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"MICROFORAMINIFERS" — A SPECIFIC FAUNA OF ORGANIC-WALLED FORAMINIFERA FROM THE CALLOVIAN-OXFORDIAN LIMESTONES OF THE PIENINY KLIPPEN BELT (WESTERN CARPATHIANS)

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Abstract: The organic linings of minute foraminifers can be naturally stained by Fe-oxides during early diagenesis. This protects them against destruction and make them visible in thin sections. Up till now the microforaminiferal linings were described only from extractions for palynological investigation. A set of morphotypes of the foraminiferal linings from thin sections of Callovian-Oxfordian limestones and Lower Cretaceous cherts is illustrated with comments. The morphological aspects of the foraminiferal linings allow us to associate them into morphogroups and form genera. Some of well-developed linings are sufficient for their generic as well as subgeneric classification enclosing more than 30 foraminiferal taxa. The reasons for the organic-walled structure of "microforaminifers" are inferred in environmental stress or dissolution of rigid tests after death. The possibility of using some linings in foraminiferal stratigraphy is discussed.

Key words: Western Carpathians, Norian, Callovian-Oxfordian, Hauterivian-Barremian, organic linings, foraminifers.

Introduction

The term microforaminifers was introduced by Wetzel (1957) for linings of juvenile parts of foraminiferal tests — chitinous membranes. The first mention concerning these objects is in the paper of Wilson & Hofmeister (1952). They found them in the palynological preparations. Due to their minute dimensions (according to most authors below 150 μm) the term microforaminifers became usual, but many authors considered it unsuitable and other synonyms were proposed: ***Scytinascia*** (Deák l964; Courtinat 1979), "basales membranes" (e.g. Taugourdeau-Lantz & Poignant 1964), microforaminiferal linings (e.g. Stancliffe 1989), chitinous linings (Tappan & Loeblich 1965), nannoforaminifers, palynoforaminifers (Pantić & Bajraktarević 1988), tapeta of foraminifers (e.g. Pacltová 1978).

State of preservation

Microforaminiferal linings are rarely preserved; in such favourable cases they can be extracted by the palynological preparation procedure. Some linings were also isolated by the cautious dissolution of the recent foraminifers by very diluted acids (Taugourdeau-Lantz & Poignant 1964; Loeblich & Tappan 1964; Cohen & Guber 1968). Up till now they were almost always reported from palynological preparations, from the insoluble residues, therefore we want to present here the first larger collection from thin sections of limestones.

The foraminiferal linings isolated by the palynological procedure can be well stained by safranin (Stancliffe 1989). Our findings are based on the fact that under the favourable conditions they can be naturally stained to a red colour by diage-

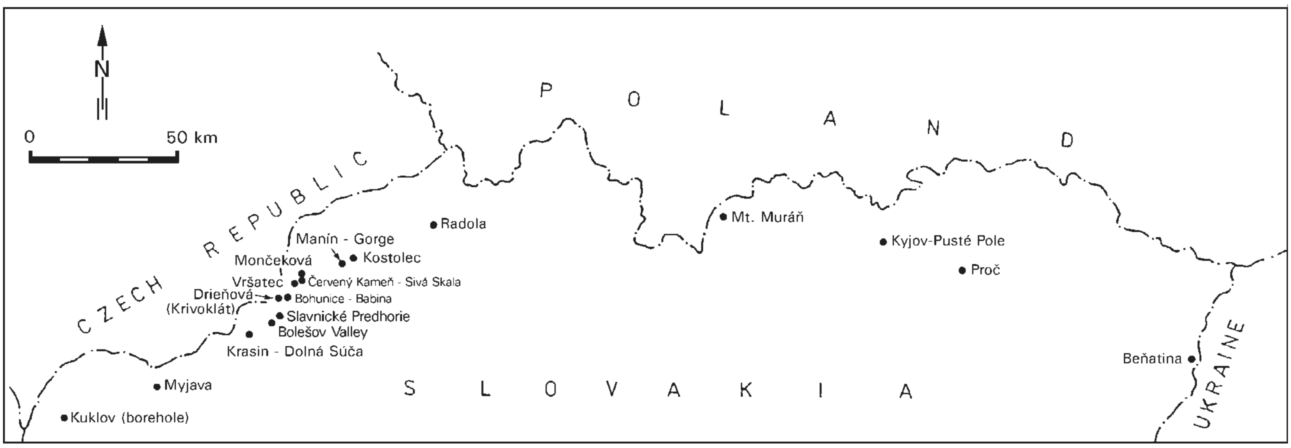

Fig. 1. Location of the cited localities with "microforaminifers" in the Western Carpathians.

netic impregnations of Fe-oxides and become visible in thin sections of limestones. The impregnation took place in an early stage of diagenesis and is a conservation agent conditioning the preservation of the microforaminiferal linings. A huge majority of non-impregnated microforaminiferal membranes are obviously destroyed during diagenesis. They are however abundant in thin sections from the studied red or reddish limestones (Pl. I: Fig. A), although part of the calcitic tests was dissolved. Their organic membranes "attracted" and concentrated the migrating Fe-oxides and acquire a deep red colour in contrast to the neighbouring parts of the limestone. Occurring rarely in the grey limestones they are also stained red, because they can trap the Fe-oxides from the very diluted solutions. We did not succeed in extracting the iron-impregnated linings using the conventional palynological methods. They probably lose their elasticity as a result of the impregnation and break down easily during the preparation.

Several microforaminiferal linings were found in thin sections from chert nodules in the Hauterivian-Barremian Muráň Limestone (Pl. VII: Figs. K, L) and chert nodule in a Tithonian pelagic limestone (Pl. VII: Fig. M); in those cases they were not impregnated by Fe-oxides. Silicites are known to be favourable for the preservation of microfossils consisting of organic compounds; e.g. in thin sections of the mentioned locality Muráň. Besides microforaminiferal linings pollen grains and *Fungisporonites* occurred there (Mišík 1990, Pl. III, IV).

The disadvantage of thin section studies of microforaminiferal linings (non-oriented sections) is counterbalanced by some advantages. Unlike palynological preparation (centrifugal procedure) specimens are not broken or additionally deformed, larger specimens are not eliminated by the separation of fine fraction (several palynologists use fraction below 0.0025 mm), some sections can render an indication of the internal structure of the test.

Possible reasons for the tiny dimensions of "microforaminifers"

The very small dimensions of the chitinous membranes are peculiar. The most common explanation is that they represent only the juvenile part of the foraminiferal test. However they could represent dwarf forms of adult individuals living under unfavourable conditions. It should be stressed that a quarter of the specimens illustrated here are from neptunian dykes filled by red micrite, others occurred in the condensed facies of "ammonitico-rosso" type. It is surprising that in our thin sections with abundant linings of juvenile tests almost no large adult representatives of the same species were found. Courtinat (1989) also stressed the fact that the found microforaminiferal types correspond neither to the foraminiferal taxa cited from the Oxfordian of the Jura Mts., nor to families known for the presence of organic linings in their tests. The lack of adult individuals corresponding to the embryonic stages could also be explained by the adult specimens living in different environments or their calcitic tests being entirely dissolved during early diagenesis, as suggested by the dissolution of younger chambers without organic linings (Pl. II: Figs. A–L), this seeming to be the most plausible explanation. The abundance of microforaminiferal linings and the rarity of adult specimens might reflect the well-known fact that in some animal groups only a small percentage of juveniles survive to the adult age. There is another theoretical possibility that some species could remain during all their lives in the juvenile state like the well-known Mexican Amphibian Axolotl. A somewhat similar solution was proposed by Deák (1964); according to her ***Scytinascia*** could have possessed an exclusively organic test. However we observed numerous cases with the red stained membrane only in the juvenile part of the preserved calcitic foraminiferal test (Pl. II: Figs. A–L). Hence, such a generalization should be discarded. The organic lining gradually thins towards the younger chambers as was noted by previous authors, too (Stancliffe 1989, p. 350; Pantić & Bajraktarević 1988, p. 956). In exception cases the lining may also be present in the adult forms of some agglutinated foraminifers (e.g. *Spiroplectinella,* Zlinská & Čtyroká 1993).

