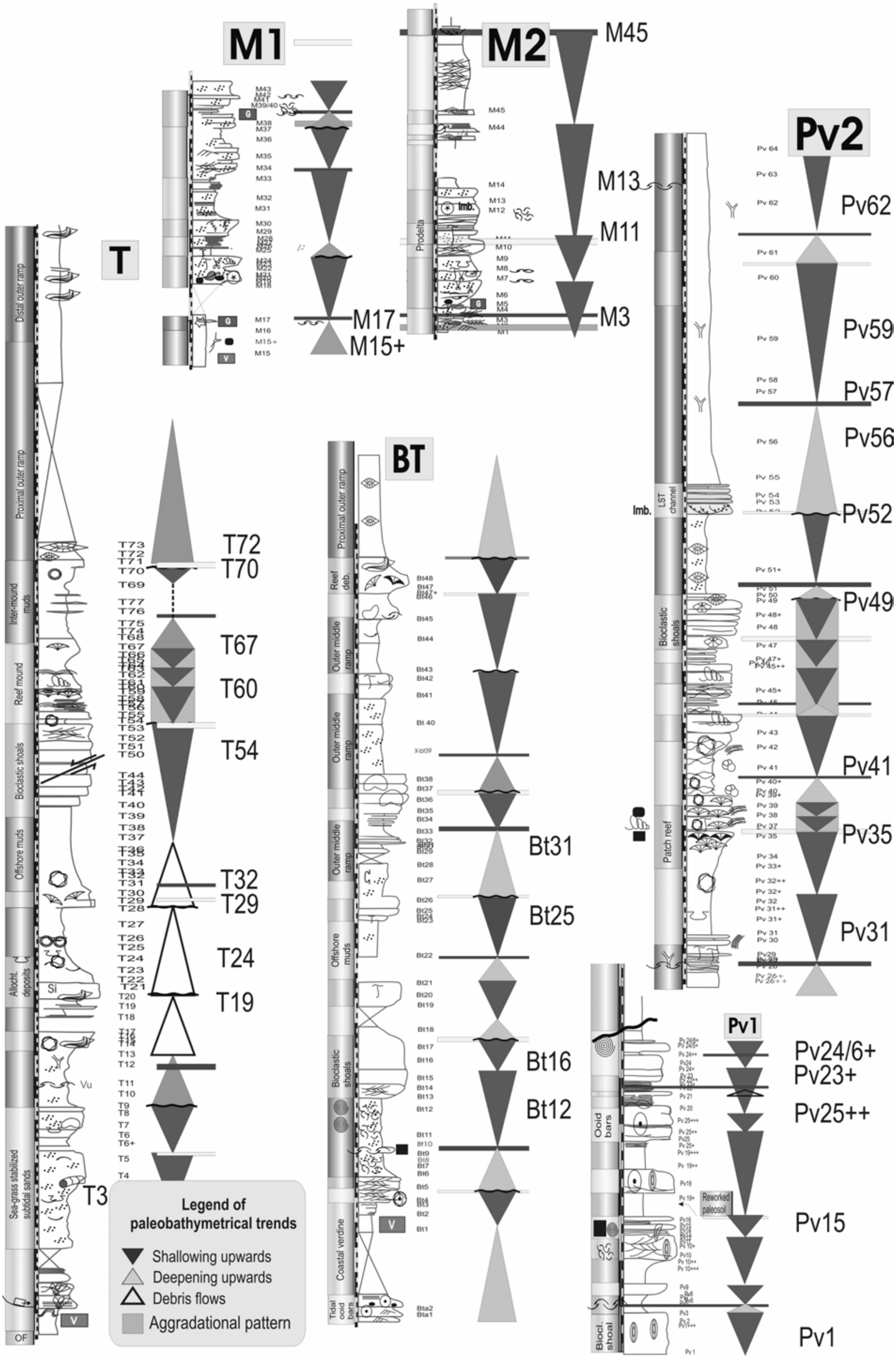

Fig. 4 Localization of samples cited. Investigated outcrops: Valea Pleşca (Pv1 and Pv2), Cheile Baciului (Bt), Turea (T) and Mera (M1and M2). Horizontal bars indicate various order Maximum Flooding Surfaces (midtone), Parasequence Boundaries (highlighted) and Sequence Boundaries (darkest, M1 and M2 section).

Erected bryozoan floatstone-packstone, PV59. This microfacies represents an in situ erected bryozoan community of a low energy environment. Well preserved and unrolled bioclasts are bad sorted, distributed uniformly in the whole section without any transportation fabrics. We do not find any hard bottom constructing or favouring biota.

Rhodolith floatstone, T24. Rhodolith floatstones may be originated in fairly diversified environments satisfying some basic conditions: the presence of an agent that periodically over turns rhodoliths, the presence of red algal taxa prone to incrustations.

Large (4-8cm) and flat rhodolithes are supposed to be subject to sparse turning on events of an intermittent flow. Rhodolithes of this sample have two major components: an inner zone constructed by the *Sporolithon* genus and an outer, relatively thinner zone of *Polystrata alba.* They were found dispersed in nodular mudstones.

