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Paleocene reef limestones near Veľký Lipník (Pieniny Mts., NE Slovakia): Facial environments and biogenic components

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Abstract: The important Paleocene reef complex of small dimensions is situated near the state frontiers of Slovakia with Poland in the Pieniny Mts. above the village Veľký Lipník. It is Lower Thanetian in age (57-58 Ma) and belongs into the Myjava-Hričov Group. In contrast to many other Paleocene reefs of Slovakia, this complex probably lies in situ below the deposits of the Early Eocene (Ilerdian). The reef complex at Veľký Lipník originated on the muddy substrate and this fact limited its size. After Höfling ´s typology (1997) the deposits of reef frameworks belong to the category of reef mounds (patch-reefs) and back-reef and fore-reef sediments to the muddy mounds. Very favourable life conditions in the area of the outer shelf, protected of waves and strong currents with abundance of nutrients and with tropical climatic conditions enabled development of many interesting elements of fauna and flora (Plates 1-8). They participated in constructor, binding, dweller and bioeroder communities. The main constructors of reef buildups were corals, crustose algae and encrusting foraminifers.

Key words: Paleocene, Thanetian, reef complex, reef mounds, muddy mounds, Pieniny Mts., NE Slovakia.

Introduction

There are not many regions on the Earth where the Paleocene reef complexes have been presented. They have been discovered mostly in the last 40 years, but in Slovakia the Paleocene reef limestones have been known more then 60 years (at first with incorrect age determination, for example "Middle to Upper Lutetian if not Lower Priabonian", cf. Lemoine, 1933).

In present 5 regions with occurrences of Paleocene reef complexes (Malé Karpaty Mts., Myjavská pahorkatina Upland, Middle Váh Valley, Orava and Eastern Slovakia, cf. Köhler, 1995) are known in Slovakia.

From the territory of Eastern Slovakia the most important Paleocene reefs are known from the Pieniny Mts. Scheibner (1968) described in the frame of zone Myjava-Hričov-Haligovka the reef framework 10 x 8 x 10 m in size above the settlement Paluby (NW margin of the village Haligovce) formed of grey algal-coral limestone.

Only four km east of this well-known Paleocene reef body another reef complex is well developed.

The presence of limestones of reef origin near the village Veľký Lipník (27 km north of the town Kežmarok, near the Slovak–Polish frontiers) was firstly noted by Nemčok & Kullmanová (1988) in the excursion guide for the national paleontological conference. Mentioned authors assumed that they are "marginal reefs" or "isolated patch reefs" in a shallow open environment, separated from each other by channels, trough which clastic material from the source area was brought into the sedimentation environment. Potfaj & Rakús (in Janočko et al., 2000b) stated that Paleocene limestones of the Pieniny Mts. area belong to Paleogene of the Klippen Belt. This locality is also described by Köhler (1995) in unpublished report of IGCP/UNESCO project N° 286 "Early Paleogene Benthos".

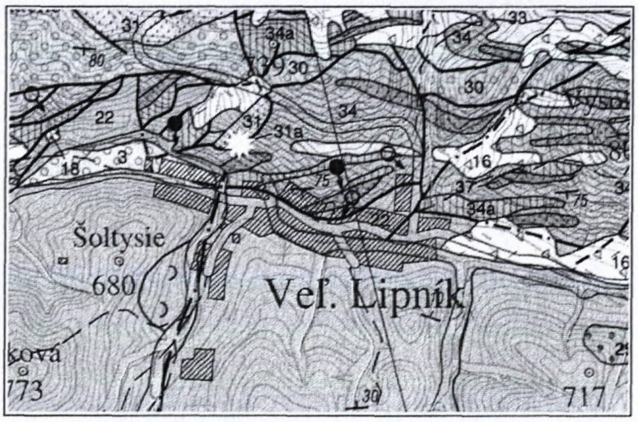

Fig. 1a. Location of the locality Veľký Lipník in Geological map of the Spišská Magura region 1:50 000 (Janočko et al., 2000a).

Very similar Paleocene reef limestones are known also from the Bavarian Alps (Moussavian, 1984) and from the Northern Calcareous Alps (Tollmann, 1976; Kambühel Limestone). Moussavian (l. c.) assumed the existence of so-called "Alpine-Carpathian reef belt". In the last time the Kambühel limestones were studied by Tragelehn (1996). From this point of view the comparative studies of Alpine and Carpathian Paleocene basins are very topical and desirable.

Description of locality and geological setting

The locality is located north of the village of Veľký Lipník below the elevation point 635 m a.s.l. (below the outlook at the road from Veľký Lipník to Lesnica – Fig. 1).

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Fig. 1b. Panoramatic view on the Paleocene reef limestones in the locality Veľký Lipník.

The belt of disintegrated blocks of grey reefal limestones has a length up to 200 m. Its width does not exceed 30-40 m. Separate blocks reach the size from 50 cm up to 10 m.

Below the lowermost blocks above the Lipník brook the red marlstones of Púchov Formation outcrop (Janočko et al., 2000a, b). They are Cretaceous in age. The immediate underlying beds of reef blocks are built by soft claystones and marlstones of Early Paleocene age. Near the road Veľký Lipník-Lesnica above the reef occurrences the outcrop of fine-grained sandstones is located, containing *Operculina azilensis* TAMBAREAU, *Assilina yvettae* SCHAUB, *Nummulites* sp. and *Discocyclina* sp. (Plate 7, Fig. 6). These sandstones belong to lowermost Early Eocene (Ilerdian). From the viewpoint of their linear occurrence, size of bodies and stratigraphic position below the deposits of lowermost Eocene, it is very probable that the reef bodies are located at the place of their origin. Their present appearance is caused by the recent erosion and karstification of limestones.

After Golonka et al. (2004) in the Pieniny belt the Paleocene carbonate forms olistoliths in the Zlatna (Myjava) unit. From this viewpoint the reef complex at Veľký Lipník appears as extraordinary one.

All Paleocene reef occurrences in the Slovak territory are closely connected with the Klippen Belt. After the opinion of presenting authors the reef complex originated in the shallow parts of the basin bordering the Klippen Belt from the inner side. Deposits of this basin are connected with the Myjava-Hričov Group (Late Cretaceous – Middle Eocene; Buček et al. in Mello et al., 2005).

From the Paleocene locality Veľký Lipník 20 reef blocks have been sampled and 122 thin sections were prepared. Samples and thin sections are stored in the Geological Survey of Slovak Republic, Bratislava.

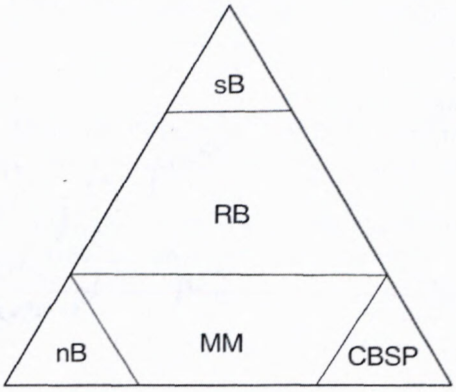
Lithology

Lithology depends on the position of rocks in the reef complex.

All environments have very typical high content of micrite matrix; 20.5-39 % in back-reef environments, 19.5-35 % in reef frameworks, 28-35 % in fore-reef deposits and more than 80 % in channel deposits. The micrite consists of disseminated fragments of Mesozoic carbonates (up to 3.5 mm), grains of quartz (to 0.3 mm) and very scarce fragments of mica plates. Primary cavities in buildups were filled by micrite of second generation, by sparite (often with geopetal textures) or by siltstones. Micrites locally pass into siltstones. Substantial part of rock is formed by organic remnants. Despite the anorganic component of rock is more or less stable, the content of organic components is very variable.

The back-reef environment is predominated by packstones, wackestones and bindstones. For the reef framework the boundstones are typical, locally also bindstones (foralgal crusts). In fore-reef environment the wackestones and packstones originated and in channel deposits the mudstones formed.

2a



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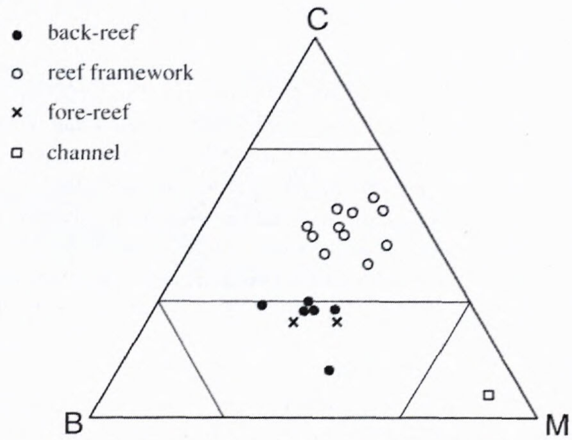

Fig. 2a. Schematic quantitative display of bioconstructions and their transition into non-reefal deposits (Höfling, 1997). Bioconstructions: sB – skeletal bioherm and biostrome, nB – non skeletal stromatolite bioherm and biostrome, RB – reef mounds, MM – mud mounds. Non-reefal deposits: C- cluster, B – bank, S – Schill-horizonte, P – pseudobioherm.

Fig. 2b. Place of samples from the Veľký Lipník locality in Höfling's triangle.

The high content of micrite matrix demonstrates the quiet protected environment without strong activity of waves and currents. The transport of terrigenous material from the sea-shore was minimal.

Biogenic components

Favourable conditions for organic life in the Pieniny area caused that the reef complex inhabited much diversified association of organisms. They are briefly described in the next pages. For the limited scope of this article the presenting authors abandon the detailed description of taxons.

F l o r a

Cyanobacteria (Pl. 3, Fig. 2)

In several thin sections with crustal coralline algae there are present also the light-grey crusts not displaying any structural signs. These crusts 50-550 μm thick were the product of organisms having the structure so fine that it has not been preserved. The inorganic origin of these covers may be excluded since they are copying the undulated course of algal crusts on which they were lying and they were again covered by algal layers.

Coralline algae

Division *Rhodophyta*

Owing to poor description and different valuation of diagnostic criteria the status of most fossil species of red algae is unclear in present time. The main problem consists of the conflict between traditional identification of fossil species and modern neontological taxonomic concepts (Rasser & Piller, 1999). The original diagnostic characters of many fossil taxa are meaningless according to the modern criteria. In present time many authors attempt to apply the criteria, used for identification of Recent species, also for fossil coralline algae. It appears that practically all descriptions of fossil algae before 1990 are unusable in the sense of new neotological view. As the result of this state the authors of modern articles,

Tab. 1. Volume % of the main components in samples from the reef complex at Veľký Lipník.