Stratigraphic horizons with "microforaminifers"

Microforaminiferal linings were found in the sediments from the Permian to the Quaternary. Stancliffe (1989, text-figure 5) summarized the papers of more than 60 authors in a table. Most of the cited authors described them from the Upper Jurassic which is also the age of our specimens. We can complete Stancliffe's list by some more authors who cited and illustrated foraminiferal linings: Soták (1986, p. 30–31, Pl. 5) from neptunian dykes of Upper Triassic? limestones (blocks in conglomeratic flysch of the Magura Unit,

Plate I: Microforaminiferal linings (basales membranes) impregnated by Fe-oxides. Fig. A — Abundant occurrence in the red nodular Czorsztyn Limestone with "filament" microfacies (juvenile planktonic bivalves *Bositra*). Oxfordian, Czorsztyn Succession, Pieniny Klippen Belt, Kyjov-Pusté Pole. Thin section No. 211127, ×40. **Fig. B** — Microforaminifer in the channel of a crinoidal columnalium. Upper Tithonian filling of a neptunian dyke. Kyjov-Pusté Pole. Thin section No. 19440, ×80. **Fig. C** — Morphotype of buliminid foraminifer (aff. *Dentalinopsis oolithica* (Terq.)). Red micrite from a neptunian dyke synchronous with the surrounding Callovian limestones, klippe Babina near Bohunice. Thin section No. 12385, ×80. **Fig. D** — Morphotype of verneulinid foraminifer (aff. *Verneuilinoides minuta* Said & Barakat). At the difference to the preceding cases it was not naturally stained. Nodular chert from the Muráň Limestone, Upper Hauterivian-Lower Barremian, southern wall of Muráň peak, Belanské Tatry Mts. Thin section No. 12520, ×120. **Fig. E** — Morphotype of trochamminid foraminifer (aff. *Trochammina squamatoformis* Kaptarenko-Chernousova). Organic membrane is finelly perforated. Callovian-Oxfordian limestones of the Vršatec-castle klippe. Thin section No. 11494, ×150. **Fig. F** — Morphotype of trochamminid foraminifer with granular structure of organic membrane. Callovian limestone, klippe Kostelec near Považská Bystrica, Kostelec Succession. Thin section No. 21205, ×100. **Fig. G** — Morphotype of textularid foraminifer (aff. *Bigenerina jurassica* (Haeusler)). Callovian-Oxfordian filling of a neptunian dyke, Vršatec-castle klippe. Thin section No. 21095, ×100.

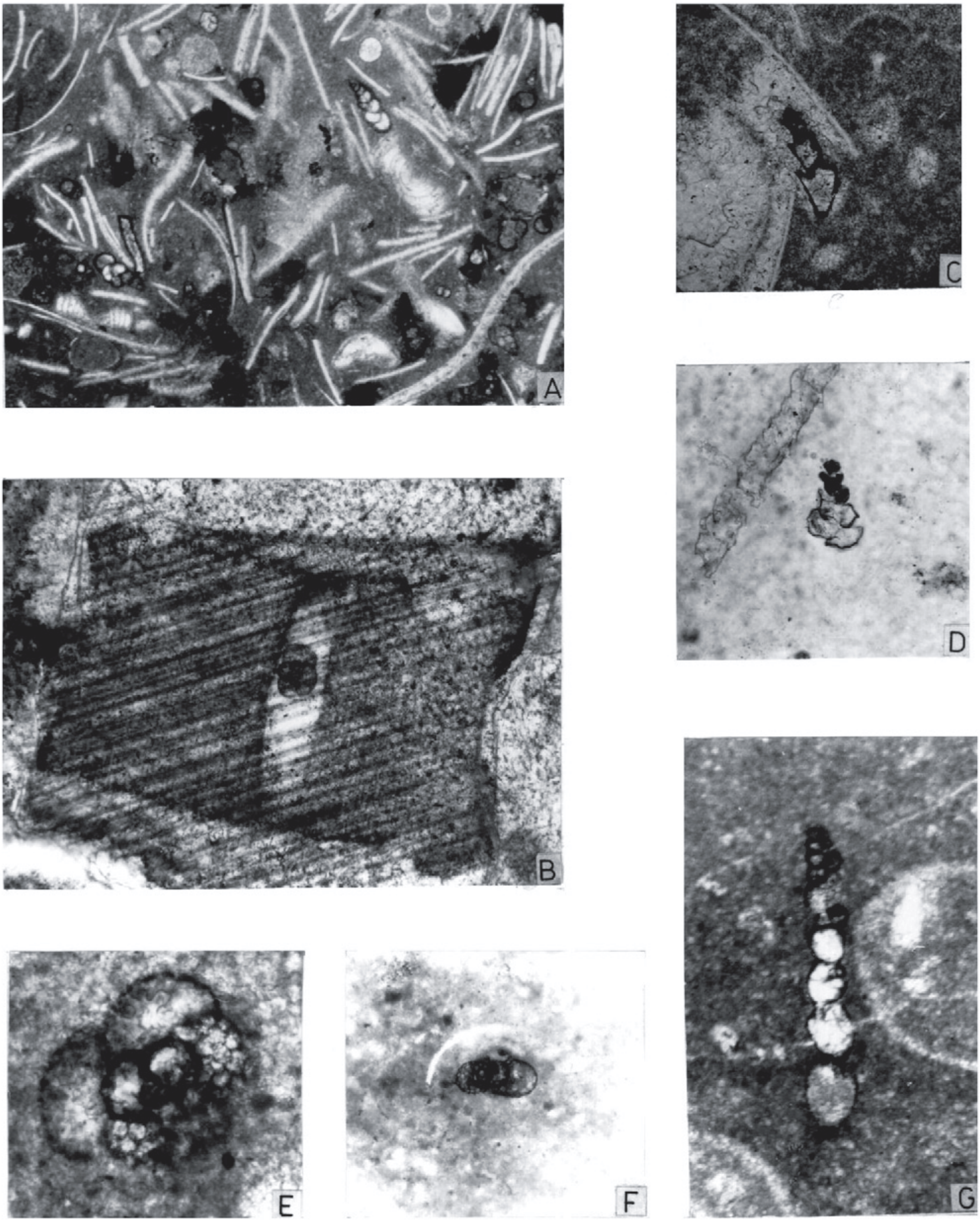
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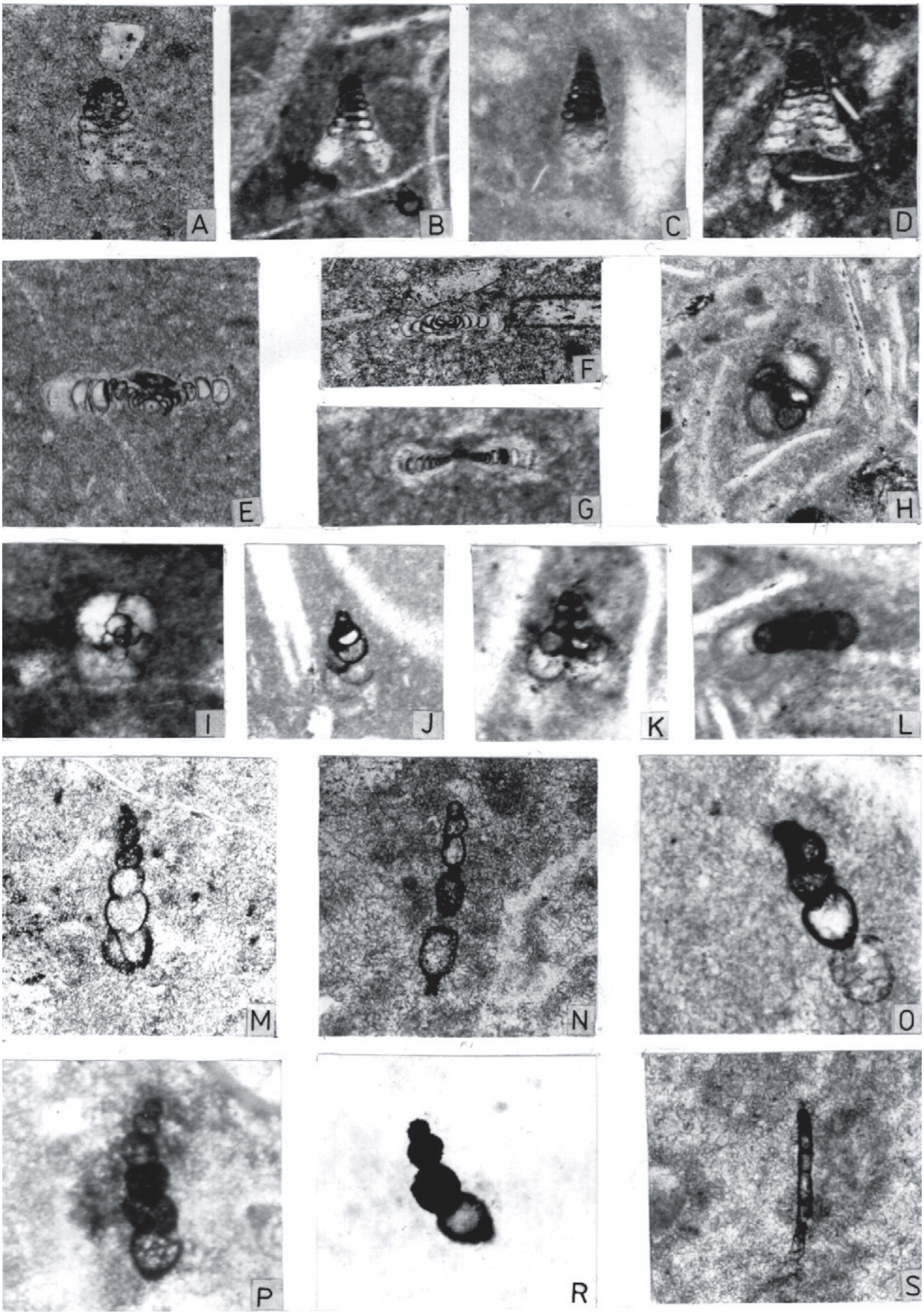
PLATE II



Western Carpathians), Derman et al. (1995, Pl. 1, Fig. 19) from the Middle Jurassic of Turkey; Čorná (1972, Pl. 11, Figs. 4–9) from the Albian of the Manín Unit, Western Carpathians; Čorná in Grün et al. (1972, Pl. 22, Figs. 8–10) from the Aptian of the Flysch Belt, Eastern Alps, Wienerwald; Snopková & Samuel (1981, Pl. LIII, Fig. 3) from the Upper Senonian to Paleocene of the Dukla Unit, Flysch Belt, Western Carpathians; Pacltová (1978, Pl. 1, Fig. 3) and Žítt et al. (1997, Pl. 5, Figs. 1–3, 9) from the Cretaceous of the Bohemian Massif; Holcová et al. (1996, Tab. 5, Fig. 12) from the Lower Badenian, South Slovakia; Head (1993, Fig. 5, 1–4) from the Pliocene of England.

