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Poleogeographic outline of the Tithonian in the Czechoslovakian Carpathians

ABSTRACT: In the Tithonian of Czechoslovakia the following sedimentation areas can be discerned: 1) Pelagic marly limestones with *Calpionella* in all troughs with the Tešin subunit displaying turbidites and maximum subsidence. 2) W-NW marginal shallow-water sediments with occurrences of corals and Dasycladaceae — the Pavlov — Štramberk Belt. 3) SE marginal shallow-water limestones with Dasycladaceae — the Gemer area. 4) Shallow-water sediments with occurrences of corals — the Czorsztyn cordillera. 5) Shallow-water limestones with Dasycladaceae — the exotic succession of the Klippen Belt. 6) High-tatric cordillera with volcanites. 7) Submarine elevation of Vysoká-Belá-Ďurčiná.

INTRODUCTION

Czechoslovak geologists are preparing a set of paleogeographic and facial maps to scale 1 : 1 000 000, the first draft of which will be finished before 1976. This contribution contains starting-point material, concerning the problems of the Tithonian. Numerous data scattered over the literature were completed with some facts gained by my own research. Several areas with characteristic environmental features have been tentatively discerned on the basis of selected facial indicators. Some neighboring localities from the Polish territory have been taken into consideration as a valuable help. This outline submitted for discussion still contains many gaps; several stratigraphic data are not proved and some facts seem to be contradictory. Their revisions and supplements require further studies. For consultations I am indebted to Prof. D. Andrusov, Dr. K. Borza, Dr. M. Rakús, Dr. A. Kullmanová, Dr. J. Mihalík (all from Bratislava) and Dr. A. Dragastan (Bucharest).

PROBLEMS CONNECTED WITH PALEOGEOGRAPHIC MAPS

An almost total lack of paleogeographic maps (with exception of the Neogene) from the territory of Slovakia was caused by common difficulties concerning all strongly tectonized areas. In the territories with nappe structure the following disadvantages, unknown in the platform regions, must be taken into consideration.

1. Stretching of folds and nappes, reconstruction of original width of the sedimentary area; the supposed width of buried cordilleras should be added.

2. Straighten or diminish the curve of the mountain arc, if we suppose that such a bending of the geosynclinal system took place during the orogeny (*e.g.* compare the bending of Japanese Archipelago proved by paleomagnetic data — Takeuchi & *al.* 1967).

3. Tectonic shortening, evidenced by thrust sheets and nappes, might by accompanied by lateral spreading; thus the trajectory of a transported point was not parallel to the general direction of the transport. Considerable lateral transport mainly of plastic members is connected with the origin of big boudinage structure. The same must be taken into consideration if a gravitational sliding into transverse depressions took place (*e.g.* Kotański 1961, assumed sliding of the recumbent fold of Červené Vrchy from ESE and that one of Giewont from WSW). Radial trajectories are required if we claim the curve of the Carpathians arc was the original one and only its radius changed into a larger one (Scheibner 1963).

The nappes need not move always by translation what is regularly applied in our "unfolding" operation, but they could have moved by partial rotation (such a rotation was really proved by paleomagnetic methods in the case of Choč Nappe — Kotásek & Krs 1965).

5. Beside normal erosion, caused by meteoric agents, a tectonic erosion ("rabotage") and tectonic denudation (denudation of basement by gravity sliding of its sedimentary cover from the top of an elevation, "geotumor") occur.