Sample N°	Thin section N°	algae Corallinaceae	algae - Solenoporaceae	algae - Peyssonneliaceae	corals	sessile forams	other forams	other fossils	matrix	environment
2	VL9	23		9	4	6	10	9	39	back-reef
6	VL28	13	9		3	34	9	8	24	back-reef
7	VL31	29				27,5	1	15	27,5	back-reef
15	VL72	28,5	16		3	10,5	8.5	3	30.5	back-reef
19	2024	34	12			10	3	10	31	back-reef
20	2036	33	2.5		5	25	7	7	20.5	back-reef
1	VL4	11.5	23	5.5	2	11.5	6	5	35.5	back-reef to
5	VL22	8.5	47.5			7.5	2.5	2.5	31.5	framework
8	VL35	8	28			9	12	6	37	detto
18	1873	18	38.5		11	3.5	3.5	6	19.5	detto
3	VL12	5			47.5	2	7.5	5.5	32.5	framework
9	VL42	13	6.5		35	10	5	6	24.5	framework
10	VL45	13.5	5.5		35.5	7.5	3.5	5	29.5	framework
11	VL49	12.5	7	2	23.5	15	5	7	28	framework
13	VL60	18			31	14	6	2	29	framework
16	VL74	9			46.5	1	6.5	8	29	framework
17	1866	12			37.5	12	3	5	30.5	framework
12	VL58	28	2		8	12	5	9	36	fore-reef
14	VL68	31	8.5	4.5	10	7	7	4	28	fore-reef
4	VL20	4			1	7	3	3	82	channel

employ only generic designations without concrete species determination. This way is followed also in the presented paper.

It is necessary to mention that many Paleocene red algae were firstly described from Slovakia, but from the other area (Middle Váh valley; Lemoine, 1933). Modern revision of these well-known taxa is very desirable and it is also the aim of presenting authors in the future.

Genus *Sporolithon* HEYDRICH, 1897
***Sporolithon* sp.** (Pl. 2, Figs. 5-6)

It is the most important genus in the algal communities at the Veľký Lipník reef complex.

This genus is characterized by a great variability of growth forms, but the encrusting, layered and foliose growth forms are the most common. This genus is characteristic with its reproductive organs. The numerous simple sporangia are arranged in rows (sori) (Pl. 2, Fig. 5) or in lenses (Pl. 2, Fig. 6) on the peripheral filaments. Several zones of sporangia may be observed within one thallus (buried in the deeper parts of tissue). Sporangia are 30-50 μm high and 15-30 μm in diameter.

This genus is the main element of bindstones in the back-reef environment, but it lived also in the coral communities of reef frameworks. So, it is not only binding element, but also constructer of reefs.

Similar forms of the genus *Sporolithon* described Rasser & Piller (1994) from Paleocene deposits of Austria.

Genus *Lithoporella* (FOSLIE) FOSLIE, 1909
Lithoporella sp. (Pl. 2, Fig. 2)

This genus is characterized by thin thalli and multiple overgrows of large primigenous filaments composed of palisade cells. Filaments are 30-40 μm thick, cells are very narrow (10-15 μm). This genus is present only rarely in thin sections.

Genus *Mesophyllum* LEMOINE, 1928
Mesophyllum sp. (Pl. 2, Fig. 3)

Thalli of this genus are present in encrusting but also in warty and lumpy growth forms. These plants have a dorsiventral nomonerous thalli with a coaxial core and well developed peripheral region. The conceptacules are multiporate, they measure 130-180 μm in diameter and 60-90 μm in height.

Non-oriented sections of this genus can be very easily confused with the genera *Lithothamnion* and *Lithophyllum*.

Genus *Mesophyllum* belongs to common binding algae in the back-reef environment.

Genus *Pseudoamphiroa* MOUSSAVAN, 1999
***Pseudoamphiroa propria* (LEMOINE, 1933)** (Pl. 2, Fig. 4; Pl. 3, Fig. 1)

The Paleocene limestones of Slovakia frequently contain algae with a very characteristic structure of thalli. They may be identified with the species *Pseudoamphiroa propria*, found by Lemoine (1933) on the basis of material from the locality Hričovské Podhradie (Middle Váh valley). Doubts about the correctness of this genus classification were led by Schaleková (1964) to the reclassification of species into the genus *Archaeolithothamnium* (present *Sporolithon*). It does not appear to be a good solution since the structure of the core of both genera is quite different.

In the studied thin sections *Pseudoamphiroa propria* (LEM.) forms 1-2 mm large nodules displaying characteristic bent cell rows sharply separated from each other by the dark walls. Thalli are monomerous with coaxial cores. Dubious sporangia in the peripheral part of thalli are arranged irregularly under the surface of this plant, their diameter does not exceed 50-70 μm (Pl. 3, Fig. 1).

This genus is mentioned in the literature of Paleocene algae only rarely (for example by Johnson, 1964).

Genus *Distichoplax* PIA, 1934
***Distichoplax biserialis* (DIETRICH) PIA, 1934** (Pl. 2, Fig. 1)

Pia (1934) described in detail so far little known species from Paleocene reef bodies near the village Hričovské Podhradie (Slovakia, Middle Váh valley) and he also gave it a genus name.

Sections of fragments of *D. biserialis* (DIETRICH) PIA are rare in thin sections from Veľký Lipník (back-reef and fore-reef environment). The thalli may reach length 1 mm, their diameter varying between 90-110 μm. The typical arrangement of the cells corresponds to that described by Pia (1934).

D. biserialis (DIETRICH) PIA was considered as a marker for Paleocene time, but Schaleková (1964) demonstrated its time span as Paleocene-Middle Eocene. Despite, this species is one of the most characteristic Paleocene algae.

Genus *Elianella* PFENDER et BASSE, 1947
***Elianella elegans* PFENDER et BASSE, 1947** (Pl. 4, Figs. 1-3)

Nodules and fragments of this species are one of the most frequent components of some samples from Veľký Lipník.

This species reaches size up to 12 mm and have an various outer morphology. The most typical one is the cauliflower-like structure. Thallus consists of parallel filaments 30-45 μm thick. A barrel-like shape of the cells is very characteristic. The height of cells is very variable – 20 to 60 μm. The cells in tangential sections are circular to polygonal in outline.

In the literature the contradictory opinions concern the systematic position of these forms. Some authors (Moussavian, 1984; Poignant, 1991) accepted the existence of the genus *Elianella*. The other authors (Segonzac, 1962; Stockar, 2000) claim that it is a synonym of long known genus *Parachaetetes* DENINGEN, 1907. The fundamental criteria for the differentiation of both genera are in the shape of cells in filaments: *Elianella* has an irregular structure of thalli and the horizontal partitions of cells are bent and irregularly distributed, while *Parachaetetes* has a regular structure and the partitions of cells are arranged in regular rows. The barrel-like shape of cells has only *Elianella*. Moussavian (1989) and Stockar (l. c.) affirm that both structural types may occur in the same thallus (the regular and irregular structure), so the differentiation of mentioned genera is not justified and *Elianella* is a young synonym of *Parachaetetes*.

The presenting authors know from the Veľký Lipník locality only forms with the very irregular structure of cells in filaments with distinctly barrel-shaped cells. After their opinion in the Paleocene lived both genera (*Elianella* and *Parachaetetes*) together in some reef complexes.

E. elegans PFENDER et BASSE was found in more than 80 % of thin sections. Locally it forms large accumulations and participates in the composition of frameworks. The present authors suppose that the best conditions for the life of these algae were on the back sides of coral frameworks or in protected back-reef environments.

Genus *Polystrata* HEYDRICH, 1905
***Polystrata alba* (PFENDER) DENIZOT, 1968** (Pl. 3, Figs. 5 and 7)

The thalli are usually well preserved with easily distinguishable details of the structure. The growth form is layered to foliose; layers are to 100-200 μm thick. Thalli are often twisted (Pl. 3, Fig. 5). The thalus consists of primigenous and postigenous filaments. They are very thin – 5 to 10 μm. Very interesting are roundish cavities in the dorsal side (15-110 μm in diameter). After Aguirre & Braga (1999) and Stockar (2001) they are interpreted as reproductive structures buried within the thalus.

This species was described from the Slovak Paleocene under the name *Pseudolithothamnium album* PFENDER by Andrusov (1938, 1950) and as *Ethelia alba* (PFENDER) by Samuel et al. (1972).

Species does not display any special dependence on the environment and occurs in the whole range of environments. Despite, it flourished in the shallow protected environments mainly during the Thanetian.

P. alba (PFENDER) DENIZOT was found in 50 % of thin sections, but specimens are very rare.

Genus *Acicularia* D'ARCHIAC, 1843
***Acicularia* sp.** (Pl. 3, Figs. 3 and 4)

The generic name *Acicularia* is employed for the fertile ampullae of algae of which thalli have not been preserved. They are common in all Paleocene reefs in Slovakian territory.

The circular sections 200-250 μm thick in diameter are known from 68 % of thin sections from all environments of the reef complex.

Genus *Neomeris* LAMOUROUX, 1816
***Neomeris* sp.** (Pl. 3, Fig. 6)

Rare specimens of these dasycladal algae lived only in protected back-reef environment.

F a u n a

Foraminiferida

Genus *Alveolina* D'ORBIGNY, 1826
***Alveolina (Glomalveolina) primaeva* REICHEL, 1936** (Pl. 6, Fig. 1)

One of the most important species of undoubtedly Thanetian age is *Alveolina (Glomalveolina) primaeva* REICHEL. Tests of this tiny spherical form are very rare in thin sections from Veľký Lipník (only in 5 thin sections – 4 %) and all lived in the back-reef environment.

The tests are spherical with diameter 300-600 μm; the protoconch has a diameter of 50-60 μm. At the diameter 150-200 μm there are 3 whorls.

This small form is comparable with subspecies *A.* (*G.*) *primaeva ludwigi* REICHEL (in Reichel, 1936) and testify to lower part of Thanetian (typical species *A.* (*G.*) *primaeva* REICHEL is common in Upper Thanetian).

Genus *Discocyclina* GÜMBEL, 1868
***Discocyclina seunesi* DOUVILLÉ, 1922** (Pl. 6, Fig. 2)

Only 3 sections of this species were distinguished in samples from Veľký Lipník. The tests are flat, 1.3-1.6 mm in diameter; the embryonic apparatus (only one measurement) has a diameter 150 μm. It seems that our specimens belong to primitive stage of *D. seunesi* DOUV. (after Less, 1998, diameter of deuteroconch is < 260 μm).

Genus *Miscellanea* PFENDER, 1935
***Miscellanea* cf. *primitiva* (RAHAGHI, 1983)** (Pl. 6, Fig. 3)

We know only 6 sections of this form. The tests are small (diameter 1.0 mm), inflated, with slightly rounded margin. The spherical protoconch has 80 μm in diameter (only one measurement). The chambers increase gradually to the last whorl. The wall of test is expressively perforated.

Similar form was described by Leppig (1988) and Sirel (1998) also from Paleocene.

***Miliolidae* EHRENBERG, 1839** (Pl. 7, Fig. 4)

Miliolid foraminifers are very frequent in the shallow and protected back-reef deposits. The tests are dispersed in micrite or silty matrix. The precise determination on the generic and species level in thin sections is impossible. They certainly include representatives of such genera as *Triloculina* and *Quinqueloculina*, but surprising is the absence of the genus *Idalina* which is common in other Paleocene reefs in the Slovak region.

The sections are circular to oval, thick 300-400 μm in diameter, protoconch is thick 50-90 μm in diameter. In many aspects these forms are similar to unidentified miliolid genera in the monograph by Sirel (1998).

Genus *Solenomeris* DOUVILLÉ, 1924
***Solenomeris ogormani* DOUVILLÉ, 1924** (Pl. 5, Figs. 1 and 2)

Very common tests were distinguished in 45 % of thin sections. Tests are lamellar, encrusting, comprising of

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numerous layers. They are coalescent with algae and coating solid substrate or (rarely) build macroids. Very interesting is a juvenile part with true nepiont stage having 250-300 μm in diameter (protoconch has 50-60 μm in diameter).