Flat Nummulites floatstone-packstone, T72. - In contrast with the *Nummulites* rudstone facies of PV52, this facies contains a much larger proportion of muddy matrix, which suggests its setting to be situated below storm weather wave base. On field description of the facies also argues for the same setting, where could be recorded in a marly appearance. At this level, appear the largest planktonic foraminifera of the Turea Group sequence. The great abundance of totally unsorted *Nummulites* of both, macrospheric and microspheric generations, is thought to be generated by an early transgressive condensation of a higher order parasequence (see fig.4), in lack of sediment supply.

Allochtonous facies

Type microfacies (thin-section nr.): PV 52 (Pl. III/4), T29. Type facies: sharp based decimetric banks of compact limestones at Pleşca Valley and Turea.

Quartzitic Nummulites rudstone, *PV52*. The allochtonous nature of this lithofacies is proven by its sharp erosional base, the well sorted type of clasts, the lack of muddy matrix and the presence of quartzitic continental sediment input. However, transportation should occur on shorter distances given the unbroken state of bioclasts.

Biota of this lithofacies argue for the outer middle ramp setting, although the *Nummulites* rudstone lithofacies could be deposited by shedding outer middle ramp biota onto proximal outer ramp depozones, as well.

Coral-red-algal rudstone, T29. This facies has been deposited by debris flows, transported by tidal channels ending in a fore-reef environment. Clasts are truly unsorted, larger fragments are oriented in flow direction. Broken clasts are also present.

Outer middle ramp shoals

Facies zone lower limit: ramp profile breaking point. Facies zone upper limit: fair weather wave base. Type microfacies (thin-section nr.): PV 49, T3.

It is the final element of coarsening up, thickening up ramp breaking point parasequences.

Nummulites packstone-floatstone-rudstone, *PV 49*. It is remarked by the high concentration of large-sized bioclasts presenting robust shell morphology facing hard mechanical abrasion. Bioclast species are diversified. Large gastropods (e.g. *Campanile parisiense clujensis* Mészáros) may be present. Aragonitic shells are partly leached.

Middle ramp

Facies zone lower limit: ramp profile breaking point. Facies zone upper limit: fair weather wave base. Type microfacies (thin-section nr.): PV31-34 , Bt31, Bt12.

"Maerl", PV31-34. True "maerl" facies (sensu Bosence, 1983) are hardly detectable. However, red-algal packstones with free living branching red algae (geniculate algae) and algal debris are to be found in the Pleşca Valley 2 outcrop and in packstone-grainstones at Cheile Baciului, in the latter mostly associated with a foram-rich association.

Foraminifera packstones-wackestones, Bt31.

This deepest facies member of the Cheile Baciului parasequences represents an outer middle ramp microfacies. Besides *Operculina*, the most abundant bioclasts are thin walled *Pararotalia* species and echinoderms. The general grain size is small, almost siltic, and these facies components constitute the matrix to larger 'floating' bioclasts. On field, one may find them in friable lithology presenting more or less intensive horizontal bioturbations.

Bivalve shell accumulations, Bt12. Analyzing *Vulsella* accumulations is a very challenging task. In thin section, we may find together a great amount of broken fragments besides entire shells. Imbrication is a common feature. Thus a complex origin is ought to be taken into account. Nevertheless, sediment supply was reduced at the time of sedimentation. Foraminifera bioclasts are dominated by the Elphidiidae, several conical morphotypes also occur. Hardground development was not observed.

Reef-mound, 'patch-reef'

Facies zone lower limit: ramp profile breaking point. Facies zone upper limit: fair weather wave base. Type microfacies (thin-section nr.): PV35 (Pl. IV/2), PV 36 (Pl. IV/3), PV 42

Bafflestone, PV35. This microfacies is found in somewhat nodular limestones installed above rhodolith carpets as the initiative facies of 'coral patch' reefs. At this stage, solitary corals have a significant contribution to the bioherm building process, where bafflestone microfacies constructs rather reef-mounds then true patch reefs. Incrusting foraminifera and red algae are also an important facies element. At the level of PV35 it was identified a 10 to 20 cm thick level with fabric selective dissolution of coral tests, too.

Coral framestone, PV 36. It has hermatypic corals as a major framebuilder agent, and is developed mainly in the Pleşca Valley succession. In this place, they were found in various colonial morphology sequences according to deepening or shallowing tendencies. Domal shapes are the most widespread, but platy morphologies are also detectable. At Turea, framestones are to be found only as large clasts within allochthonous rudstones.

Reef-front debris rudstone, PV 42. Within this microfacies the most frequent allochems are broken pieces of corals. A great amount of these fragments are leached and give rise to secondary moldic porosities.

Sandy inner ramp

Facies zone lower limit: fair weather wave base. Facies zone upper limit: minimum wave base. Type microfacies (thin-section nr.): Bt16 (Pl. IV/4).

Bioclastic grainstone, Bt16. Within the Cheile Baciului succession, sedimentary facies are organised into shoaling up parasequences, while packstones are grading into grainstones.