We present in this paper with a kind permission V. Sitár his non-published material extracted for palynological studies from the Norian Hauptdolomite in the basement of the Slovak part of the Vienna Basin (Pl. VII: Figs. A–G) and from the Posidonia marls (Podzamcze Formation), Middle Jurrassic, Slovak part of the Pieniny Klippen Belt (Pl. VII: Figs. H–J).

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Plate II: Microforaminiferal linings (basale membranes) from the Callovian-Oxfordian limestones, Czorsztyn Succession, Pieniny Klippen Belt. Figs. A–G — Organic membranes developed only in the juvenile parts of the foraminiferal tests. They were naturally stained by Fe-oxides (black on the photos). Last chambers were dissolved; several of them are still visible as ghosts. All specimens are from the Callovian-Oxfordian limestones of the Czorsztyn Succession, Pieniny Klippen Belt (except Fig. G). Figs. A–D — Morphotype of involutinid foraminifers (*Trocholina gracilis* Blau). Limestone in the neptunian dyke filling. Klippe Babina near Bohunice. Fig. A — Thin section No. 12497, ×150. Fig. B — Klippe Kyjov-Pusté Pole. Thin section No. 21085, ×100. Fig. C — Klippe Krasin near Dolná Súča. Thin section No. 21527, ×50. Fig. D — Klippe Kyjov-Pusté Pole. Thin section No. 21101, ×100. **Figs. E–F** —Morphotype of ammodiscid foraminifers (*Glomospirella otorica* Romanova). Fig. E — Klippe in the Bolešov Valley. Thin section No. 19347, ×160. Fig. F — Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 8536, ×60. **Fig. G** — Morphotype of spirillinid foraminifer (*Semiinvoluta violae* Blau). Middle Liassic limestone, Nižná Succession, klippe Lutý Potok. Thin section No. 21177, ×100. **Fig. H** — Uncertain foraminiferal linings. Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 21091, ×100. **Fig. I** — Morphotype of trochamminid foraminifer (aff. *Trochammina pulchra* Ziegler), the same locality. Thin section No. 21096, ×100. **Fig. J** — Morphotype of textularid foraminifer (aff. *Textularia ripleyensis* Berry). As above. Thin section No. 21080, ×60. **Fig. K** — Morphotype of verneulinid foraminifer (*Verneuilinoides minuta* Said & Barakad), neptunian dyke filling, klippe Kyjov-Pusté Pole. Thin section No. 21085, ×120. **Fig. L** — Morphotype of trochamminid foraminifer, last chamber as a ghost, the same locality. Thin section No. 21107, ×100. **Figs. M–S** — Morphotype of "dentaliferous" species of ***Reophacidae – Hormosinidae***, all samples from the Callovian-Oxfordian limestones, Czorsztyn Succession. **Fig. M** — *Scherochella* aff. *minuta* (Tappan), Vršatec-castle klippe. Thin section No. 5875, ×140. **Fig. N** — *Nodulina* aff. *dentaliformis* (Brady), thin section No. 5058, ×140. **Fig. O** — *Reophax* aff. *chrysalis* (Haeusler), klippe Babina near Bohunice. Thin section No. 12479, ×230, **Figs. P–R** — *Reophax* aff. *scorpiurus* Montford, Fig. P — Klippe Kyjov-Pusté Pole. Thin section No. 23991, ×200. Fig. R — Klippe Drieňová near Krivoklát. Thin section No. 10792, ×185. **Fig. S** — *Pseudonodosinella* aff. *nodulosa* (Brady), compressed specimens, the same locality. Thin section No. 10622, ×185.

Descriptive nomenclature of "microforaminifers"

Deák (1964) proposed the term ***Scytinascia*** for the whole group of microforaminiferal linings and also formal names for some genera and species (e.g. *Ormathascia* covering straight uniserial tests of *Nodobacularia* type; *Trochiliascia* for planispiral or trochospiral tests of *Globigerinoides* type; *Rhodonascia* for the tests of *Trochammina* type etc.). Tappan & Loeblich (1965) rejected this procedure and tried to attribute some of these objects to existing families and with a question-mark up to the generic level. The term ***Scytinascia*** was rarely used (e.g. Courtinat 1989; Courtinat & Méon 1991); nobody is now introducing of new names for similar artificial taxa. Courtinat (1989) and Stancliffe (1989) used informal classification based on the morphotypes. We do not consider it useful to apply the terms of Pantić & Bajraktarević (1988), either "palynoforaminifers" for the foraminifers found in the macerate for palynomorph studies, or "nannoforaminifers s. str." for tiny foraminifers in the preparations for the study of calcareous or siliceous nannoplankton. In such a way it would be necessary to designate our material as "thin-section microforaminifers".

Comments on "microforaminifers" presented from the Western Carpathians

The large majority of the specimens reproduced on the plates comes from red Callovian-Oxfordian limestones, mainly of the Czorsztyn Succession of the Pieniny Klippen Belt, rarely from the Manín Succession (Pl. I: Fig. D; Pl. VI: Figs. H,J; Pl. VII: Figs. K,L), Kostelec Succession (Pl. I: Fig. F; Pl. III: Fig. J), from the Liassic of the Nižná Succession (Pl. II: Fig. G) and from pebbles of rocks in the Paleocene Proč Conglomerate (Pl. III: Figs. C,F; Pl. IV: Figs. E,F; Pl. V: Fig. G; Pl. VI: Fig. L). For the situation of localities see Fig. 1.

As an example of the associations with foraminiferal linings from the Callovian-Oxfordian limestones a thin section description is given (locality Kyjov-VIIa): Red biomicrite-packstone with "filaments" — foraminifer microfacies. The main constituent is "filaments" — thin juvenile bivalve shells of *Bositra* sp., non-oriented (bioturbation), rarely also fragments of thicker shells perforated by boring algae. Abundant foraminifers belong to the genera *Trocholina, Patellina*, *Ophthalmidium*, *Globuligerina*, and to the foraminiferal linings (Pl. I: Fig. A). Less frequent are echinoderm ossicles, ostracodes, sponge spicules, mainly rhaxa, filled by calcite aggregate, gastropods and exceptionally holothurian sclerites *Theelia* sp. A slight admixture of clastic quartz (silt size); microstylolites stained in red and small irregular concentrations of Fe-oxides are found.

The suspicion that sometimes not only the chitinous linings but also the calcitic wall of foraminiferal tests was replaced by iron oxides can be discarded by their simultaneous presence in the same thin sections visible on the Pl. II. Several unstained microforaminiferal linings are also figured here for the purpose of comparison. They come from thin sections of black nodular cherts in Barremian Muráň Limestone (Pl. VII: Figs. K,L) and specimens extracted by palynological procedure from the Norian Hauptdolomite with shaly intercalations (Pl. VII: Figs. A–G) and Bajocian "Supraposidonia" shales (Podzamcze Formation — Pl. VII: Figs. H–J); both kindly provided by V. Sitár.

The basal membranes (linings) from foraminiferal tests dissolved during early diagenesis are rarely wrinkled by drying and compaction (Pl. I: Figs. C,D). Sometimes they possess a granular (pitted) structure reflecting the uneven internal surface of tests agglutinated of larger particles (Pl. I: Figs. E,F). The necks between the chambers in uniserial and biserial types (Pl. I: Fig. G; Pl. II: Fig. N) are rarely preserved.

The size of all studied microforaminifers varies between 68 μm and 144 μm.

Typology of foraminiferal linings and their systematic classification

The morphologies of foraminiferal linings allow us to associate them into morphogroups and form genera, some forms could also be attributed to known taxa of Jurassic or Early Cretaceous species (cf. Haeusler 1890; Mjatljuk 1939; Wicher 1938; Dain 1972; Bartenstein & Brand 1937, 1951; Loeblich & Tappan 1950; Bielecka & Pozaryski 1954; Kaptarenko-Chernousova 1959; Seibold 1960; Neagu 1972; Kuznetsova & Gorbachik 1985; Blau 1987a,b; Weidlich 1990; Nagy & Johansen 1991; Neagu & Neagu 1995, etc.).