This species was a long time classified as algae, but in present time there is no doubt of its foraminiferal nature. Many authors employed the genus name *Acervulina* or *Gypsina*, presenting authors agree with Bassi (2003) and prefer the original name *Solenomeris* (details see in Bassi, l. c.).

Genus *Smoutina* DROOGER, 1960
***Smoutina* sp.**

Among rotalid foraminifers the most characteristic are the lenticular tests having 600-900 μm diameter with heavy pillars in the central part. The protoconch is 50-90 μm in diameter.

Sections of this form are very similar to *Smoutina* sp. in Sirel (1998, Pls. 37 and 68).

Smoutina sp. belongs between rare dwellers of the reef complex at Veľký Lipník.

Genus *Miniacina* GALLOWAY, 1933
***Miniacina multicamerata* (SCHEIBNER, 1968)** (Pl. 6, Figs. 4 and 5)

This species was originally described by Scheibner (1968) from the Pieniny area (reef framework Paluby – Haligovce). His description is accompanied only by drawings (l. c., p. 84, textfigs. 9-13).

Tests were attached to various solid substrates. Proloculus is spherical (Pl. 6, Fig. 4 right) 50-70 μm in diameter, the walls are 150 μm thick and perforated. Chambers of this species form irregular clusters and they have diameter 40-150 μm.

This species is not as common as *M. multiformis* SCHEIBNER. Long time was *M. multicamerata* known only from Paleocene rocks, but Bosselini & Papazzoni (2003) mentioned this species also from the Late Eocene deposits in northern Italy. Samuel et al. (1972) determined this species from the Paleocene rocks of the Middle Váh valley (Slovakia).

***Miniacina multiformis* SCHEIBNER, 1968** (Pl. 6, Figs. 6-8; Pl. 8, Fig. 6)

Encrusting tests form thin layers repeated densely or lose one another. The layers are 90 to 250 μm thick, very irregular, their calcite walls are 20-40 μm thick. In some samples from the Veľký Lipník these layers are so common that they take part in the construction of reef framework.

Scheibner described this genus (1968) from the reef framework at Paluby – Haligovce near our locality. Bosselini & Papazzoni (2003) mention *M.* aff. *multiformis* from the Late Eocene of northern Italy. Samuel et al. (1972) mentioned this species from the Paleocene limestones of the Middle Váh valley (Slovakia).

Described species is present in 75 % of all thin sections.

Genus *Planorbulina* D'ORBIGNY, 1826
***Planorbulina cretae* (MARSSON, 1878)** (Pl. 5, Figs. 3-6)

The tests are either attached to firm substrates or they have been broken away. The shape of the tests was determined by a relief of the substrate (very often substrate consists of layers of coralline algae). The protoconch is 60 to 100 μm thick in diameter. The adult tests reach 1.5-2.5 mm in diameter. Chambers are arranged irregular in position. The adult chambers are arcuate, their diameter reaches 150-250 μm and walls of chambers are 20-60 μm thick.

This species is very common in protected shallow back-reef environment and with coralline algae binds the soft muddy sea bottom (foralgal crusts).

Family *Placopsilinidae* RHUMBLER, 1913
Genus *Placopsilina* RHUMBLER, 1913
***Placopsilina* sp.**

The agglutinated tests of this genus were attached on various substrates but especially on algal crusts and in the cavities of organic structures. They reached to 3 mm in diameter. Chambers grow usually in one row and attached 700 μm in height. Thick arched walls are composed of calcite and quartz grains.

Genus *Acruliammina* LOEBLICH et TAPPAN, 1946
***Acruliammina praeheissigi* (SAMUEL, KÖHLER et BORZA, 1977)** (Pl. 7, Figs. 1 and 3)

Agglutinated tests are attached on substrate by their initial parts, the adult parts are free and erected. Specimens are 2-7 mm high. Archieved walls are 150-350 μm thick, agglutinated and composed by one layer from calcite and quartz grains. Common presence of quartz grains is surprising, since the quartz grains in micrite matrix are very rare or nearly absent.

These specimens differ of the genus *Haddonia* CHAPMAN by walls from only one layer (e. g. *Haddonia heissigi* HAGN has walls from two layers; cf. Hagn, 1968). *Acruliammina robusta* BIGNOT from Montian reef complex in Vigny (France) is smaller (up to 2 mm in diameter) and is known only from Bignot 's drawings (Bignot, 1991, textfig. 6 and 7).

Samuel et al. (1972) presented this species on numerous plates under the name *Haddonia* sp. and *Reophax* sp. from Montian-Thanetian reef limestones of the Middle Váh valley (Slovakia). As a new species *Haddonia praeheissigi* SAMUEL, KÖHLER et BORZA these authors (Samuel et al., 1977) described this form again from the Middle Váh valley area but as locus typicus they designated the Late Senonian locality Pod Húštim (to SW of the town Považská Bystrica).

Family *Eoglobigerinidae* BLOW, 1979
Genus *Eoglobigerina*, MOROZOVA, 1959
***Eoglobigerina pseudobulloides* (PLUMMER, 1926)** (Pl. 7, Fig. 2)

This species is present only in samples of fore-reef part of reef complex or from the outer sides of reef buildups.

Sections of free tests (determined by J. Salaj[1]) have 500-900 μm in diameter, coiling is trochospiral, composed by 2-2.5 whorls. Walls are calcareous, perforated.

After Samuel & Salaj (1968) this species in Slovak Paleogene occurs in the stratigraphic range Danien-Thanetian (l. c., textfig. 27).

Other small foraminifers

Very sporadically in thin sections also sections of other foraminifers are present belonging to the genera *Anomalina, Cibicides, Spirobulimina* (Pl. 7, Fig. 5) and to undermined agglutinated genera.

M e t a z o a

Phyllum *Porifera*

Spines of Porifera belong to the very scarce elements in some thin sections.

Phyllum *Coelenterata*

Class *Anthozoa*

Order *Scleractinia* (Pl. 1, Figs. 3-6; Pl. 8, Figs. 1-2)

The fragments of corals are present in 83 % of thin sections, but they are common only in 36 thin sections (29 %) from samples of reef framework, building these frameworks.

The determination of scattered small fragments of corals is uncertain. These fragments are obviously broken and bored, their structures are recrystallized. Only in 7 samples corals play an important role as constructers of reef buildings. After comparison with description and illustrations of Turnšek (in Drobne et al., 1988) and Turnšek & Drobne (in Hottinger & Drobne, 1998) from these samples the following species were determined: *Actinacis* sp., *Aastrocoenia* sp., *Dendrophyllia* sp., *Litharaea* sp., *Rhizangia* sp. and *Stylocoenia* sp.

Firm frameworks could be built by genera *Actinacis* (Pl. 1, Fig. 5; Pl. 8, Fig. 2), *Dendrophyllia* (Pl. 1, Fig. 4), *Litharaea* (Pl. 1, Fig. 6) and *Aastrocoenia* (Pl. 8, Fig. 1). These frameworks have a large cavities filled mostly by the marine micrite. The initial diagenesis was not intensive. It rather appears that the frameworks were exposed to intensive bioerosion. Only colonies cemented by crusts of coralline algae were resistant.

The structures containing bodies of *Pieninia oblonga* Borza et Mišík are very interesting. Mišík (1998) mentions that there are different opinions on the nature of skeletons obtaining *Pieninia oblonga* (Pl. 4, Figs. 4-6). After some authors they represent the fragments of corals, after others the bodies of Keratose sponges. Presenting authors regard the coral genus *Litharaea* Milne Edwards et Haime as a "host" of *Pieninia oblonga*.

Phyllum *Annelida* (Pl. 8, Fig. 6)

Typical tubes with the dark inner and light outer layer can be found only occasionally. Worms were rare dwellers of the reef complex.

[1] The authors wish to thank Dr. Joseph Salaj for identification of planktonic foraminifers.

Phyllum *Bryozoa* (Pl. 8, Fig. 7)

Bryozoa are present only in small fragments, whole zoaries are very exceptional (Pl. 8, Fig. 7). Study in thin sections does not enable their classification. All specimens belong to the order *Cyclostomata*.

Cyclostomata prefer shallow protected waters and so they lived prevailingly in back-reef environment.

Phyllum *Mollusca*

Class *Bivalvia*

Small fragments of shells occur in almost all studied thin sections, but whole shells are a great rarity. Their more accurate determination is not possible (order *Dysodonta*).

Class *Gastropoda* (Pl. 8, Figs. 3 and 4)

Shells of gastropods are present in some samples but they are not common. The sections do not enable the determination on the level of genus or species.

The gastropods lived in protected back-reef environment and also in the cavities in reef frameworks.

Subphyllum *Crustacea*

Class *Ostracoda* (Pl. 8, Fig. 5)

Whole unbroken shells of ostracods are found relatively rarely in thin sections. Ostracods occur mostly in the back-reef environment. The determination of genera and species in thin sections is so far not possible.

Phyllum *Echinodermata*

Class *Crinoidea*

Dispersed crinoidal segments and their fragments are rare in studied samples and the importance of these animals in the construction of reef communities is negligible.

Class *Echinoidea*

Echinoid spines belong to very rare organic remnants in reef complex at Veľký Lipník.

Vertebrata

Fish teeth

Only in one thin section was determined one fish tooth (sample 2, thin section 10 VL/K).

Incertae sedis

Genus *Pieninia* Borza et Mišík, 1976

***Pieninia oblonga* Borza et Mišík, 1976** (Pl. 4, Figs. 4-6)

The genus *Pieninia* with a very unclear systematic position was defined in 1976 by Borza and Mišík. These authors suggested the affinity of *Pieninia* to algae (probably *Codiaceae*). Only one species was described – *Pieninia oblonga*.

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In 1998 Mišík returned to the problem of *Pieninia oblonga* on the basis of the new material (also from Veľký Lipník). He mentioned opinions of some specialists about taxonomic position of this fossil. He stated that *Pieninia* was found in fragments of *Coelenterata* or *Sponge* skeletons in Paleocene biohermal limestones. Skeletal fragments were not definitely determined. Problematic bodies often occur not in the cavities but inside of the calcified skeletons. The question remains whether bodies of *Pieninia* are unusual sclerites or parasites because the way of their loosening from the skeletons was not observed.

The presenting authors refer to article of Mišík but in their opinion at the locality Veľký Lipník the genus *Pieninia* is endoparasite in the skeletons of corals (see Pl. 4, Figs. 4-6).

The sections are circular, oval or irregularly angular. Bodies with a diameter of 150 to 250 μm with more or less marked central channel are distinguishable in 39 % of thin sections but only in 10 thin sections (8 %) they are common.

Species *Pieninia oblonga* BORZA et MIŠÍK is known from stratigraphic time span Barremian – Late Eocene.

Age of the reef complex

The age of the reef complex at Veľký Lipník locality is unambiguous. For age determination the most useful are foraminifers, first of all *Alveolina* (*Glomalveolina*) *primaeva* REICHEL, *Discocyclina seunesi* DOUVILLÉ, *Miscellanea* cf. *primitiva* (RAHAGHI) and *Eoglobigerina pseudobulloides* (PLUMMER). This association situates reef complex into Thanetian SBZ 3 zone (in the terminology of Shallow Benthic Zones, see Serra-Kiel et al. 1998) (= P4 and NP 5-8 zones). This age determination coincides also with the composition of all organic remnants in 20 rock samples at Veľký Lipník and with the age determination of overlying Ilerdian (Early Eocene) beds.