This microfacies, being the upper element of these parasequences, contains bad-sorted bioclasts: large foraminiferas like *Orbitolites*, *Borelis*, but most abundantly miliolids and lituolids. Echinoderm fragments are also in a significant amount. They often present sintaxial overgrowth of cements. Branching red algae contribute to the smaller sediment fraction. Bioturbation can be observed occasionally. Dissolution is characteristic especially to miliolid foraminfera tests.

Restricted inner ramp or shallow lagoon

Facies zone lower limit: minimum wave base. Facies zone upper limit: low tide. Type microfacies (thin-section nr.): Bt3, Pv1.

Bioclastic packstone, Pv1. It resembles somewhat to the Cheile Baciului packstone-grainstones, but it is more mud-supported and its fauna is composed almost exclusively from miliolid foraminifera accompanied by scarce lituolids. These carbonate banks may hold small rip-up clast from the underlying offshore muds, at their basal part.

Bt3. The most restricted facies elements are represented by costal 'verdine' muds, grading into bioclastic packstones containing oolites and aggregated facies components, too. In the thin-section of verdine muds (BT3), the only signs of life are shown by some ferruginous filaments (precipitations pointing to the presence of organic material in a reducing environment) that might be of a bacterial origin.

Siliciclastic-dolomitic? wackestone-packstones, T3. Slightly bioturbated facies. It has a significant proportion of siliciclastic allochems. This microfacies shows scarce fragments of bioclasts, if any, those are of red algae and foraminifera from the *Pararotalia* morphogroup. Taking into account its rich content of sirenian skeleton fragments, it can be deduced that it functioned as habitat for animals grazing sea-grass rhizome and growing great bodies. There are no comparable microfacies within other investigated sections.

Flooded strandplain

Facies zone lower limit: undefined. Facies zone upper limit: fair weather wave base. Type microfacies (thin-section nr.): PV22 (Pl. IV/6). It is present as thin, decimetric intercalations in the Pleşca Valley 1 outcrop.

Mudstone-wackestones with planktonic forams, Pv22. It is a laminated mudstone, containing abundant foraminifera specimens. Besides small benthic foraminifera, an important amount of small planktonic foraminifera occurs, that might represent the first opportunistic, rapidly flourishing species, accompanying an accelerated sea-level rise episode, over an open, strandplain type carbonate ramp, at times of early transgression. However, laminated mudstones coupled into peritidal parasequences with ooid precipitating facies, might denote the restrictive and stressful nature of water-masses.

The exclusive presence of small forms can be explained in terms of water depth too, i.e. when water depth is not deep enough the reproduction cycle is interrupted, and only juvenile forms are recorded (Arnaud-Vanneau, 2006 pers. com).

Nearshore

Facies zone lower limit: low tide. Facies zone upper limit: high tide. Type microfacies (thin-section nr.): Pv15, Pv24/5+ (Pl. IV/8).

Ooid grainstone, Pv 15. This is a greatly homogenous, well-sorted microfacies, containing almost absolutely ooid grains and bivalve shell fragments and in a smaller amount gastropods. Shell fragments present a micritic envelope. The nucleus of ooids is often dissolved, aragonite shell fragments behave in the same manner. In other samples, a few ooids might be broken. Ooid bearing sediments are to be found in the Pleşca Valley 1 outcrop and at the base of the Cheile Baciului section.

Grainstone- wackestone couples, spill-over lobe tempestite, Pv24/5+. These carbonate tempestite beds appear at the top of ooidal parasequences, sometimes interbedded with 10-15 centimetres of paleosoil. They contain gastropods in a significant amount. In thin-section view wackestone-mudstones are overlying grainstones presenting a sharp base, meaning that sediments have been deposited by vanishing storm-induced erosive flows.

Environments of the siliciclastic delta depositional profile

Thin-sections prepared from siliciclastic facies have been convincing from a paleoecological point of view in rare cases. Thus, sedimentary structures and wash-out materials have been considered for supplementary information.

Delta slope, M11 (Pl. IV/10). These facies were identified exclusively based on sedimentary structures (e.g. relatively cemented chute channels in fine arkozic sands).

Delta front floatstone, M12 (Pl. IV/9). This is one of the relevant microfacies of the delta depositional profile, due to its relatively abundant bioclast content. These are: echinoids, *Pararotalia* species and miliolid foraminifera, gastropods and imbricated bivalve fragments. The matrix is a fine arkozic silt cemented into low magnesium calcite.

Delta plain, M45. Identified as fluvial channel deposits (meter scale true cross-bedded siliciclastic sands) and overbank fines. Thin-section shows only gastropod shells.

CONCLUSIONS

Paleobathymetry within the Turea Group sequence is approached by paleoecological and sedimentological argumentations.

Statistical paleoecological data, acquired by a thin-section mapping method, have been used to define seven 'Idealized Depth Reference Assemblages' (IDRA) and ten subassemblages in order to serve as a reference for 'Real Depth Related Assemblages'. RDRA might be acquired through counting within a fix-sized counting-frame, from samples originating in the correlative deposits of the Turea Group sequence. IDRAs are valid for the whole time-span of the analyzed sequence.

By this procedure, Eocene paleoecological assemblages have been tuned for paleobathymetry estimations. By plotting RDRA percentages against sedimentological logs, sea-level changes can be revealed.