Morphotypes of textularid, bolivinid and buliminid foraminifers

The linings of this morphogroup are triangular shape, biserially coiled and globularly or cuneately chambered. Series of chambers are joined by narrow necks forming a zigzag proliferation between them (e.g. Pl. VII: Figs. C,D). Such morphotypes of lininigs respond to the Stancliffe's "oblique necks giving a zigzag appearence" in his biserial type I. Some of them are also consistent with Courtinat's (1989) biserial type S2. Among linings of this morphogroup the four main form genera are recognizable — ***Textularia*** (aff. *T. anglica* Lalicke — Pl. IV: Figs. I–S; *T. ripleyensis* Berry — Pl. II: Fig. J), ***Bolivina*** (aff. *B. rhumbleri* Franke — Pl. IV, Figs. A–C), ***Pseudobolivina*** (aff. *P. variana* Eicher — Pl. IV: Figs. E–H; Pl. VII: Figs. C–E; *P. clavellata* (Loeblich & Tappan) — Pl. III: Fig. B) and ***Dentalinopsis*** (aff. *D. oolithica* (Terq.) — Pl. I: Fig. C). This morphogroup also includes biserial forms later abruptly reduced to a uniserial and rectilinear stage with terminal aperture. Considering the biseriallity of these forms they could not be triserial ataxophragmiids (e.g. *Gaudryinella*), but probably a textularid species of the genus ***Bigenerina*** (*B. jurassica* (Haeusler) — Pl. I: G; Pl. III: I,J — a species with wholly uniserial and not lax-uniserial adult stage as in the emended species of *Bicazammina* Neagu & Neagu 1995) and the genus ***Haghimashella*** (*H. arcuata* (Haeusler), emend. Neagu & Neagu 1995 — Pl. III: Figs. G–H; Pl. V: Fig. O).

Morphotypes of ataxophragmiid and verneulinid foraminifers

The linings of this morphogroup occur as trochoidal tests with triserial chambers and interiomarginal aperture. They are developed as triserial high-spired forms (*Verneuilinoides minuta* Said & Barakat — Pl. I: Fig. D; Pl. II: Fig. K), conical forms coiled in 2–3 whorls (*Duotaxis metula* Kristan — Pl. V: Fig. 6, Jurassic foraminifers originally referred as ***Tetrataxis*** are thought to be a synonymum of ***Duotaxis*** — Fugagnoli 1996) and forms with sutures depressed in growth axis (*Belorussiella* aff. *bolivinaeformis* Akimets — Pl. III: Figs. E–F).

Morphotypes of trochamminid, haplophragmoid and lituolid foraminifers

This morphogroup encloses a number of lininigs registrated in the thin sections as well as in the palynological preparations. Some of the low-spired linings in our thin sections show a close similarity to the species of *Trochammina squamatoformis* Kaptarenko-Chernousova (Pl. I: Fig. E), *Trochammina pulchra* Ziegler (Pl. II: Fig. I) and *Trochammina globoconica* Tyszka & Kaminski (Pl. V: Fig. D). Small Globigerina-shaped linings (Pl. V: Figs. A–B) of this morphogroup correspond to the trochamminid species *Ammoglobigerina canningensis* (Tappan) and *A. globigeriniformis* (Parker & Jones). Other specimens with subcircular outline, planispiral whorls and trapezoid-shaped chambers could be attributed to the form genera ***Recurvoides*** (Pl. VI: Figs. A, C–D, E–G, K). Among the thin section microforaminifers there are also linings resembling in their appearance ***Ammobaculites*** (*A. irregularis* (Gümbel)), ***Bulbobaculites*** (*B. oviloculus* Nagy & Johansen) and ***Haplophragmium*** sp.