The Thanetian has duration about 2 million years (56-58 Ma, see table in Serra-Kiel et al., l. c.).

Since in association the alveolinids and discocyclinids are represented by primitive forms (Alveolina (*G.*) *primaeva ludwigi* REICHEL and primitive *Discocyclina seunesi* DOUVILLÉ) the age of this reef complex is contracted into the interval 57-58 Ma, i. e. lower part of the Thanetian.

Composition of communities in the Veľký Lipník reef complex

Each reef system is characterized by a specific composition of the community of its fauna and flora. Community consists of numerous mutually interacting species. As wrote Fagestrom (1987, pp. 172-173) "The complex interactions of factors and processes are biologically expressed as communities and subcommunities. Because these interactions vary from place to place and reef to reef, no two reefs should be expected to have precisely the same subcommunities arranged in precisely the same patterns". In the sense of Fagestrom (l. c.) and Höfling (1997) in reef complex there is possible to distinguish some characteristic members of communities (guilds in sense Fagestrom, l. c.). The main reef complex communities are: constructor, binding, dweller and bioeroder community.

These communities were distinguished also in Veľký Lipník reef complex.

a) Constructor community

This community build the reef framework. The members are colonially living forms having large, strong and heavy skeletons. Their upward growth is more intensive than the growth sideward and the growth of the skeletons is more rapid than sedimentation.

Typical representatives of constructor community in the Tertiary are corals – *Scleractinia*. On the table 1 with volume % of the main reef components is possible to see that also at the Veľký Lipník locality corals are the main constructors of reef framework. Their surfaces are bearing also encrustings of coralline algae and sessile foraminifers, but their volume portion on the construction of rigid reef buildups is small.

A peculiar role is played by genus *Elianella*. Its accumulations are connected with back-reef environment but chiefly with the back sides of coral buildings. Present authors attribute genus *Elianella* also as a constructor of inner parts of reef frameworks (Table 1).

b) Binding community

When we take into consideration that sea-bottom at Veľký Lipník was muddy and underlying beds consisted of claystones and marlstones of Late Cretaceous-Early Paleocene age, the role of binding community in the stabilization of the substrate was enormous. Only on the relatively firm bottom there arised the conditions for life of colonial large forms as corals. The binding forms were the pioneers and owing to their activity the reef complex has arised in such inconvenient place.

The main components of binding community are coralline algae (chiefly *Corallinaceae* and in the first place genus *Sporolithon*), perhaps also cyanobacteria and some sessile foraminifers (genera *Acruliammina, Miniacina, Solenomeris*). These taxa have heavily calcified structures.

The authors connect binding and baffling communities into one unit because the activity of waves was minimal (micrite matrix without traces of washing).

c) Dweller community

It is the most variable part of reef organic life. It includes the forms living on the sea bottom, being active in reef buildups, or inhabiting the shallow sea water.

This community includes:

- some algae as *Distichoplax biserialis* (DIETRICH) PIA and dasycladal algae,
- foraminifers as miliolids, anomalinids, larger foraminifers and in the fore-reef deposits also planktonic foraminifers,
- bryozoans, ostracods, bivalvia, gastropods, echinoids, fishes.

d) Destroyer community

It left traces in the form of various borings and the breaking of corals branches. On the destructive activity there participated the boring (endolits) algae and sponges, rasping bivalvia and gastropods, polychaete worms and fishes grazing the reef surfaces.

An important factor in the destruction of coral tissue was *Pieninia oblonga* BORZA et MIŠÍK, that is considered as endoparasite in coral colonies.

Classification and typology of the reef complex

The terminology and classification of fossil reef structures is very complicated with many vague terms. The critical review of various opinions gave Höfling (1997). This author defined various bioconstructions of the reefal and non-reefal nature with many examples from the geological history of the Earth. For the unification of typology he proposed the triangle presentation of the main biostructures (Höfling, 1997, p. 40, Fig. 2). The terminal points of his triangle are "constructors in situ" (C), "binding organisms" (B) and "micrite and clasts (M), see Fig. 2a.

For the classification of Veľký Lipník reef complex all collected samples (20) were analysed. One (rarely 2-3) thin section was selected and analysed in details from each sample. The composition of rock was studied by putting a grid with a cell side 4 mm² over the 20 x 20 mm plane. In spite of great variability of reef composition the obtained data render valuable information of composition of reef complex (Table 1).

The studied samples can be divided into 4 categories:

1. Back-reef deposits

are characterized by packstones, wackestones and bindstones with a high percentage of crustose coralline algae, dasycladal algae, sessile and benthic foraminifers (especially miliolids and large foraminifers) with small amount of corals. This environment is preferred also by bivalvia, gastropoda and cyclostomate bryozoa (samples Nos. 2, 6, 7, 15, 19 and 20).

2. Reef frameworks

are built up by boundstones, locally also bindstones (foralagal crusts). In the organic composition there dominate corals (35-47.5 volume %) in association with algae (5-19.5 %), benthic foraminifers (8-14.5 %) and various dwellers (mainly in cavities).

The common presence of alga *Elianella* (23-38.5 volume %) is characteristic for the back side of reef buildups. This alga lived also in protected back-reef environment, but main accumulations of thalli are on the back sides of frameworks. The samples Nos. 1, 3, 5, 8, 9, 10, 11, 13, 16, 17 and 18 belong into this group.

3. Fore-reef environment

consists of wackestones and packstones with algae, fragments of corals, benthic but also planktic foraminifers (*Neoglobigerina*). We have studied only two samples, Nos. 12 and 14.

4. The special case is the sample No. 4 with 82 % volume % of micrite (mudstone) and clasts and with small amount of fragments of corals, algae and benthic foraminifers. According to authors of presented article this sample represented original muddy sediment between the reef buildups (channel deposit).

The data from table 1 after adaptation were substituted into Höfling ´s triangle (Fig. 2b). Deposits of back-reef and fore-reef environment are placed into field MM (muddy mounds), the sample from channel into CBCP field (non-reef deposits).

The most interesting are samples from the reef construction. All samples are placed into the field of reef mounds. This arrangement coincides with the idea of authors that in the space of Veľký Lipník originated only patch reefs with very limited dimensions (up to 10 m). These patch reefs were surrounded by muddy channels with fragments of reefs. In the protected shallow area beyond the reef constructions the favourable conditions for the very diverse life occurred. The fore-reef deposits are conserved only in small rests. In all environments the traces of intensive bioerosion of carbonates were observed.

Conclusions

At the locality Veľký Lipník (Pieniny area, NE Slovakia) the separate reef complex originated on the muddy sea bottom during the lower part of Thanetian (57-58 Ma).

After the stabilization of soft muddy sediment by encrusting algae and foraminifers the very restricted reef constructions have originated. With respect to Höfling ´s categorization (1997) they belong to the category of reef mounds. These frameworks had very limited dimensions (to 10 m). Simultaneously with the growth of reefs also back-reef and fore-reef environments have developed with characteristic elements of fauna and flora. The corals and algae were the main constructors of reef buildups.

Reef complex originated in the very shallow quiet environment relatively distant of sea shore, protected from waves and currents (in outer part of shelf) and without traces of washing (well preserved internal sediment in reef frameworks). Only reduced transport of silty material was recorded.

Bioerosion was the main agent of the destruction of reef constructions.

The organic content indicates the high taxonomic diversity in comparison with adjacent non-reef areas.

In 20 studied samples (122 thin sections) we were able to define the back-reef, reef and fore-reef deposits with characteristic composition of fauna and flora.

The great taxonomic diversity confirms the normal salinity of sea-water, abundance of nutrients and tropical climatic conditions during the growth of the reef complex.

The growth of reef complex had only small duration (under one million years) and extincted during the Thanetian. The reasons of its extinction are various: deepening of sea-bottom and filling of surface of reefs by muddy material (the deepening was due to rising of the sea level or by subsidence of bottom owing the tectonic movements). The other possibility is that due to the heavy weight frameworks their rigid foundation was broken and they buried into the soft substrate.

Peculiarity of this locality consists from the fact that deposits of reef complex are probable in situ on the place of their origin (under the deposits of Early Eocene) and they were not transported into younger deposits as is a rule in other Paleocene reef deposits of Slovakia.

References

Aguirre, J. & Braga, J. C., 1998: Redescription of Lemoine´s (1939) types of Coralline algal species from Algeria. Palaeontology (London), 41, 3, 489-507.

Andrusov, D., 1938: Rôle des Thallophytes dans la constitution des roches sédimentaires des Carpathes tchécoslovaques. Věst. Král. české spol. Nauk, (mat.- přír.) (Praha), 1-32.

Andrusov, D., 1950: Les fossiles du Mésozoïque des Karpates. I. Plantes et protozoaires. Práce Štát. geol. Úst., Sošit (Bratislava), 25, 3-163.

Bassi, D., 1997: Vegetative anatomy and paleoecology of *Polystrata alba* (PFENDER) DENIZOT, 1968 (Cryptonemiales, Peyssonneliaceae) from the Upper Eocene of northern Italy. Revue Paléobiol. (Genève), 16, 2, 309-320.

Bassi, D., 2003: Reassessment of *Solenomeris afonensis* Maslov, 1956 (Foraminifera): Formerly considered a coralline red alga. Rev. Españ. Micropaleontol. (Madrid), 35, 3, 357-363.

Bignot, G., 1992: Une association de Foraminifères du récif montien de Vigny. Considerations sur la paléobiogéographie dano-montienne du Nord-Ouest européen. Revue Micropaléontol. (Paris), 35, 3, 179-196.

Borza, K. & Mišík, M., 1976: *Pieninia oblonga* n. gen., n. sp. aus kretazischen und paläogenen Kalken der Westkarpaten. Geol. zbor. Geol. Carpath. (Bratislava), 27, 1, 65-77.

Bosselini, F. R. & Papazzoni, C. A., 2003: Palaeoecological significance of coral-encrusting foraminifer association. A case-study from the Upper Eocene of northern Italy. Acta Paleont. Pol. (Warszawa), 48, 2, 279-292.

Fagestrom, J. A., 1987: Evolution of reef communities. Wiley et Sons, New York, 600 p.

Golonka, J., Cieszkowski, M., Kiessling, W., Krobicki, M., Marko, F., Matyszkiewicz, J., Olszewska, B., Oszczypko, N., Potfaj, M., Rajchel, J., Ślączka, A., Słomka, T., Tłuczek, D. & Wieczorek, J., 2004: Paleocene reef patterns: Global and Carpathian view. In. Zlinská, A. (Ed.): 5. Paleontologická konferencia, Bratislava, jún 2004. Zborník abstraktov. Štát. Geol. Úst. D. Štúra, Bratislava, 39-40.

Hagn, H., 1968: *Haddonia heissigi* n. sp. ein bemerkenswerter Sandschaler (Foram.) aus dem Obereozän des Bayerischen Kalkalpen. Mitt. Bayer. Staatssamml. Paläont. hist. Geol. (Münich), 8, 3-50.

Henson, F. R. S., 1950: Cretaceous and Tertiary reef formations and associated sediments in the Middle East. Bull. Amer. Assoc. Petrol. Geol. (Tulsa, Okla.), 34, 2, 215-238.