Considering a shallowing depth gradient, the following depositional environments were identified in the study area: 1. Offshore basin, 2. Outer ramp, 3. Outer middle ramp shoals and reef mounds, 4. Middle ramp coralline sands, 5. Inner middle ramp bioherms and 'patch-reefs', 6. Inner ramp shoals, 7. Restricted inner ramp or shallow lagoon/ Flooded strandplain, 8. Nearshore. These eight depositional environments and their particular IDRAs not necessarily occur together at the same time on the same depositional profile. Some of them are replaced during basin morphology evolution, while some may appear simultaneously, but in different paleogeographical positions of the basin.

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PLATE CAPTIONS

PLATE 1 – IDRA Morphogroups I

1, 2. Morphogroup of planktonic foraminifera (T55, T71)
3, 6. Morphogroup of small calcitic trochospiral forams (T59, T55)
4. Morphogroup of small erected foraminifera (T41)
5. Morphogroup of bolivinids (PV24)
7. Morphogroup of small agglutinated forams (M9)
8. Bulimina morphogroup (PV40+)
9, 11. Valvulina morphogroup (BT12, PV46)
10. *Gaudryina - Marssonella* morphogroup (T55)
12. *Reussella - Clavulinoides* morphogroup (T65)
13. *Operculina* morphogroup (BT32)
14. *Verneuilina* morphogroup (BT16)
15. Morphogroup of large aragonitic rotaliids (T67)
16. *Sphaerogypsina* morphogroup (PV57)
17. Morphogroup of alveolinids (BT13)
18. *Chapmanina* morphogroup (T29)
19. Morphogroup of lenticular *Nummulites* (T71)
20. Morphogroup of amphistiginid foraminifera (T71)
21. *Baculogypsinoides* (*Sylvestriella*) morphogroup

PLATE 2 – IDRA Morphogroups II

1. Morphogroup of 'pseudo-agglutinated' miliolids, showing partial dissolution of the chamber-walls (BT45)
2. *Polystrata alba* (T53)
3. Morphogroup of large agglutinated forams (PV35)
4. Morphogroup of large miliolids (PV49)
5. Protuberance of a melobesioid red algae with distinct growth rhytms (T55)
6. *Gyroidina* morphogroup (PV64)
7. Morphogroup of medium *Pararotalia* species (PV29)
8. *Cibicides* morphogroup (PV45++)
9. Morphogroup of elphidiids (PV2)
10, 14 Morphogroup of medium-sized miliolids (M10)
11. *Clavulina* morphogroup (PV1)
12. *Spirolina* morphogroup (SZP1)
13. *Arenobulimina* morphogroup (PV26++)
15. *Spiroloculina* morphogroup (PV1+++)
16. Green algae (PV1+++)
17. *Orbitolites* morphogroup (BT16)
18. *Glomospira* morphogroup (PV27)
19. *Spirobranchus* morphogroup (T38)
20. Arthropod (M24)
21. Balanids (M19)

PLATE 3 – Microfacies I

1. Current induced concentration of bryozoans (M15+)
2. Floatstone of *Nummulites* very diversified in size and shape (T72)
3. In situ erected bryozoan community (PV59)
4. Quartzitic rudstone with *Nummulites fabianii* (Pv52)
5. Bioclastic packstone with thin walled, small aragonitic rotaliids (BT25)
6. Red algal bindstones (T54)
7. Vermetid? bioconstuctions (T70)
8. Boring activity of *Pseudotriloculina* sp. within reef-flat muds (T70)
9. Upper delta front deposits with *Scutella* (M12)
10. Rhodoliths composed of *Sporolithon* and *Polystrata alba* (T32)

PLATE 4 – Microfacies II

1. Transgressive lag, with silicified rhodoliths and coral fragments (T19)
2. Solitary *Antiguastrea lucasiana* and hermatypic *Astreopora* sp. (PV35)
3. Framestone of hermatypic corals (PV36)
4. Bioclastic shoals with cf.*Borelis* and *Orbitolites* (BT16)
5. Wackestone with miliolids and *Orbitolites complanatus* (Pv27)
6. Mudstone-wackestone with small planktonic foraminifera (PV23+), possibly dolomitic
7. Peloidal packstone with bivalves and scarce ooids (PV25++)
8. Tempestites (PV24/5+)
9. Siliciclastic tidal channel ripples (M3)
10. Sandy bioclastic grainstone with rotaliids (M11)