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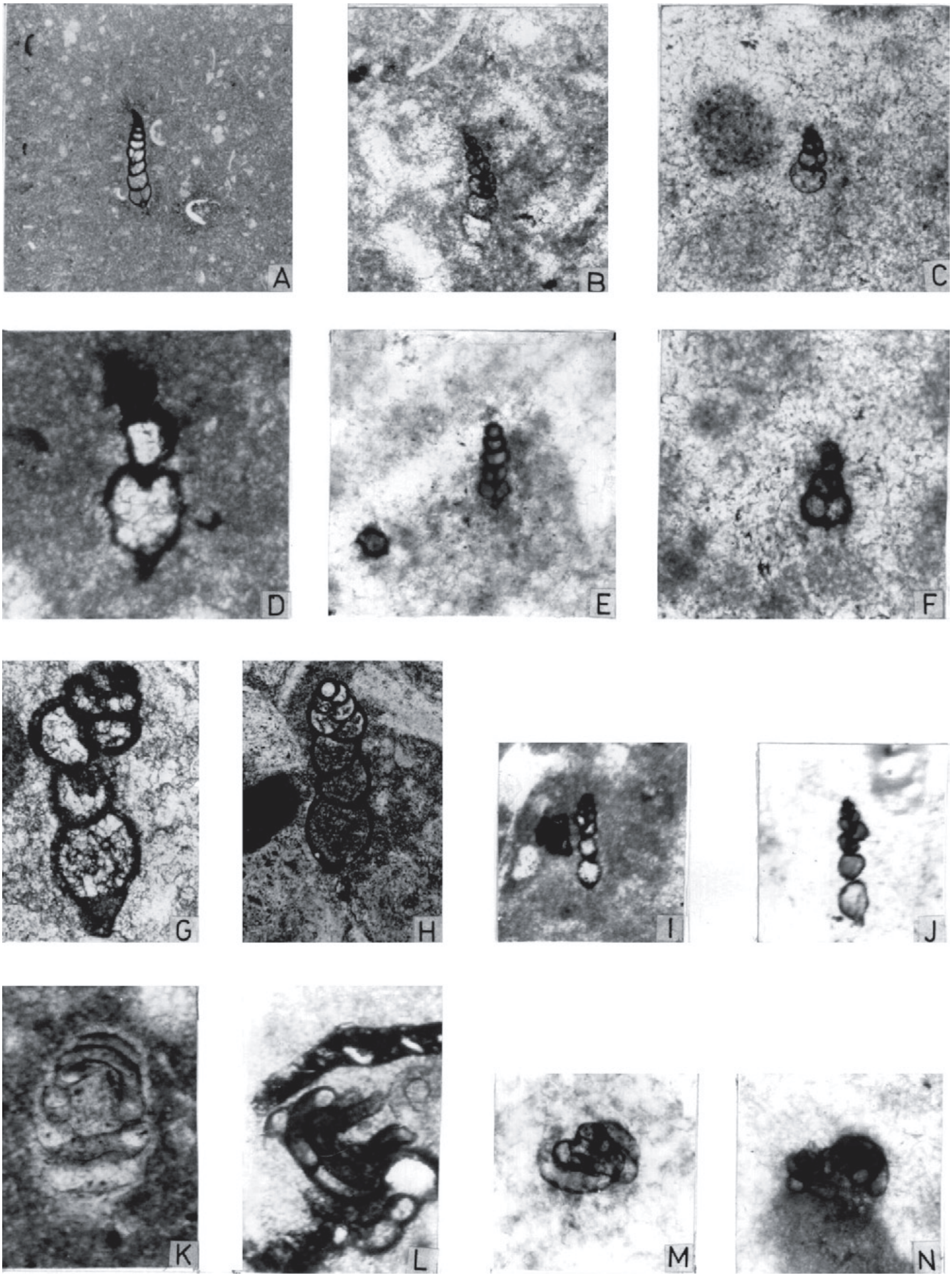
Plate III: Microforaminiferal linings (basale membranes) from the Callovian-Oxfordian limestones, Czorsztyn Succession, Pieniny Klippen Belt (except Figs. C,F). **Fig. A** — Lining of "dentaliferous" species of ***Hormosinidae*** (aff. *Scherochella minuta* (Tappan)). Klippe Krasin near Dolná Súča. Thin section No. 21117, ×80. **Figs. B–C** — Morphotype of bolivinid foraminifers. Fig. B — *Pseudobolivina* aff. *clavellata* (Loeblich & Tappan). Thin section No. 19558, ×120. Fig. C — *Pseudobolivina* aff. *variana* Eicher, pebble of the Liassic limestone in the Paleocene Proč Conglomerate, Klippen Belt. Beňatina-II-108. Thin section No. 17167, ×185. **Fig. D** — "dentaliferous" lining of ***Reophacidae*** (aff. *Reophax scorpiurus* Montfort), klippe Krasin near Bohunice. Thin section No. 19487, ×100. **Figs. E–F** — Morphotype of verneulinid foraminifers with sutures depressed in growth axis (aff. *Belorussiella bolivinaeformis* Akimets) Fig. E — Klippe Babina near Bohunice. Thin section No. 20181, ×160. Fig. F — Thin section No. 17168, ×185. **Figs. G–H** — Linings of textularid species *Haghimashella arcuata* (Haeusler), Vršatec-castle klippe. Thin section No. 7005, ×136. Fig. H — Klippe Kyjov-Pusté Pole. Thin section No. 17187, ×100. **Fig. I–J** — Linings of textularid species *Bigenerina jurassica* (Haeusler). Fig. I — Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 12221, ×150. Fig. J — Klippe Kostelec, Kostelec Succession. Thin section No. 11633, ×185. **Figs. K–M** — Morphotype of nubeculariid foraminifers (*Nubecullinella infraoolithica* (Terq.)) Fig. K — Klippe Krasin near Dolná Súča. Thin section No. 23892, ×200. Fig. L — Klippe Kyjov-Pusté Pole. Thin section No. 23991, ×170. **Figs. M–N** — Morphotype of nubeculariid? foraminifers. Fig. M — Klippe Mončeková near Červený Kameň. Thin section No. 10797, ×270. Fig. N — Klippe Babina near Bohunice. Thin section No. 20191, ×160.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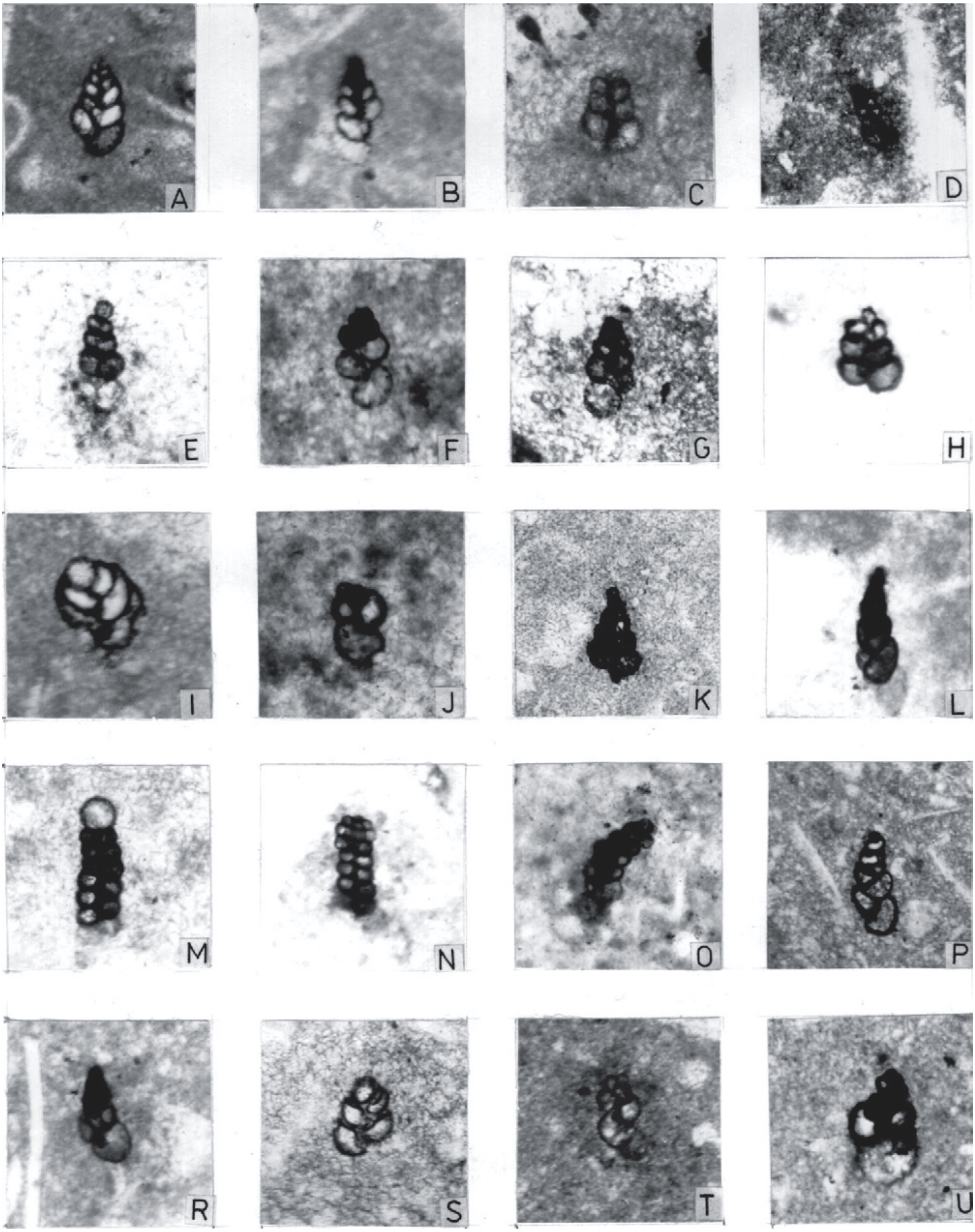
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The foraminiferal linings extracted from the Upper Triassic (Pl. VII: Figs. A,B) and Middle Jurassic sediments (Pl. VII: Figs. H,J) and in the thin sections of silicites (Pl. VII: Figs. K–M) show the same appearance of linings illustrated from the palynological preparations. In Stancliffe's nomenclature they are linings of planispiral type III and IV. Courtinat (1989) quoted them from the Oxfordian as PS type. Derman et al. (1995, Pl. I: Fig. 19) illustrated them from the Middle Jurassic. Deák (1964, Pl. X, Figs. 17–19) cited them from the Albian under the name *Trochiliascia cuvillieri*; Macko (1963) from the Turonian under the name *Knasteria spiralis*, Čorná (1972, Pl. XI: Figs. 4,8) from the Albian, Čorná in Grün et al. (1972, Pl. 22: Figs. 8–10) from the Aptian; Sidó (1975) equally from the Aptian as species of *Globigerinelloides algerianus* Cushman & Ten Dam and *Hedbergella* sp., Pacltová (1978, Pl. I: Fig. 3) from the Upper Cretaceous; Pantić & Bajraktarević (1988, Pl. I: Figs. 11–23; Pl. II: Figs. 4–10) from the Cenomanian; Head (1993, Fig. V: 1–4) from the Pliocene.

Morphotypes of our extracted linings (Pl. VII: Figs. A–B, E–M) show an ovate proloculus followed by planispirally or low-trochospirally enrolled, evolute or slightly embracing coils. The chambers are piriferous, lobate on periphery, joined by intracameral necks on the umbilical side. Sutures are deeply depressed, backwards and expanding from the outer wall. The features described are diagnostic for a wider range of foraminiferal taxa. Nevertheless, they should be rather agglutinated foraminifera which normally secreted thick organic inner layers with a high iron, sulphur and magnesium content (e.g. ***Trochamminacea*** — Brönnimann & Whittaker 1988). Considering the morphological aspects and agglutinated nature of these linings, they could be attributed to the form genera ***Haplophragmoides*** (aff. *H. concavus* (Chapman) — Pl. VII: Figs. A–B, K–M; aff. *H. globigerinoides* (Haeusler) — Pl. VII: Figs. F–G) and ***Trochammina*** (aff. *T. inflata* (Montagu) — Pl. VII: Figs. H–J).

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Plate IV: Microforaminiferal linings from the Callovian- Oxfordian limestones, Czorsztyn Succession, Pieniny Klippen Belt (except Figs. E,F,J). **Figs. A–C** — Morphotype of bolivinid foraminifers (aff. *Bolivina rhumbleri* Franke). Fig. A — Klippe Sivá Skala near Červený Kameň. Thin section No. 21183, ×60. Fig. B — Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 21080, ×120. Fig. C — Klippe Kyjov-Pusté Pole. Thin section No. 19438, ×240. **Figs. D–H, J–L, O–R, T–U** — Morphotype of bolivinid foraminifers (aff. *Pseudobolivina variana* Eichler). Fig. D — Klippe Kyjov-Pusté Pole. Thin section No. 18018, ×80. Fig. E — Liassic limestone pebble from the Paleocene Proč Conglomerate, Beňatina-II-108. Thin section No. 17168, ×185. Fig. F — As above. Thin section No. 16443, ×180. Fig. G — Klippe Krasin near Dolná Súča. Thin section No. 21098, ×160. Fig. H — Klippe Kyjov-Pusté Pole. Thin section No. 21107, ×120. Fig. J — Klippe Kostelec, Kostelec Succession. Thin section No. 11633, ×185. Fig. K — Klippe Babina near Bohunice. Thin section No. 12479, ×115. Fig. L — Klippe Drieňová near Krivoklát. Thin section No. 9614, ×130. section No. 10792, ×185. Fig. O — As above. Thin section No. 11379, ×185. Fig. P — Neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 12479, ×100. Fig. R — Klippe Kyjov-Pusté Pole. Thin section No. 2399l, ×200. Fig. T — Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 23383, ×145. Fig. U — Neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 12479, ×230. **Figs. I,S** — Morphotype of textularid foraminifers (aff. *Textularia anglica* Lalicker). Fig. I — Klippe near Krivoklát. Thin section No. 12221, ×150. Fig. S — Klippe Hrebeň near Červený Kameň. Thin section No. 2393l, ×200. **Figs. M–N** Morphotype of *Turriglomina*-like linings comparable also with a tube-like "placentoid" forms of ***Reophacidae*** (e.g. *Subreophax scalaria* Grzybowski). Fig. M — Klippe near Slávnické Predhorie. Thin section No. 21370, ×150. Fig. N — Klippe Krasin near Dolná Súča. Thin section No. 21117, ×100.