Höfling, R., 1997: Eine erwiterte Riff-Typologie und ihre Anwendung auf kretazische Biokonstruktionen. Abhandl. Bayer. Akad. Wiss., Neue Folge (Münich), 169, 127 p.

Janočko, J. (Ed.), Gross, P., Jacko Jr., S., Buček, S., Karoli, S., Žec, B., Polák, M., Rakús, M., Potfaj, M. & Halouzka, R., 2000a: Geological map of the Spišská Magura region 1 : 50 000. Štátny Geol. Úst. D. Štúra, Bratislava.

Janočko, J. (Ed.), Gross, P., Polák, M., Potfaj, M., Jacko Jr., S., Rakús, M., Halouzka, R., Jetel, J., Petro, Ľ., Kubeš, P., Buček, S., Köhler, E., Siráňová, Z., Zlinská, A., Halasová, E., Hamršmíd, B., Karoli, S., Žec, B., Fejdiová, O., Milička, J., Boorová, D. & Žecová, K., 2000b: Explanations to geological map of the Spišská Magura region 1 : 50 000. Štátny Geol. Úst. D. Štúra, Bratislava, 174 p. (In Slovak.)

Köhler, E., 1995: The Paleocene reef complex in the Western Carpathians. Final Report of the Slovak participation in IGCP/ UNESCO No. 286 "Early Paleogene Benthos". MS – Archív GÚ SAV, Bratislava, 238 p. + Photoatlas.

Lemoine, P., 1933: Algues calcaires de la familie des Corallinacées recuillies dans les Carpathes occidentales par M. D. Andrusov. Věst. St. geol. Úst. Čs. Republ. (Praha), 9, 5, 269-289.

Leppig, U., 1988: Structural analysis and taxonomic revision of *Miscellanea*, Paleocene, larger Foraminifera. Eclogae geol. Helv. (Basel), 81, 3, 689-721.

Less, G., 1998: The zonation of the Mediterranean Upper Paleocene and Eocene by Orthophragminae. Dela-Opera SAZU, 4. razr. (Ljubljana), 34, 2, 21-43.

Loeblich Jr., A. R. & Tappan, H., 1988: Foraminiferal genera and their classification. Van Nostrand Reinhold Co., New York, 970 p.

Mišík, M., 1998: *Pieninia oblonga*: Skeletal parts or endoparasites of Keratosa sponges? Geol. Carpath. (Bratislava), 49, 6, 401-407.

Moussavian, E., 1984: Die Gosau- und Alttertiär-Gerölle der Angerberg-Schichten (höheres Oligozän, Unterinntal, Nördliche Kalkalpen). Facies (Erlangen), 10, 1-86.

Moussavian, E., 1989: Über die systematische Stellung und die Bestimmungskriterien der Solenoporaceen (Rhodophyceae). Cour. Forsch. Inst. Senckenb., 109, 51-91.

Moussavian, E., 1999: Taxonomische Untersuchungen an *"Amphiroa" propria* LEMOINE (Corallinaceae/Rhodophyta, Maastischt-Thanet). Müncher Geowiss. Abh. (Münich), A, 15, 41-54.

Nemčok, J. & Kullmanová, A., 1988: Veľký Lipník. In: Guidebok to national paleontological conference held in 20.-24. June 1988 in Ružbašská Míľava. Geol. Ústav D. Štúra, Bratislava. (In Slovak.)

Pfender, J., & Basse, E., 1947: *Elianella* nov. gen. *elegans* nov. sp., organisme constructeur des calcaires typiquement développé dans le Paléocène du Sud-Ouest Malgache. Bull. Soc. géol. France (Paris), (5), 17, 4-6, 275-278.

Pia, J., 1934: Kalkalgen aus dem Eozän der Felsen von Hričovské Podhradie im Waagtal. Věst. St. geol. Úst. Čs. Republ. (Praha), 10, 14-18.

Poignant, A. F., 1991: Chapter 4: The Solenoporaceae: A general point of view. In. Riding, R. (Ed.): Calcareous Algae and Stromatolites. Springer Verlag, Berlin – Heidelberg, 88-97.

Rasser, M. & Piller, W. E., 1994: Re-documentation of Paleocene coralline algae of Austria, described by LEMOINE (1930). Beitr. Paläont. (Wien), 19, 219-225.

Rasser, M. W. & Piller, W. E., 1999: Application of neontological taxonomic concepts to Late Eocene coralline algae (Rhodophyta) of the Austrian Molasse Zone. Journ. Micropal. (London), 18, 1, 67-80.

Reichel, M., 1936-1937: Etude sur les Alvéolines. Mém. Soc. Paléont. Suisse (Lausanne), 57, 4, 1-93; 59, 2, 95-147.

Samuel, O. Borza, K. & Köhler, E., 1972: Microfauna and lithostratigraphy of the Paleogene and adjacent Cretaceous of the Middle Váh Valley (West Carpathians). Geol. Úst. D. Štúra, Bratislava, 246 p.

Samuel, O., Köhler, E. & Borza, K., 1977: *Haddonia praeheissigi* and *Miliola*? *andrusovi*, two new species from Upper Senonian and Paleocene bioherm limestones of West Carpathians (Slovakia). Záp. Karpaty, Sér. Paleont. (Bratislava), 2-3, 87-96.

Samuel, O. & Salaj, J., 1968: Microbiostratigraphy and foraminifera of the Slovak Carpathian Paleogene. Geol. Úst. D. Štúra, Bratislava, 232 p.

Schaleková, A., 1964: New information on the Cretaceous algae in the bioherm limestones of the Paleocene-Lower Eocene in Western and Central Slovakia. Geol. Sbor. Slov. Akad. Vied (Bratislava), 15, 1, 57-73.

Scheibner, E., 1968: Contribution to the knowledge of the Paleogene reef-complex of the Myjava-Hričov-Haligovka zone (West Carpathians). Mitt. Bayer. Staatsamml. Paläont. hist. Geol. (München), 8, 67-97.

Segonzac, G., 1962: Niveaux à Algues dans le Thanétien des Pyrenées (Corallinacées, Solenoporacées, Squamariacées, Incertae familiae). Bull. Soc. géol. France (Paris), 7, 3, 437-448.

Serra-Kiel, J., Hottinger, L., Caus, E., Drobne, K., Ferrandez, D., Jauhri, A.K., Less, G., Pavlovec, R., Pignatti, J., Samsó, J.M., Schaub, H., Sirel, E., Strougo, A., Tambareau, Y., Tosquella, J. & Zahrevskaya, E., 1998: Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. Bull. Soc. géol. France (Paris), 169, 2, 281-299.

Sirel, E., 1998: Foraminiferal description and biostratigraphy of the Paleocene-Lower Eocene shallow-water limestones and discussion on the Cretaceous-Tertiary boundary in Turkey. General Directorate of the mineral research and exploration, Monography series (Ankara), 2, 117 p.

Stockar, R., 2000: On the occurrence of *Parachaetetes asvapatii* Pia, 1936 (Solenporaceae) in the Montorfano Member type-section (Tabiago Formation, Como, Northern Italy). Revue Paléobiol. (Genève), 19, 2, 427-434.

Stockar, R., 2001: *Polystrata alba* (Pfender) Denizot and *Peyssonnelia antiqua* Johnson: Two Peyssonneliacean Algae (Rhodophyta) from the Paleocene of the Tabiago Formation (Montorfano Member type-section, Como, Northern Italy). Geol. Insubr., 6, 1, 15-22.

Tollmann, A., 1976: Analyse des klassischen nordalpinen Mesozoikums. F. Deuticke, Wien, 1-580.

Tragelehn, P., 1996: Maastricht und Paläozän am Südrand der Nördlichen Kalkalpen (Niederösterreich, Steiermark) – Fazies, Stratigraphie, Paläogeographie und Fossilführung des „Kambühelkalkes“ und assoziiertes Sedimente. Diss. Univ. Erlangen, Vol. I, VI+ 216, Vol. II, pls. 1-67.

Turnšek, D., 1988: Coral Fauna from Paleocene of Dolenja Vas section. In. Drobne, K., Ogorelec, B., Pleničar, M., Zucchi-Stolfa, M. L. & Turnšek, D.: Maastrichtian, Danian and Thanetian beds in Dolenja vas (NW Dinarides, Yugoslavia). Mikrofacies, foraminifers, rudists and corals. Razprave SAZU, IV. razr. (Ljubljana), 29, 5, 183-193.

Turnšek, D. & Drobne, K., 1998: Paleocene corals from the Northern Adriatic Platform. In. Hottinger, L. & Drobne, K. (Eds.): Paleogene shallow benthos of the Tethys, 2. Dela-Opera SAZU, 4. razr. (Ljubljana), 34, 2, 129-154.