PLATE 1

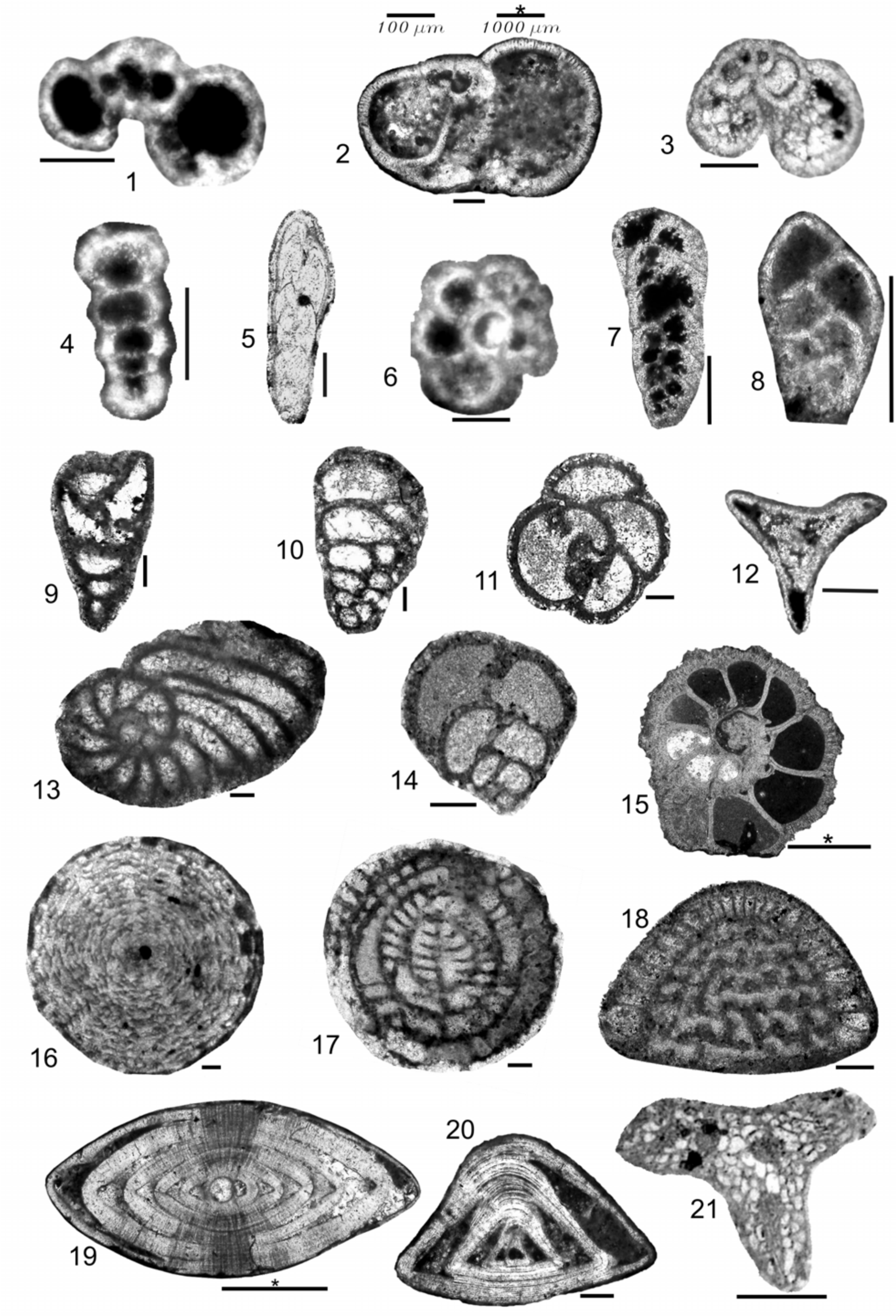
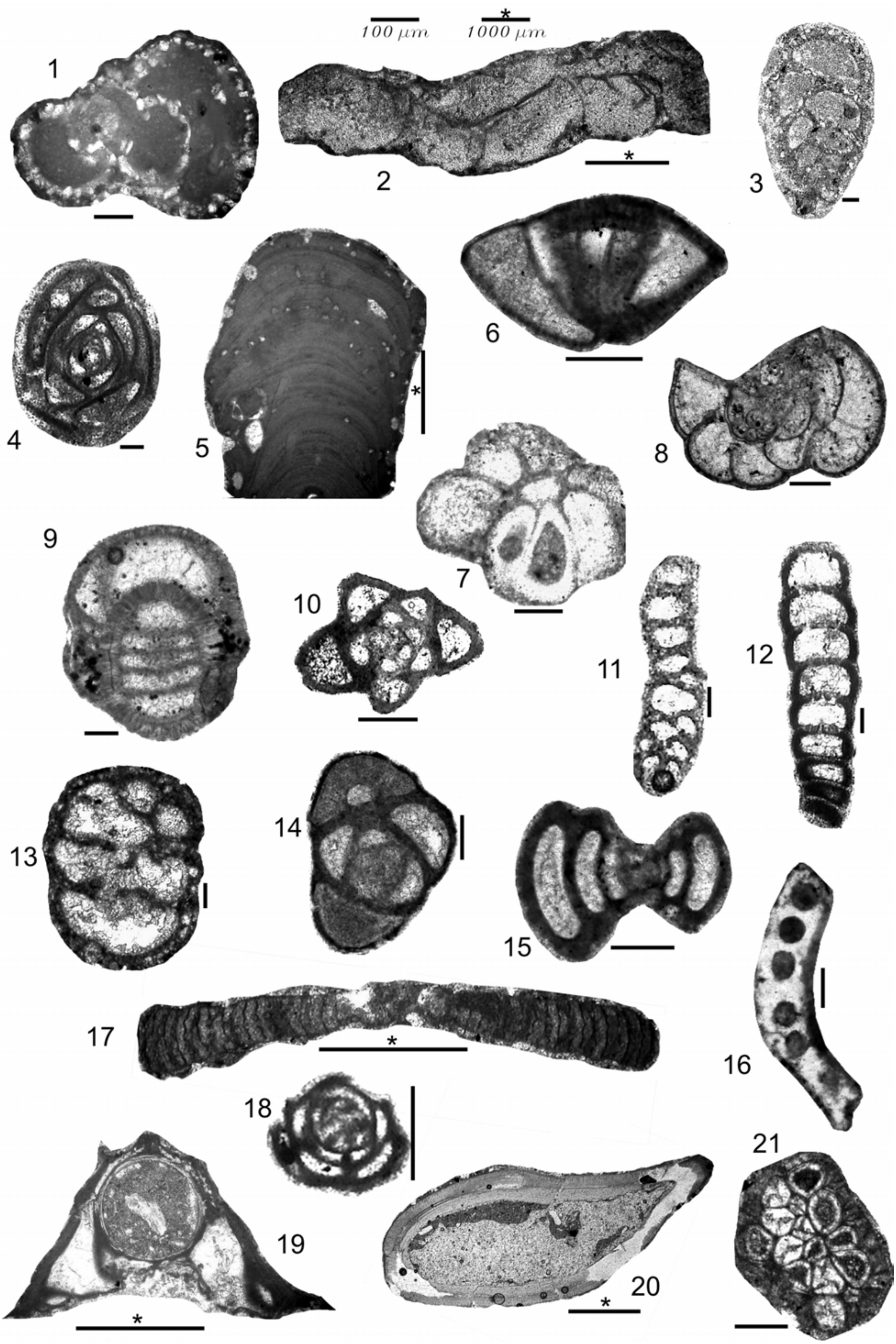