Morphotypes of involutinid, ammodiscid and spirillinid foraminifers

This morphogroup encloses conical or discoidal forms with trochospiral, planispiral and/or streptospiral coiling. Based on coiling type, there are the wholly trochospiral forms of the genus ***Trocholina*** (*T. gracilis* Blau — Pl. II: A–D), wholly planispiral forms of the genus ***Spirillina*** (*S. elongata* Bielecka & Pozaryski — Pl. V: Fig. H) and ***Ammodiscus*** (*A. varians* Kaptarenko-Chernousova — Pl. V: Fig. G), faintly trochospiral forms with shallow umbilical side of the genus ***Semiinvoluta*** (*S. violae* Blau — Pl. II: F), early streptospiral and later planispiral forms of the genus ***Glomospirella*** (*G. otorica* Romanova — Pl. II: Figs. E–F; *G. reata* (Eicher) — Pl. V: Fig. P) and trochospiral forms close to the genus ***Arenoturrispirillina*** (Pl. V: Fig. H). The organic linings of these forms are commonly reduced on juvenile parts of the calcareous tests (e.g. Pl. II: Figs. B,D,E).

Morphotypes of "dentaliferous" foraminifers

An uncertain morphogroup of rectilinear forms with uniserial chambers almost non-overlapping or slightly overlapping, mostly spheric or strongly elongated (Pl. II: Figs. M–S; Pl. III: Fig. A). The maximal number of eight chambers displays the specimen Pl. III: Fig. A with a small proloculus. Due to the lack of outer tests the attribution of these linings is not so evident. Some of them show appearance of ***Nodosariidae***. However, the co-occurrence of "dentaliferous" linings with true nodosariids makes it possible to attribute them to another taxa, most probably to multilocular forms of ***Reophacidae*** and ***Hormosinidae*** (*Reophax* aff. *helveticus* (Haeusler) — Pl. III: Fig. D; *R.* aff. *scorpiurus* Montfort — Pl. II: Figs. P–R; *R.* aff. *chrysalis* (Haeusler) — Pl. II: Fig. O; *Nodulina* aff. *dentaliformis* (Brady) — Pl. II: Fig. N; *Scherochella* aff. *minuta* (Tappan) — Pl. III: Fig. A; Pl. II: Fig. M; *Pseudonodosinella* aff. *nodulosa* (Brady) — Pl. II: Fig. S), which as agglutinated foraminifera secreted exclusively chitinous linings (Jakovleva 1979). This attribution is also supported by the raised apertural necks between successive chambers (Pl. III: Fig. D). Similarly, some other foraminiferal linings are also comparable to ***Reophacidae***. Such linings are shown on Pl. IV: Figs. M–N having a large sphaerical proloculus (macrosphaerical forms — Fig. M) or plani/streptospiral segment (microsphaerical forms — Fig. N) followed by helicoidal stage with several loops (max. 6) around the axis of the columella. These meandrospiroid? and later tubiform specimens (Pl. IV: Figs. M–N) recall the Triassic representatives of ***Turriglominidae*** Zaninetti (from the Lower Cretaceous they have been illustrated by Altiner 1991 as *Meandrospiranella* sp., Pl. 13: Figs. 6–8), but also a tube-like “placentoid” forms of ***Reophacidae*** (morphotype of *Subreophax scalaria* Grzybowski).

Morphotypes of nubeculariid foraminifers

Some of these linings are irregularly shaped having an ovate proloculus and tabular swollen chambers. They correspond to the species of *Nubecularia mazoviensis* Bielecka & Pozaryski (Pl. VI: Figs. B, H–J, M–N). Other forms (Pl. III: Figs. K–L) are characterized by extremely elongated mostly narrow chambers of irregular width — *Nubecullinella infraoolithica* (Terquem). A number of nubeculariids correspond to the species of *Nodophthalmidium jurassicum* Carozzi.

Morphotypes of uncertain linings

The linings of this morphogroup remain insufficiently known for recognition (Pl. III: Figs. M–N; Pl. V: Figs. J–N; Pl. VI: Figs. O,S,U). They are usually developed as multilocular specimens with subglobular chambers (e.g. Pl. V: Fig. J). The glomerate-types of these linings show a certain similarity to the saccamminid foraminifers of the genus ***Sorosphaera*** (e.g. Pl. V: Fig. J) and ***Thuramminopsis*** (*T.* aff. *canaliculata* Haeusler — e.g. Pl. V: Fig. N). Some of them may not pertain to foraminifera.

Conclusions

In spite of the frequent occurrences of microforaminiferal linings in the palynological preparations no attempts to use them for the systematical classification were made. The foraminiferal linings from the Callovian-Oxfordian limestones were sometimes impregnated by Fe-oxides during early diagenesis, mainly in red micrites, what contributed to their preservation and made them easily visible in thin sections. Such impregnated organic membranes lost their plasticity, became brittle and cannot be extracted by palynological methods. A set of microforaminiferal linings from the thin sections mainly from the Callovian-Oxfordian limestones, most of them from the neptunian dyke filling, is presented herein. The morphological aspects of the foraminiferal linings were used to associate them into morphogroups (foraminifers of similar morphotypes) and form genera (foraminifers with incomplete generic identity). Furthermore, some linings appear to be sufficient for their generic as well as subgeneric classification. Among the linings, more than 30 foraminiferal genera and species have been classified, belonging mostly to the agglutinated taxa (***Textulariidae, Pseudobolivinidae, Ataxophragmiidae, Verneulinidae, Trochamminidae, Reophacidae, Hormosinidae, Haplophragmoidae, Lituolidae, Nubeculariidae, Saccamminidae,*** etc.). Therefore, the linings should be preferentially derived from the agglutinated foraminifers (with the exception of some spirillinids and involutinids), which secreted organic tests better than others (e.g. Jorgensen 1977).

The problem of “microforaminifers” consists in the lack of agglutination in the tests, which are normally agglutinated. In spite of this the linings show a complete morphological organization, but they ceased developing in the organic phase of test construction. Their tiny dimensions and incomplete preservation indicates a stress sedimentary biotope of “microforaminifers” (e.g. neptunian dykes). Therefore, the abundant occurrence of “microforaminifers“ in the Callovian-Oxfordian limestones could be caused by physiochemical conditions of sedimentation and early diagenesis. The agglutinates are epipsammitic forms, which take from the sediment the grains they need to build rigid tests. Considering the slow deposition rate of the Callovian-Oxfordian limestones (starvation, strong condensation, omission surfaces, etc.), the foraminifers could not survive in the absence of building material for the test agglutination. Another possibility is a total etching of the inorganic part of the tests (submarine dissolution, bacterial and algal activity, post-mortem abrasion, etc.). The abundance of agglutinated foraminifers usually increases with slower sedimentation rate (Gradstein 1983). The Czorsztyn swell of the Pieniny Klippen Belt is thought to be upwelling area with slow deposition and a nutrient-rich environment. According to Tyszka & Kaminski (1995) these factors con-