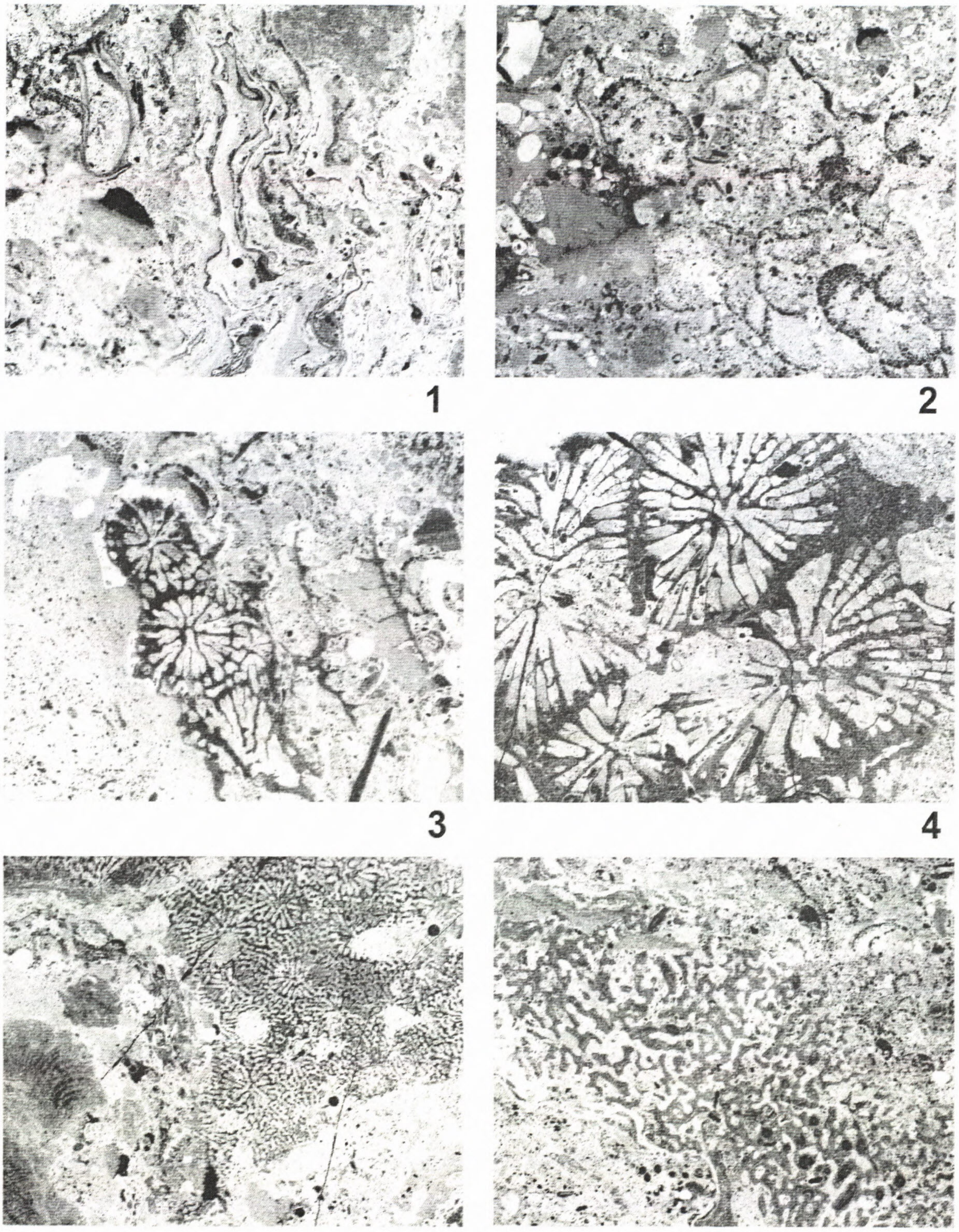

Plate 1

Fig. 1. Crusts of coralline algae (with dominance of *Sporolithon* sp.). Sample 19, thin section 2034/92, magn. 5x; Fig. 2. Crusts of coralline algae with tests of *Acruliammina praeheissigi* (SAMUEL, KÖHLER et BORZA). Sample 8, thin section 28 VL/K, magn. 7x; Fig. 3. Crusts of coralline algae with sections of *Rhizangia* sp. Sample 16, thin section 76 VL/K, magn. 7x; Fig. 4. Sections of *Dendrophyllia* sp. Sample 16, thin section 74 VL/K, magn. 5x; Fig. 5. Sections of *Actinacis* sp. Sample 10, thin section 45 VL/K, magn. 7x; Fig. 6. Sections of *Litharaea* sp. Sample 9, thin section 40 VL/K, magn. 7x. Photo by the authors.

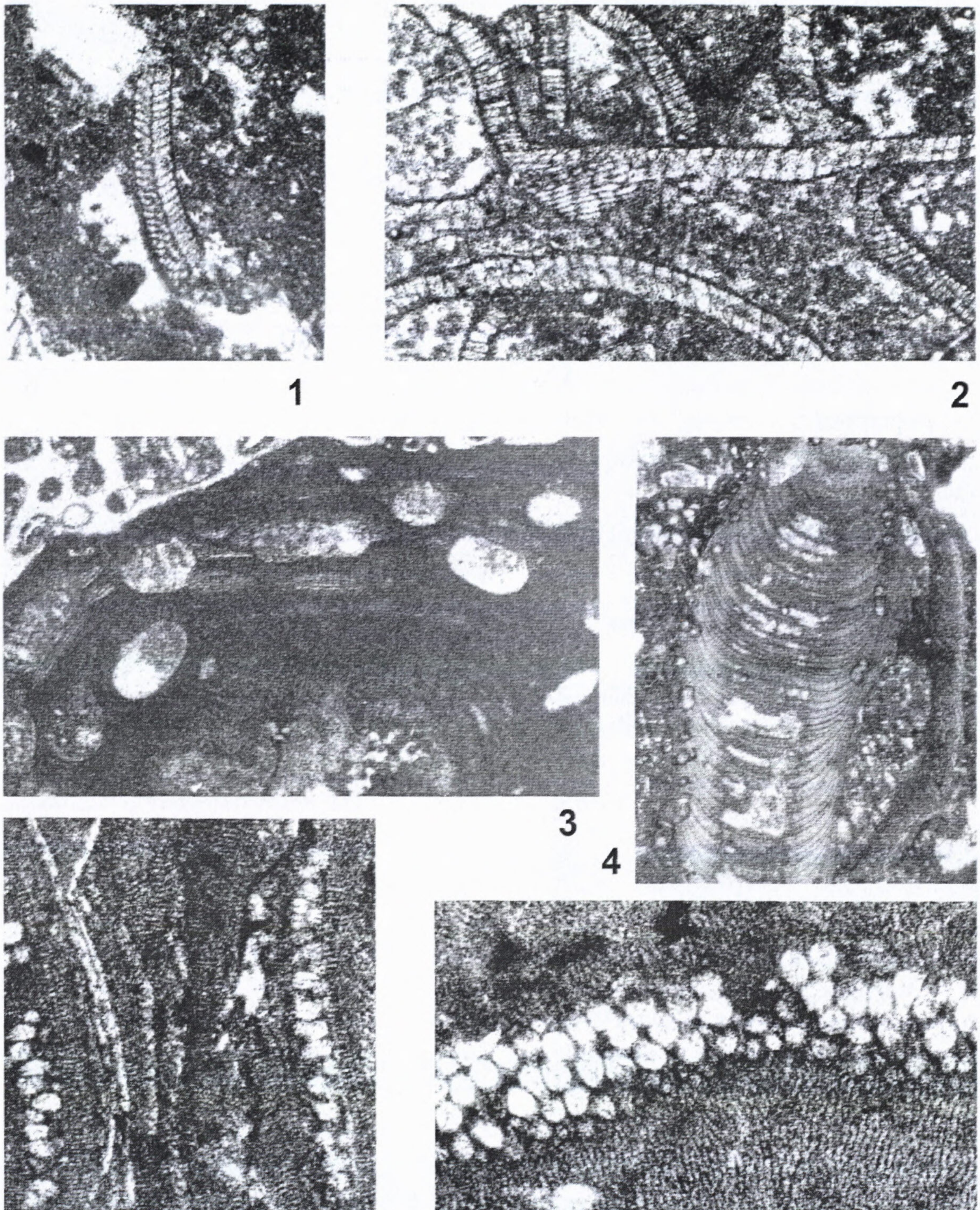

Plate 2

Fig. 1. *Distichoplax bisierialis* (DIETRICH) PIA, fragment of tissue. Sample 18, thin section 1879/91, magn. 50x; Fig. 2. *Lithoporella* sp. Sample 6, thin section 30 VL/K, magn. 80x; Fig. 3. *Mesophyllum* sp., thalus with conceptacules. Sample 19, thin section 3044/92, magn. 50x; Fig. 4. *Pseudoamphiroa propria* (LEMOINE). Sample 9, thin section 42 VL/K, magn. 30x; Fig. 5. *Sporolithon* sp., part of the thallus with sporangia. Sample 10, thin section 45 VL/K, magn. 80x; Fig. 6. Sporangia of *Sporolithon* sp. Sample 1, thin section 3 VL/K, magn. 80x. Photo by the authors.

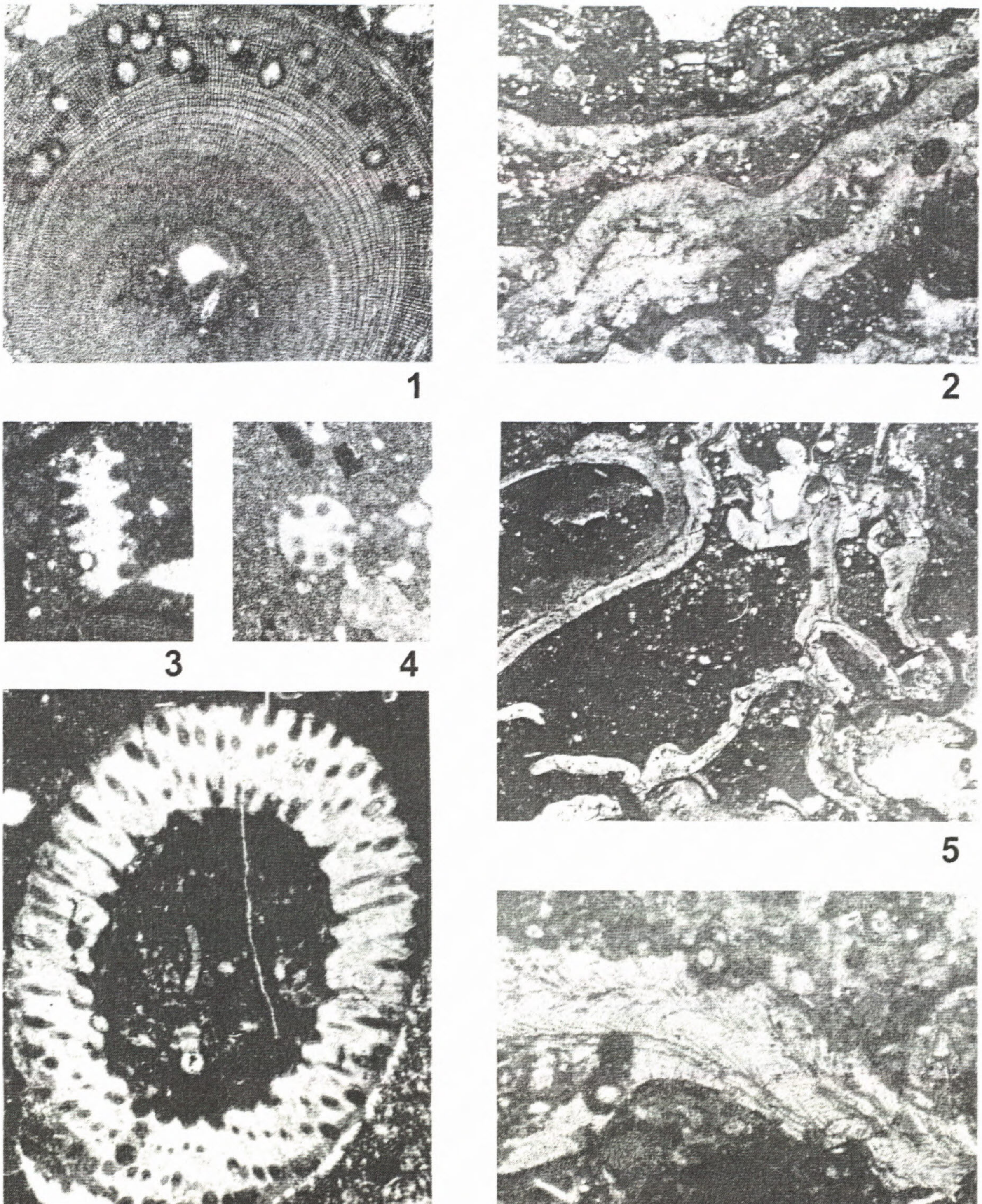

Plate 3

Fig. 1. *Pseudoamphiroa propria* (Lemoine). Sample 12, thin section 54 VL/K, magn. 50x; Fig. 2. crusts of *Cyanobacteria*. Sample 13, thin section 61 VL/K, magn. 20x; Fig. 3. *Acicularia* sp., longitudinal section. Sample 5, thin section 24 VL/K, magn. 50x; Fig. 4. *Acicularia* sp., transverse section. Sample 5, thin section 25 VL/K, magn. 50x; Fig. 5. *Polystrata alba* (Pfender) Denizot, tangle of thallii. Sample 17, thin section 1862/91, magn. 10x; Fig. 6. *Neomeris* sp. Sample 6, thin section 26 VL/K, magn. 30x; Fig. 7. *Polystrata alba* (Pfender) Denizot, thallus in longitudinal section. Sample 1, thin section 2 VL/K, magn. 50x. Photo by the authors.