PLATE 2



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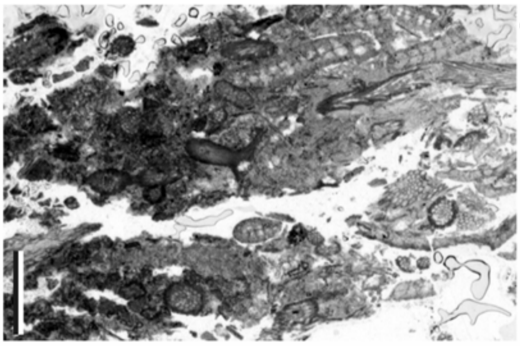
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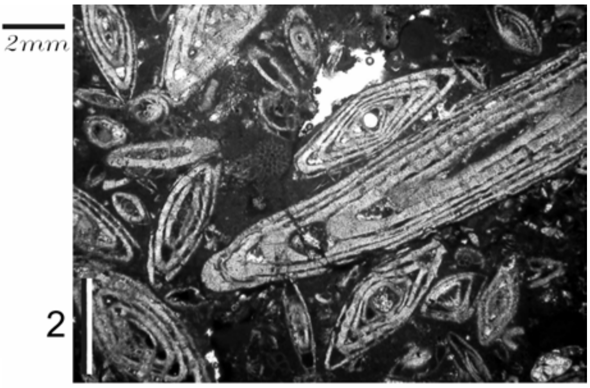