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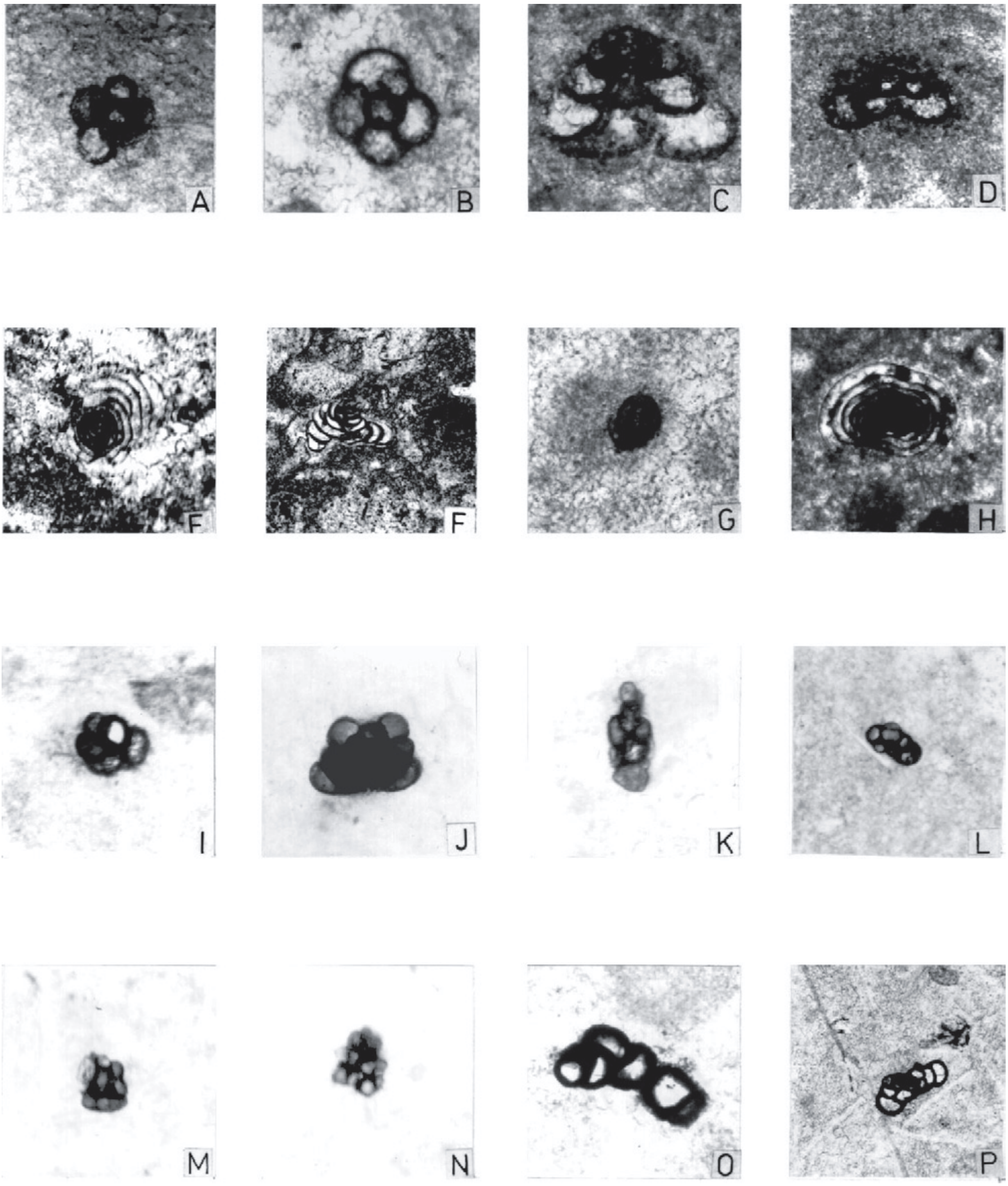
Plate V: Microforaminiferal linings from the Callovian-Oxfordian limestones, Czorsztyn Succession, Pieniny Klippen Belt (except Fig. G). **Figs. A–B** — Globigerina-shaped linings of trochamminid foraminifers (aff. *Ammoglobigerina globigeriniformis* (Parker & Jones)). Fig. A — Vršatec-castle klippe. Thin section No. 8528, ×200. Fig. B — Klippe Kyjov-Pusté Pole. Thin section No. 20437, ×150. **Fig. C** — Verneulinid foraminifer stained by Fe-oxides (*Duotaxis metula* Kristan). Klippe Babina near Bohunice. Thin section No. 12497, ×120. **Fig. D** — Trochamminid foraminifer — *Trochammina globoconica* Tyszka & Kaminski, Klippe Krasin near Dolná Súča. Thin section No. 21098, ×160. **Figs. E–H** — Morphotypes of spirillinid and ammodiscid foraminifers. Fig. E — *Glomospirella* aff. *otorica* Romanova, neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 12479, ×150. Fig. F — *Arenoturrispirillina* sp., neptunian dyke filling, klippe Kyjov-Pusté Pole. Thin section No. 17181, ×100. Fig. G — *Ammodiscus varians* Kaptarenko-Chernousova, pebble from the Paleocene Proč Conglomerate of the Klippen Belt, Beňatina-II-108. Thin section No. 17168, ×185. Fig. H — *Spirillina elongata* Bielecka & Pozaryski, neptunian dyke filling, Vršatec-castle klippe. Thin section No. 21091, ×100. **Fig. I** — Morphotype of bolivinid foraminifer. Sivá Skala klippe near Červený Kameň. Thin section No. 9588, ×120. **Fig. J** — Morphotype of saccamminid foraminifer (aff. *Sorosphaera* sp.). Klippe Drieňová near Krivoklát. Thin section No. 10792, ×185. **Figs. K–M** Uncertain foraminiferal linings. Fig. K — Sivá Skala klippe near Červený Kameň. Thin section No. 9611, ×100. Fig. L — Klippe Mončeková near Červený Kameň. Thin section No. 10343, ×185. Fig. M — Klippe Kyjov-Pusté Pole. Thin section No. 21101, ×150. **Fig. N** — Morphotype of saccamminid foraminifer (aff. *Thuramminopsis canaliculata* Haeusler). Klippe Krasin near Dolná Súča. Thin section No. 21098, ×150. **Fig. O** — Morphotype of textularid foraminifer (aff. *Haghimashella?* sp.). Vršatec-castle klippe. Thin section No. 6501, ×150. **Fig. P** — Morphotype of ammodiscid foraminifer (aff. *Glomospirella reata* (Eicher)). Neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 12385, ×76.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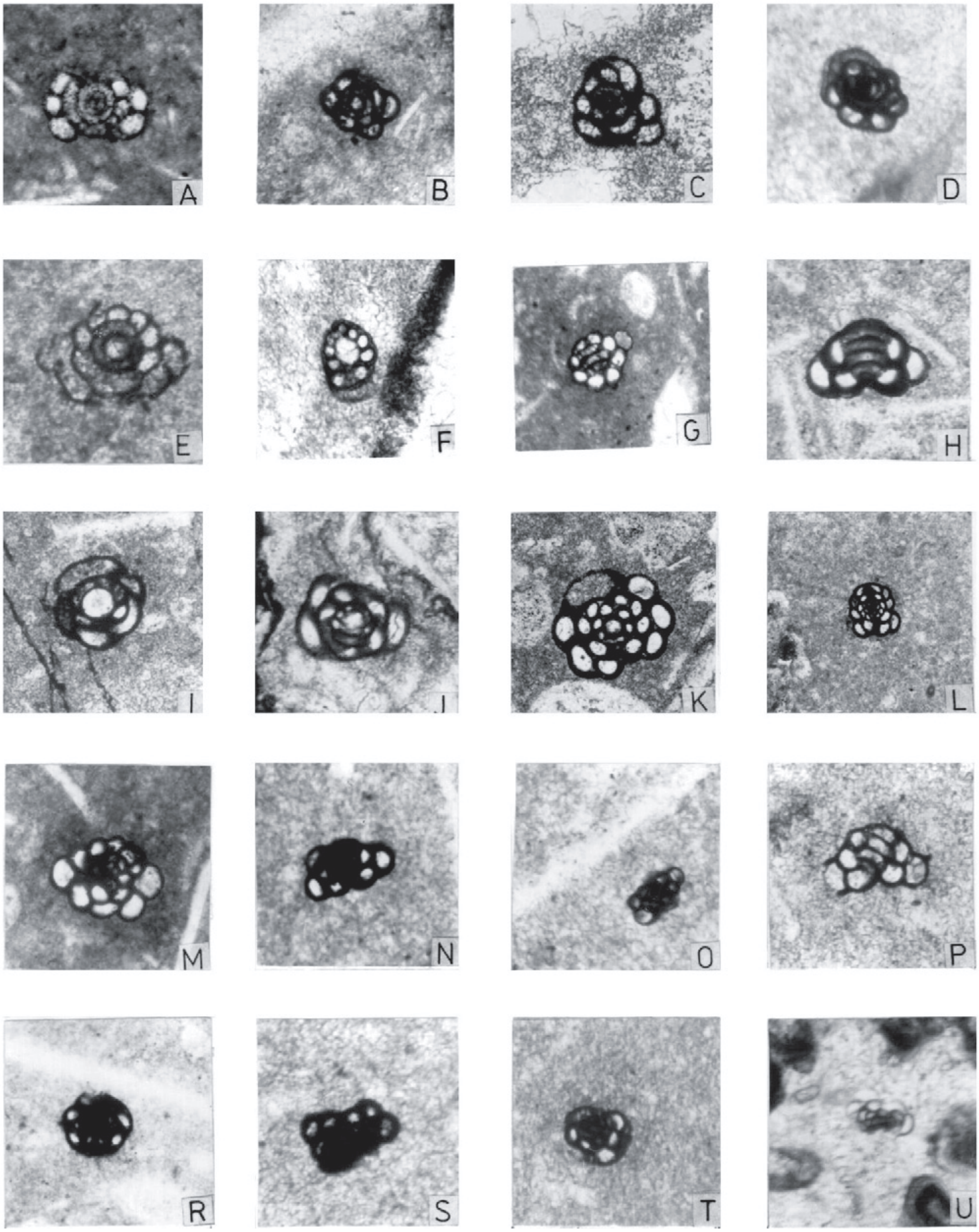
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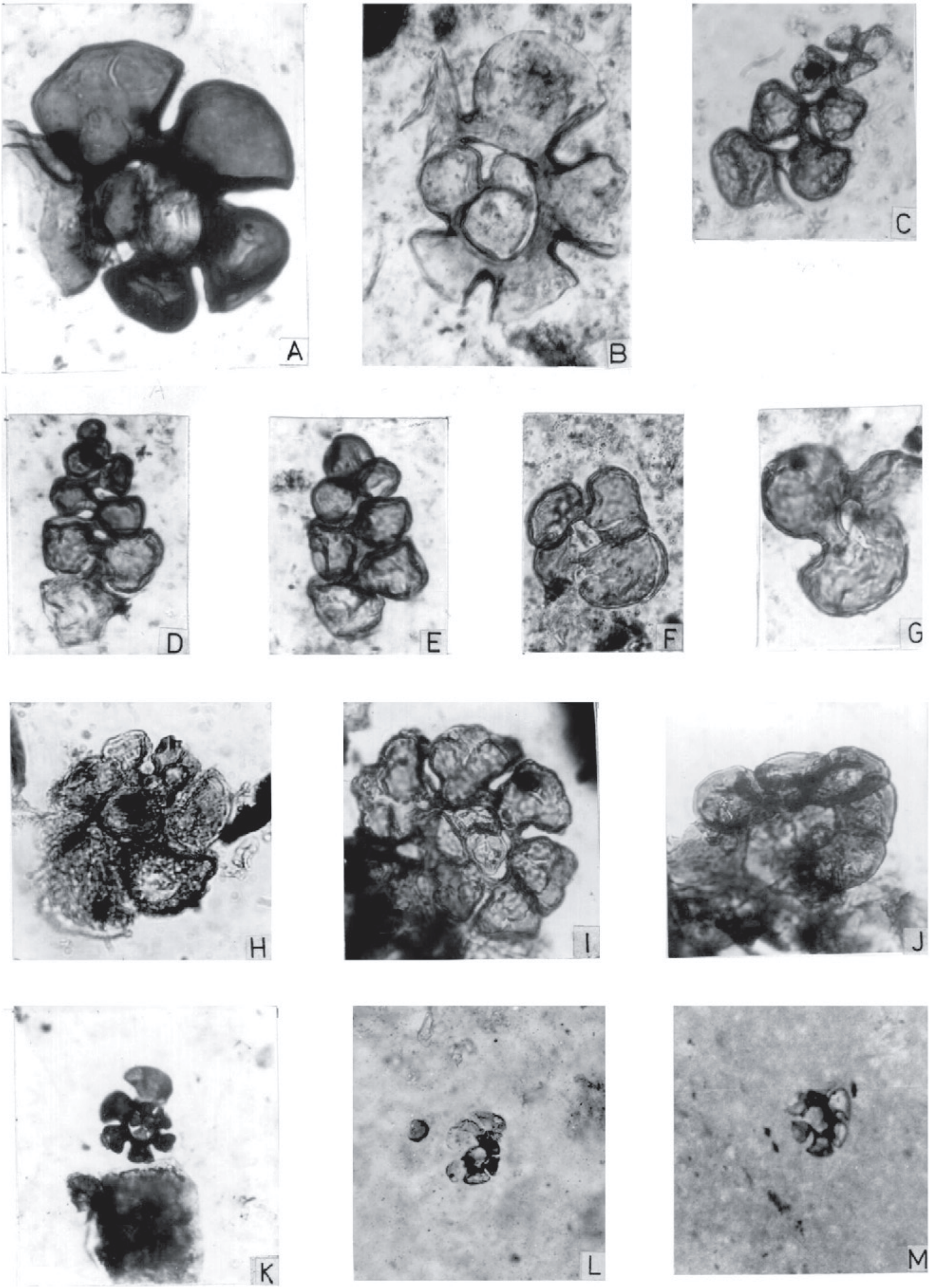
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trolled the abundance of agglutinated foraminifers and other benthics in the Czorsztyn Succession.