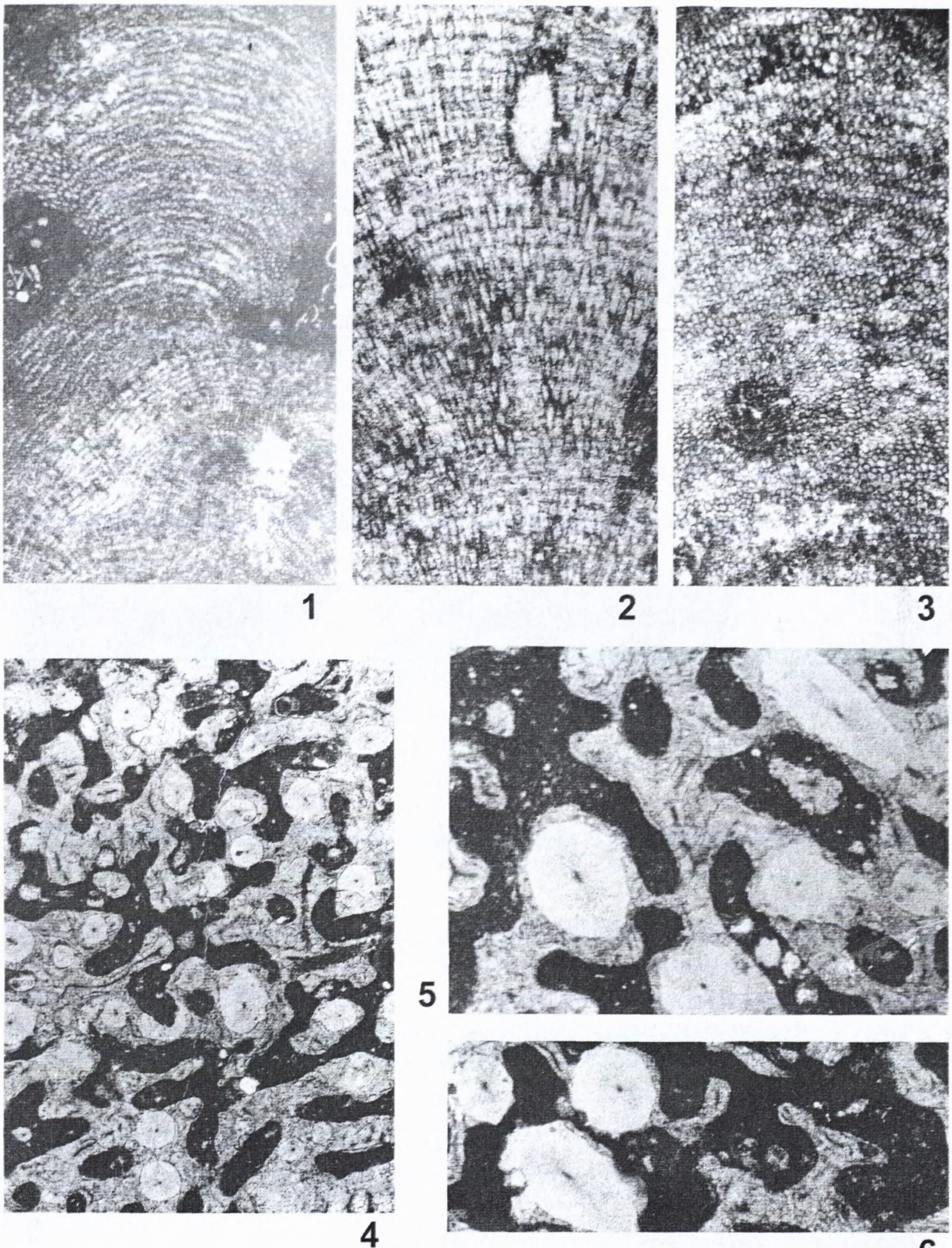

Plate 4
Fig. 1. *Elianella elegans* PFENDER et BASSE. Sample 15, thin section 71 VL/K, magn. 15x; Fig. 2. *Elianella elegans* PFENDER et BASSE. Sample 10, thin section 45 VL/K, magn. 30x; Fig. 3. *Elianella elegans* PFENDER et BASSE, tangential section. Sample 1, thin section 2 VL/K, magn. 30x; Fig. 4. *Pieninia oblonga* BORZA et MIŠÍK in coral structure. Sample 9, thin section 43 VL/K, magn. 30x; Figs. 5-6. *Pieninia oblonga* BORZA et MIŠÍK in coral tissue. Sample 9, thin section 44 VL/K, magn. 50x. Photo by the authors.

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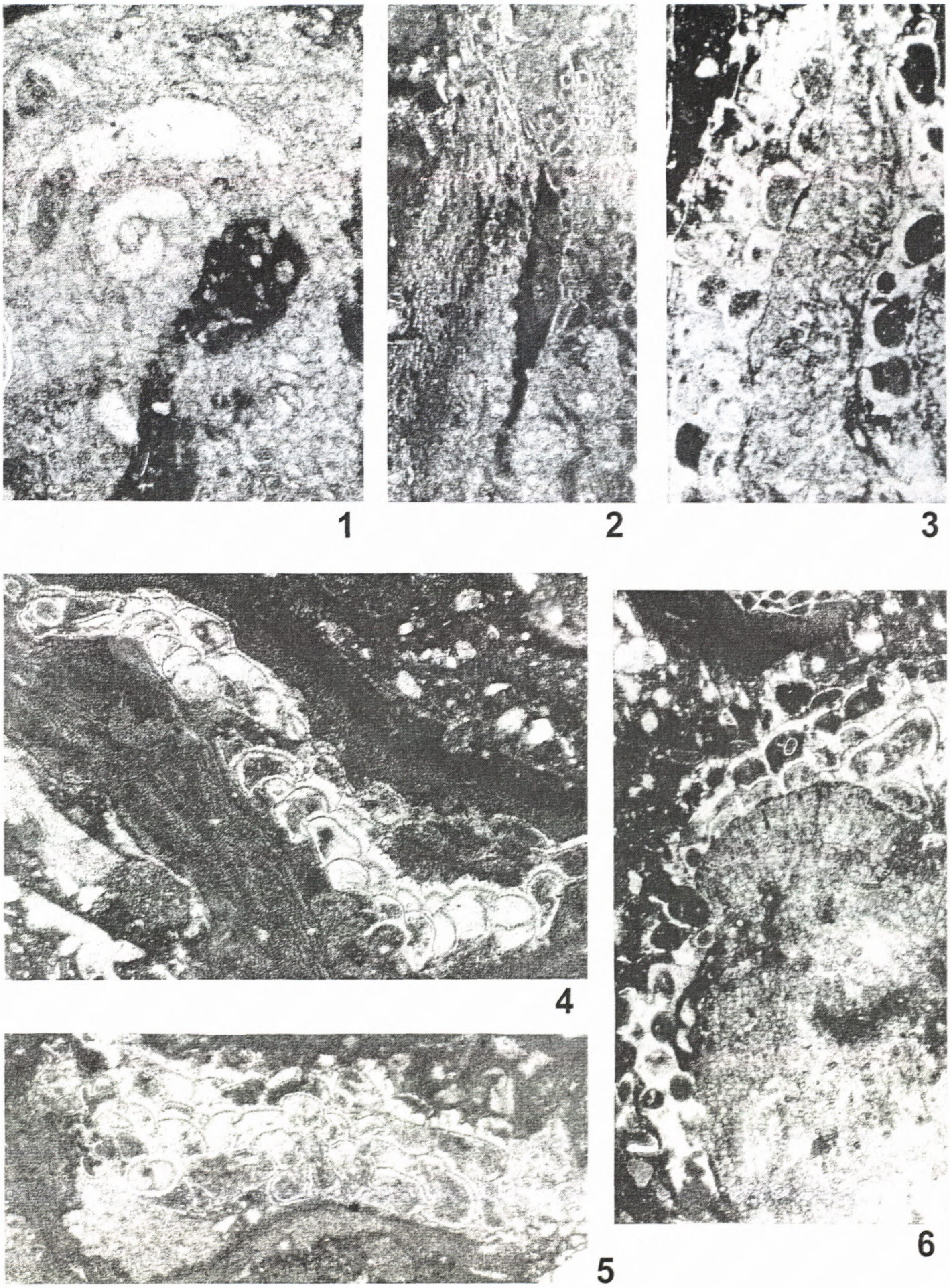


Plate 5

Fig. 1. *Solenomeris ogormani* DOUVILLÉ, central part of test. Sample 14, thin section 38 VL/K, magn. 50x; Fig. 2. *Solenomeris ogormani* DOUVILLÉ, crustose form. Sample 13, thin section 59 VL/K, magn. 50x; Fig. 3. *Planorbulina cretae* (MARSSON). Sample 2, thin section 7 VL/K, magn. 30x; Fig. 4. *Planorbulina cretae* (MARSSON). Sample 16, thin section 76 VL/K, magn. 50x; Fig. 5. *Planorbulina cretae* (MARSSON), embryonal part in left side. Sample 12, thin section 56 VL/K, magn. 50x; Fig. 6. *Planorbulina cretae* (MARSSON) encrusting the thallus of *Elianella elegans* PFENDER et BASSE. Sample 15, thin section 70 VL/K, magn. 30x. Photo by the authors.