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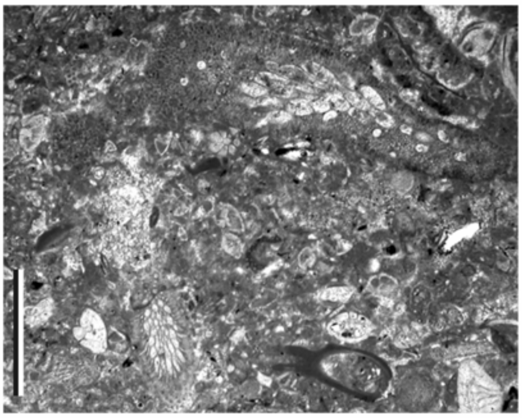
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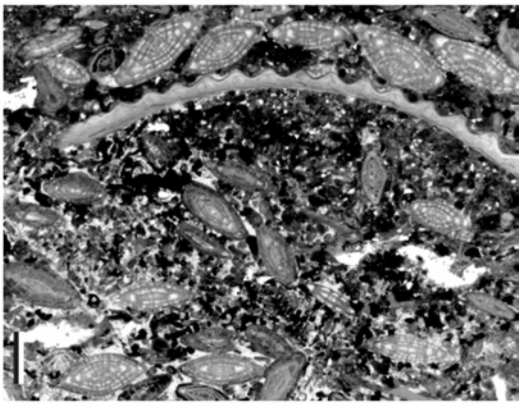
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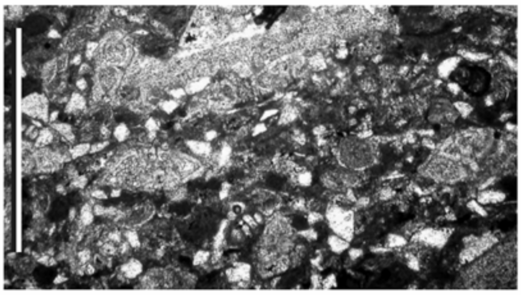
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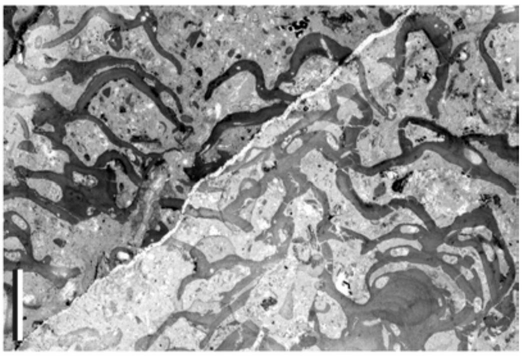
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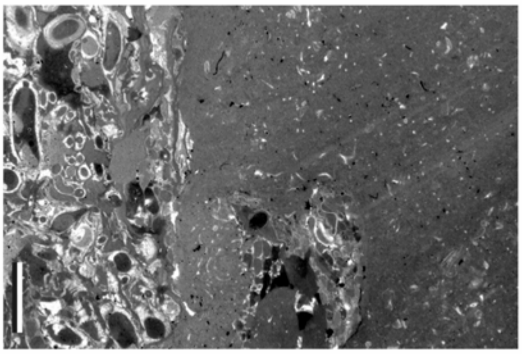
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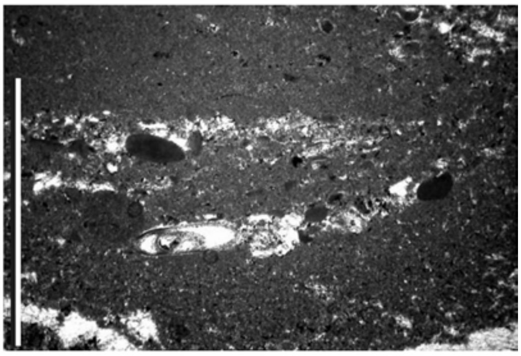
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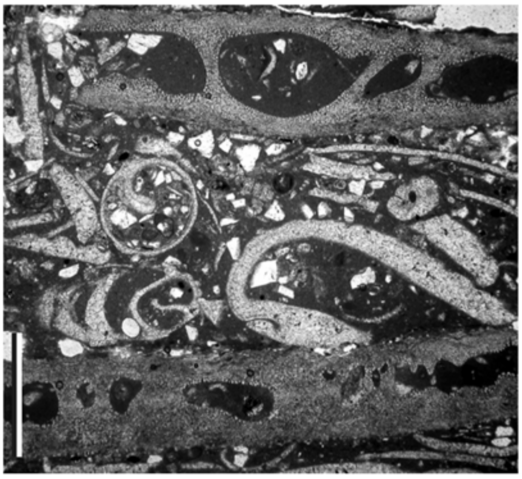
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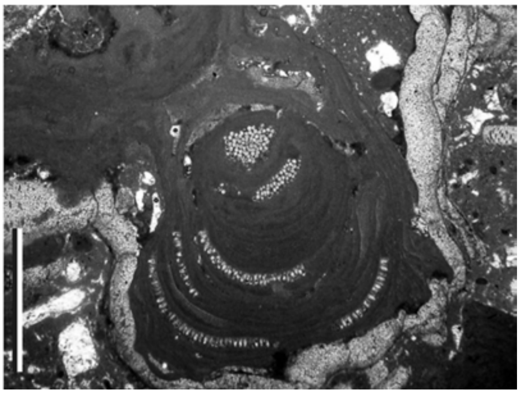
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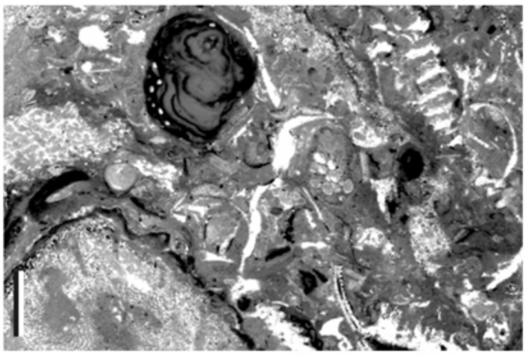
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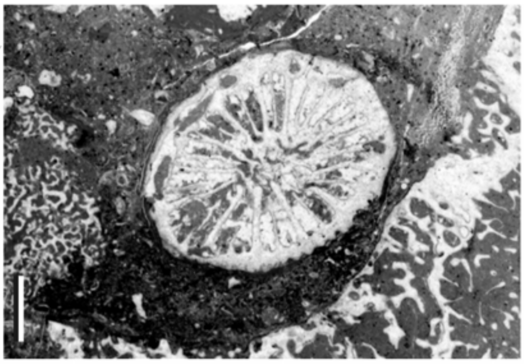