The organic linings of the agglutinated foraminifers show an ability to be better protected and more resistant, and thus, quite often preserved after death (Brönnimann & Whittaker 1988). Therefore, the well-preserved linings give the possibility to recognize their systematic position. This approach could change the opinion about stratigraphic unimportance of "microforaminifers" as was the case with the numerous other groups of microfossils (e.g. mostly Middle Jurassic species — *Trochammina* aff. *squamata* Parker & Jones, *Dentalinopsis* aff. *oolithica* (Terq.), *Bolivina* aff. *rhumbleri* Franke, *Trocholina gracilis* Blau, *Pseudobolivina* aff. *variana* Eicher, *Semiinvoluta violae* Blau, *Belorussiella* aff. *bolivinaeformis* Akimets, *Ammodiscus* aff. *varians* Kaptarenko-Chernousova, etc.; mostly Oxfordian-Kimmeridgian species — *Bigenerina jurassica* (Haeusler), *Haghimashella arcuata* (Haeusler), *Nubecullinella infraoolithica* (Terquem), *Nubecularia mazoviensis* Bielecka & Pozaryski, *Ammoglobigerina globigeriniformis* (Parker & Jones), *Spirillina elongata* Bielecka & Pozaryski, *Glomospirella otorica* Romanova, *Verneulinoides* aff. *minuta* Said & Barakat, *Thuramminopsis* aff. *canaliculata* Haeusler, *Trochammina* aff. *pulchra* Ziegler, etc.).

Plate VI: Microforaminiferal linings, naturally stained by Fe-oxides, from the Callovian-Oxfordian limestones, Czorsztyn Succession, Pieniny Klippen Belt (except Figs. H,J,L). **Figs. A, C–G, K–L** — Morphotype of lituolid foraminifers belonging to the genus ***Recurvoides***. Fig. A — Klippe Sivá Skala near Červený Kameň. Thin section No. 21194, ×100. Fig. C — Vršatec-castle klippe. Thin section No. 7010, ×200. Fig. D — Klippe Babina near Bohunice. Thin section No. 21288, ×150. Fig. E — Klippe Sivá Skala near Červený Kameň, ×100. Fig. F — Neptunian dyke filling, Vršatec-castle klippe. Thin section No. 6604, ×120. Fig. G — Klippe Sivá Skala near Červený Kameň. Thin section No. 21193, ×60. Fig. K — Klippe Kyjov-Pusté Pole. Thin section No. 17187, ×100. Fig. L — Middle Liassic limestone, pebble from the Paleocene Proč Conglomerate, Proč. Thin section No. 16016, ×40. **Figs. B, H–J, M–N** — Morphotype of nubeculariid foraminifers — *Nubecularia mazoviensis* Bielecka & Pozaryski. Fig. B — Klippe near Krivoklát. Thin section No. 12227, ×150. Fig. H — Red nodular Callovian-Oxfordian limestone of the Manín Succession, Manín Gorge. Thin section No. 5895, ×150. Fig. I — Klippe in the Bolešová Valley. Thin section No. 19343, ×160. Fig. J — The same as Fig. H, ×150. Fig. M — Neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 11441, ×185. Fig. N — The same. Thin section No. 12385, ×230. **Figs. O–U** — Linings of lituolid and saccamminid foraminifers. Fig. O — Neptunian dyke filling, klippe Babina near Bohunice. Thin section No. 12479, ×230. Fig. P — The same. Thin section No. 12479, ×230. Fig. R — The same. Thin section No. 11441, ×185. Fig. S — The same. Thin section No. 21288, ×150. Fig. T — Vršatec-castle klippe. Thin section No. 8640, ×200. Fig. U — Klippe Krasin near Dolná Súča. Thin section No. 21116, ×150.

Plate VII: Microforaminiferal linings (basale membranes) extracted by the palynological procedures (material of V. Sitár) **and in the thin sections of silicites** (well preserved linings without the Fe-oxides impregnation). **Figs. A–B, K–M** — Morphotypes of haplophragmoid foraminifers (aff. *Haplophragmoides concavus* (Chapman)). Figs. A–B — Linings extracted from the dolomites (Hauptdolomite, Norian), basement of the Slovak part of the Neogene Vienna Basin, borehole Kuklov-3, 2953 m, ×500. Figs. K–L — In a chert nodule from the Muráň Limestone, Upper Hauterivian-Lower Barremian, Mt. Muráň, Belanské Tatry Mts. Thin section No. 12527, ×150. Fig. M — In a chert nodule from the Upper Tithonian limestones, Pieniny Succession, Myjava. Thin section No. 19060, ×200. **Figs. C–E** — Morphotype of bolivinid foraminifers (aff. *Pseudobolivina variana* Eicher). Linings extracted from the dolomites (Hauptdolomite, Norian), basement of the Slovak part of the Neogene Vienna Basin, borehole Kuklov-3, 2953 m, ×500. **Figs. F–G** — Morphotype of haplophragmoid foraminifers (aff. *Haplophragmoides globigerinoides* (Haeusler)). Linings extracted from the dolomites (Hauptdolomite, Norian), basement of the Slovak part of the Neogene Vienna Basin, borehole Kuklov-3, 2953 m, ×500. **Figs. H–J** — Morphotype of trochamminid foraminifers (aff. *Trochammina inflata* (Montagu)). Linings extracted from the "Supra-Posidonia Beds" (Podzamcze Marl Fm.), Bajocian, Kysuca Succession of the Pieniny Klippen Belt. Radola, Kysuca Mts., ×500.

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