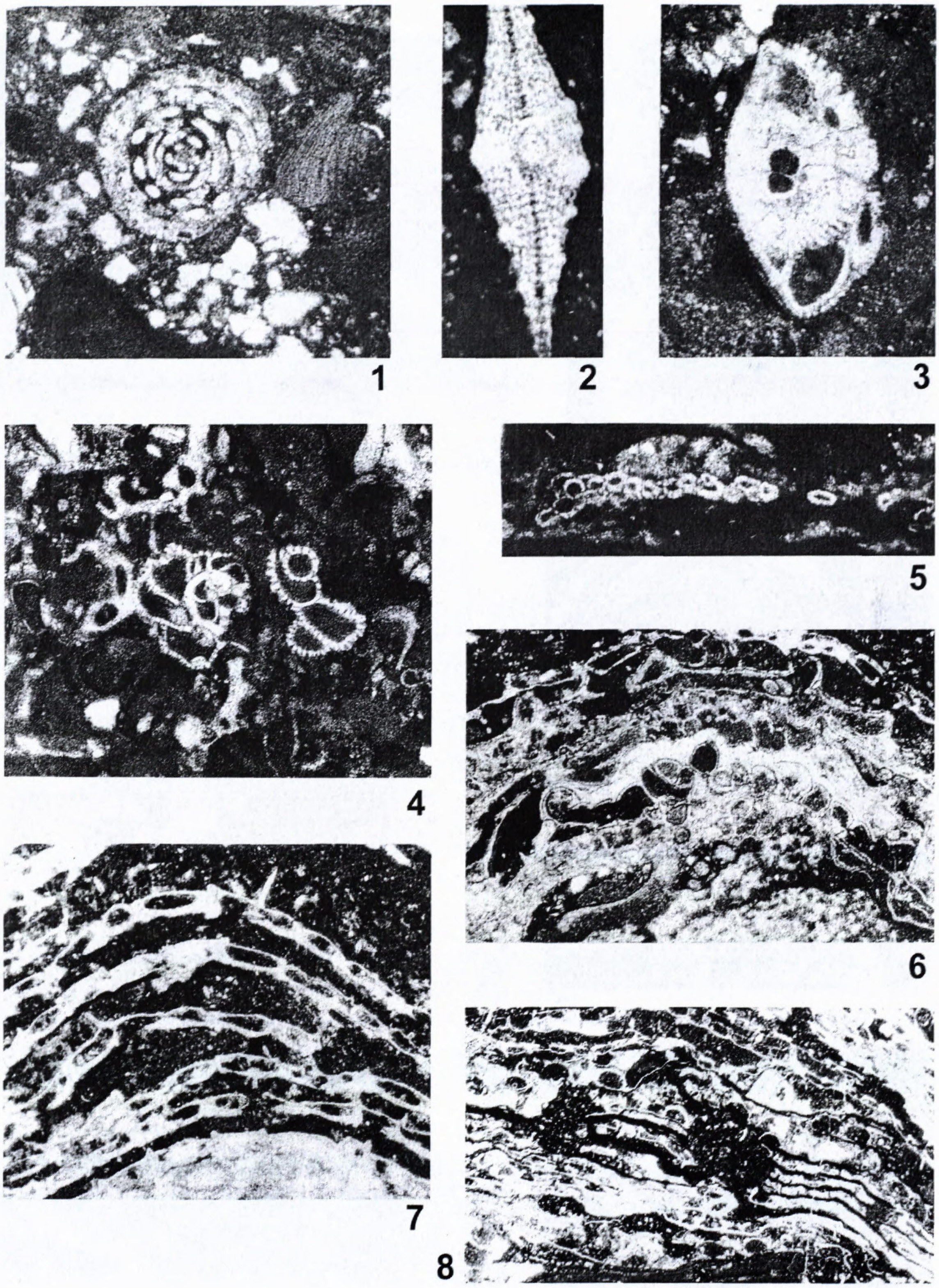


Plate 6

Fig. 1. *Alveolina* (*Glomalveolina*) *primaeva* REICHEL, oblique equatorial section. Sample 15, thin section 72 VL/K, magn. 80x; Fig. 2. *Discocyclina seunesi* DOUVILLÉ, axial section. Sample 18, thin section 1877/91, magn. 50x; Fig. 3. *Miscellanea* cf. *primitiva* (RAHAGHI) in oblique axial section. Sample 6, thin section 26 VL/K, magn. 50x; Fig. 4. *Miniacina multicamerata* (SCHEIBNER), embryonal part in right. Sample 15, thin section 71 VL/K, magn. 80x; Fig. 5. *Miniacina multicamerata* (SCHEIBNER). Sample 20, thin section 2045/92, magn. 50x; Fig. 6. *Miniacina multiformis* SCHEIBNER in crust with *Planorbulina cretae* (MARSSON). Sample 2, thin section 8 VL/K, magn. 50x; Fig. 7. *Miniacina multiformis* SCHEIBNER. Sample 7, thin section 31 VL/K, magn. 30x; Fig. 8. *Miniacina multiformis* SCHEIBNER. Sample 7, thin section 31 VL/K, magn. 30x. Photo by the authors.

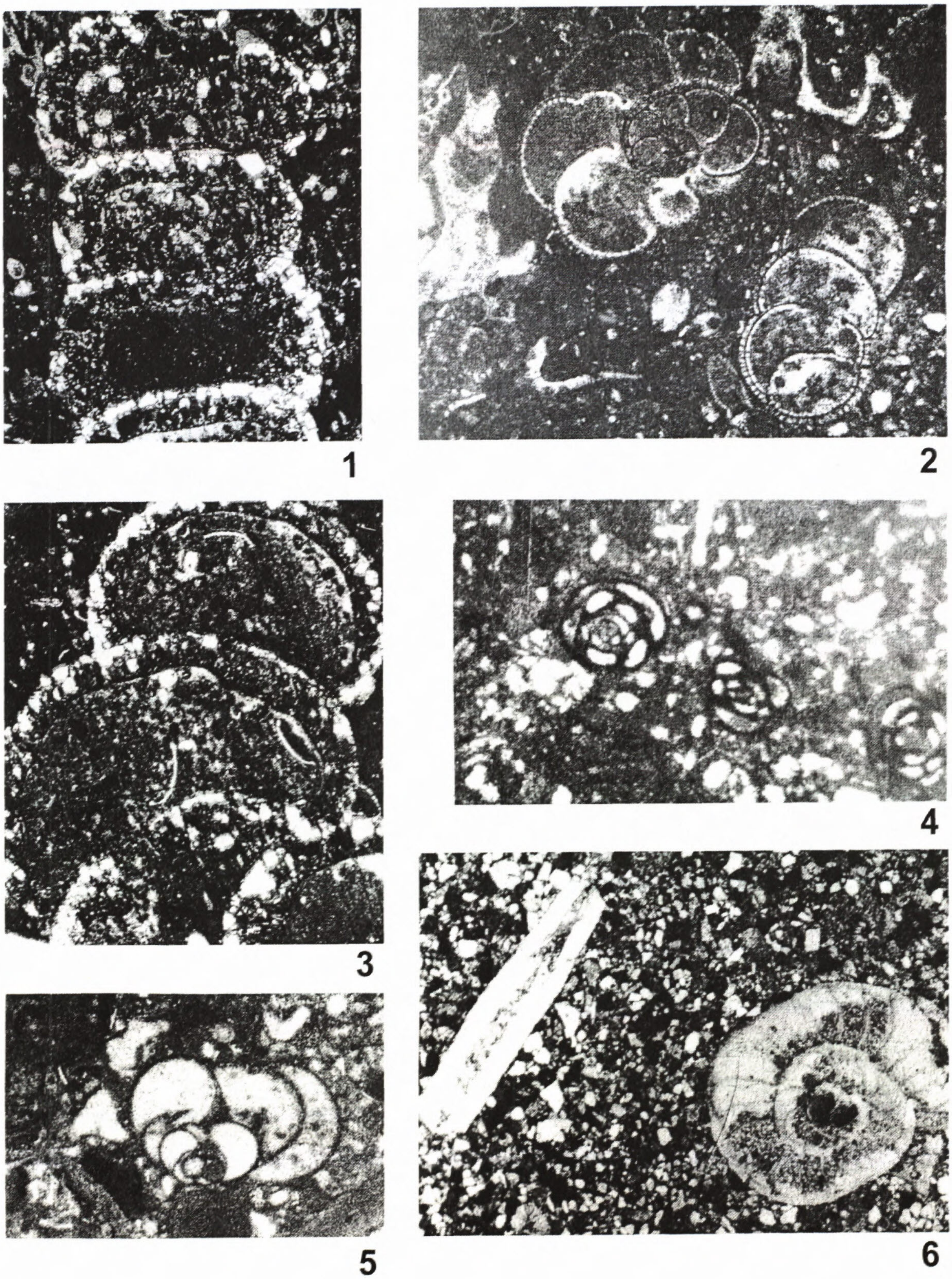
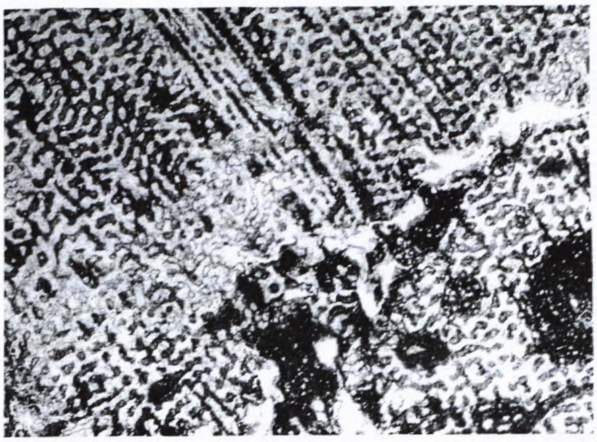


Plate 7
Fig. 1. *Acruliammina praeheissigi* (SAMUEL, KÖHLER et BORZA), axial section of chambers. Sample 9, thin section 38 VL/K, magn. 30x; Fig. 2. *Eoglobigerina pseudobulloides* (PLUMMER). Sample 17, thin section 1862/91, magn. 50x; Fig. 3. *Acruliammina praeheissigi* (SAMUEL, KÖHLER et BORZA). Sample 11, thin section 49 VL/K, magn. 30x; Fig. 4. *Miliolidae* sp. Sample 19, thin section 2034/92, magn. 50x; Fig. 5. *Spirobulimina* sp. Sample 12, thin section 57 VL/K, magn. 50x; Fig. 6. Sandstone with *Operculina azilensis* TAMBAREAU. Sample 21 (overlying beds of the reef complex), thin section 80 VL/K, magn. 20x. Photo by the authors.



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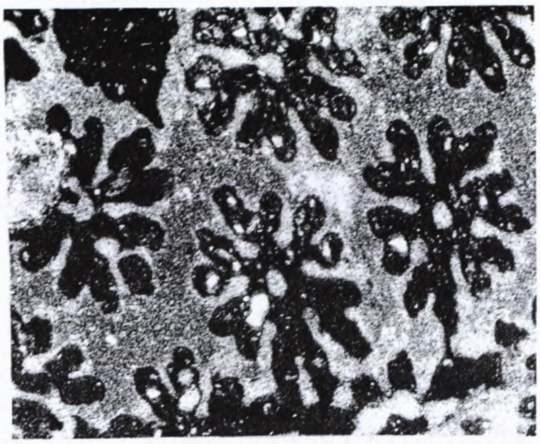

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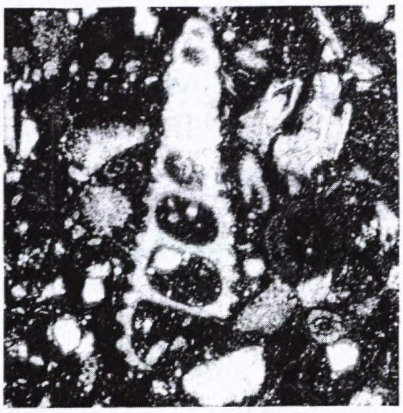

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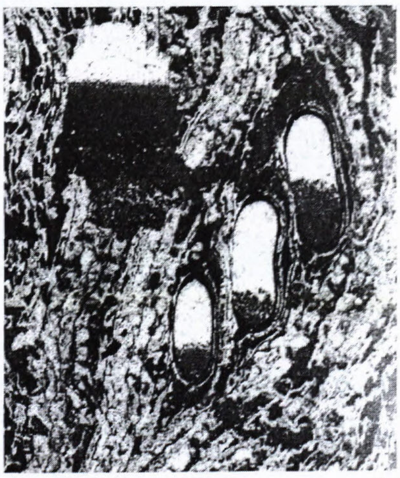

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Plate 8
Fig. 1. *Actinacis* sp. Sample 12, thin section 55 VL/K, magn. 10x; Fig. 2. *Aastrocoenia* sp. Sample 12, thin section 55 VL/K, magn. 30x; Fig. 3. Gastropod shell in axial section. Sample 8, thin section 35 VL/K, magn. 30x; Fig. 4. Gastropod shell in axial section. Sample 15, thin section 73 VL/K, magn. 30x; Fig. 5. Ostracoda shell. Sample 13, thin section 59 VL/K, magn. 50x; Fig. 6. Serpulide shell in crusts of *Miniacina multiformis* SCHEIBNER (in cavities geopetal structures). Sample 7, thin section 31 VL/K, magn. 10x; Fig. 7. *Cyclostomata* bryozoa. Sample 15, thin section 72 VL/K, magn. 50x. Photo by the authors.