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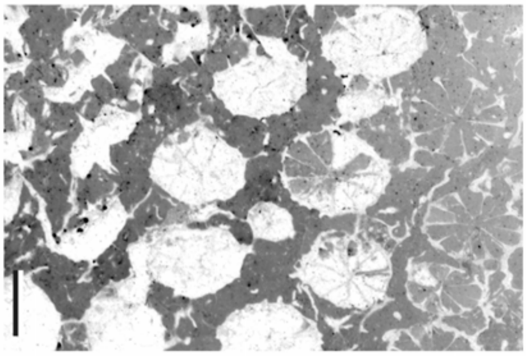
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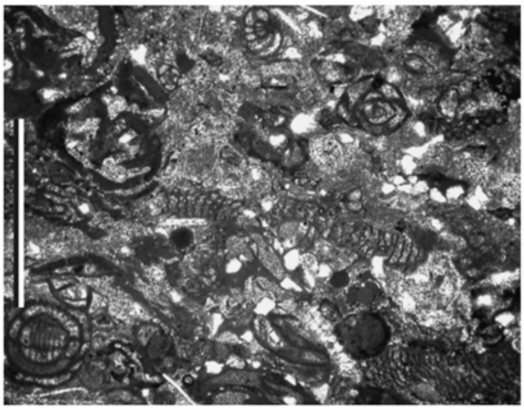
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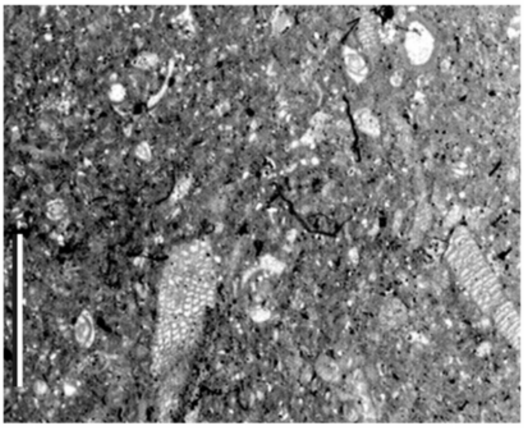
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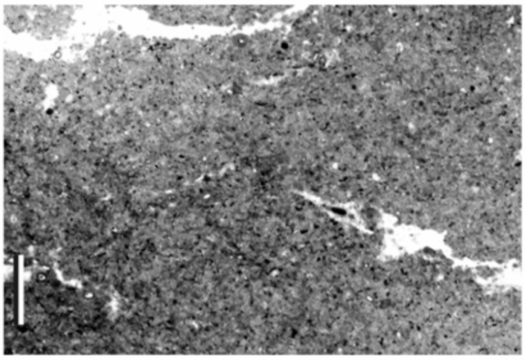
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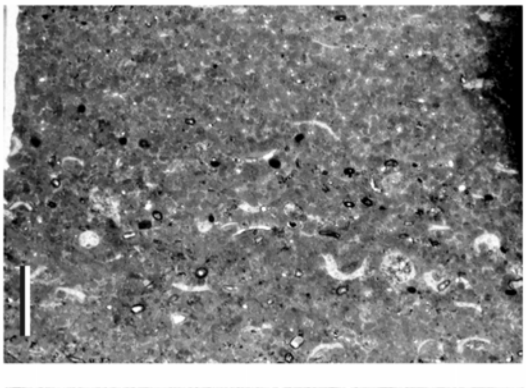
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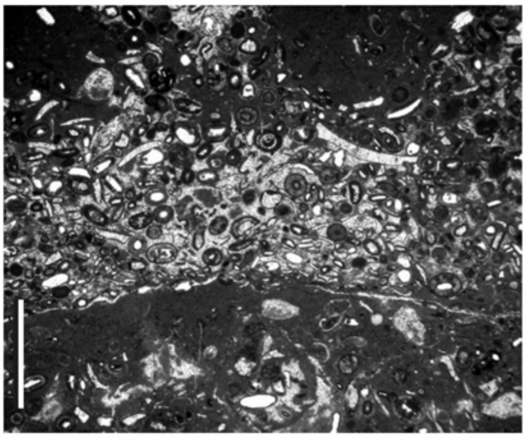
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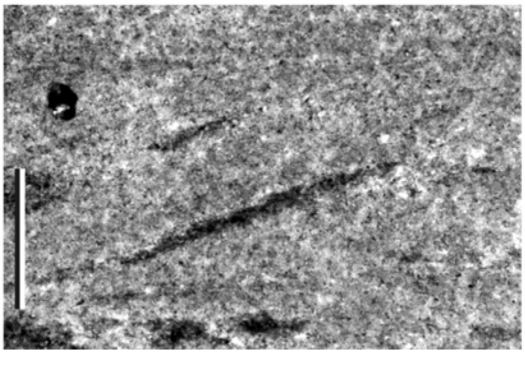
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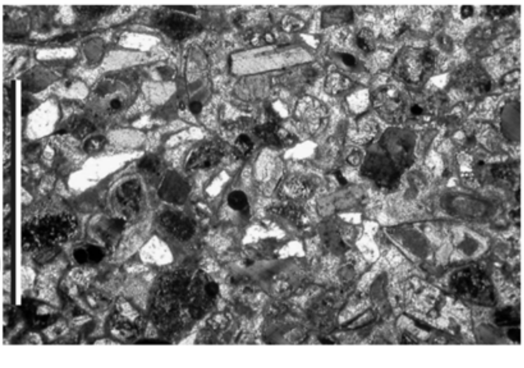
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