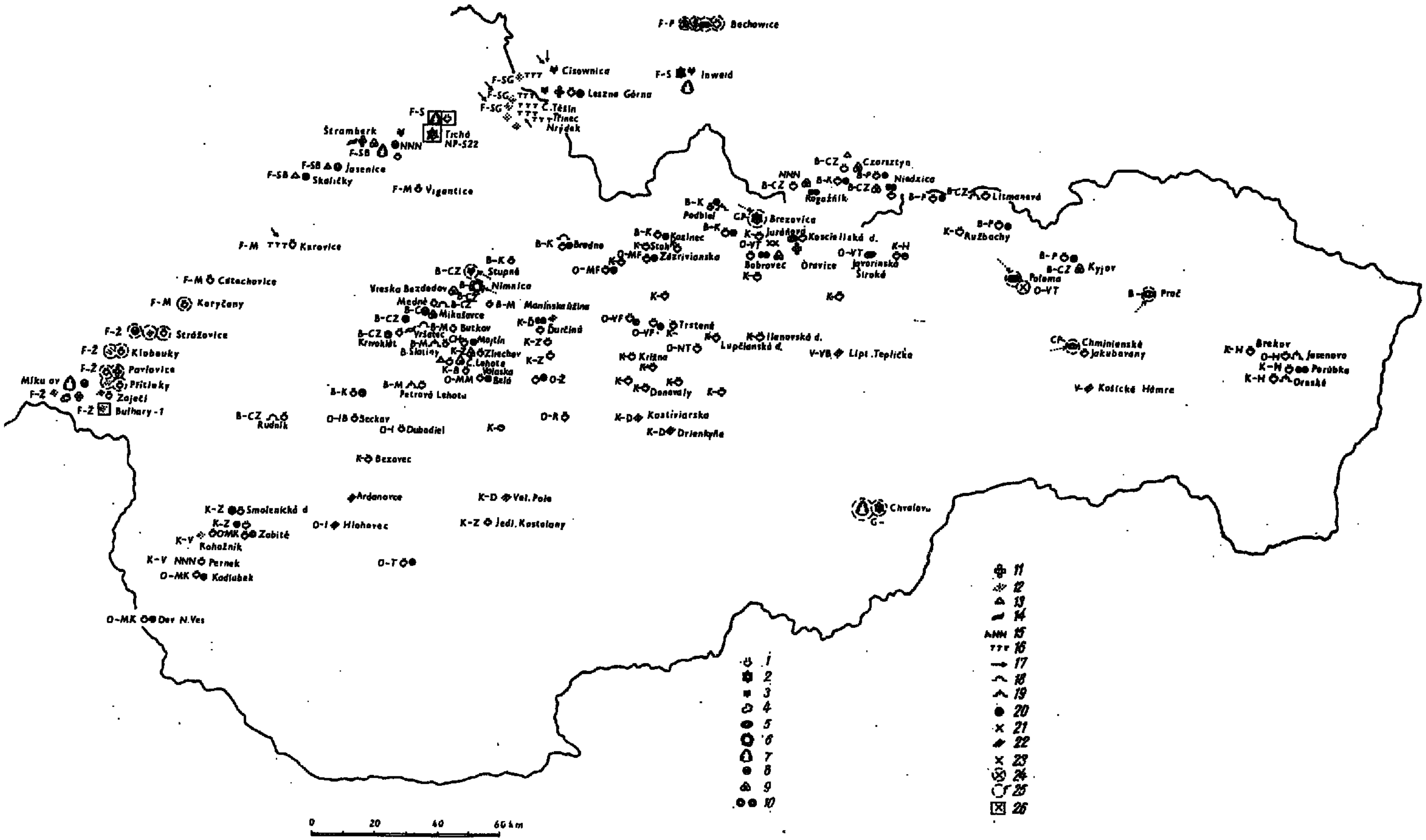
6. The problem of original sedimentation areas of allochthonous units is not always unambiguously solved (*e.g.* the original sedimentation area of the Križná Nappe according to Biely & *al.* 1968, was reduced at the surface to the so-called Čertovica line. Accordingly to Jaroš 1967, 1971, the root zone of that nappe is to be found near Banská Bystrica and in the NE part of the Tribeč Mts, its actual width being of 10—20 km). Reconstruction of the sedimentation areas of several Mesozoic nappes, divided by belts with their autochthonous Mesozoic, is especialy a difficult task (*e.g.* according to Biely & *al.* 1968, the mentioned Čertovica line — thrust plane of the Veporides over the Tatrides — represents an extremely reduced sedimentation area of the Križna Nappe; than follows the Veporide Belt with autochthonous Mesozoic cover; the last mentioned unit is limited by the so-called Ľubeník-Margecany line — thrust plane of Gemerides over the Veporides — representing another extremely reduced sedimentation area of the Choč Nappe).

There is no doubt that the "unfolded" ("unrolled") paleogeographic maps suffer a lot of subjective elements. The opinions of individual authors differ mainly as to the estimation of the tectonic shortening. Since the supporting localities, which served as the basis, are not situated into the normal geographic coordinates, it is difficult to complete and improve such paleogeographical maps. It is useful to derive the paleogeographic map from the lithofacial maps and maps of selected facial indicators (Fig. 1).

For elaboration of paleogeographic maps covering larger areas what requires an international cooperation, another type of conventional maps may be proposed, with unfolded tectonic units placed into their original position within the sedimentary area but with the widths of tectonic units proportionately reduced in order to fit in the area limited by state boundaries (Fig. 2). Otherwise it would be necessary to allot hypothetical territoires to individual participating states for designs of their paleogeographic maps, and in the case of strongly curved arcs, the unfolding (unrolling) of tectonic units towards the centre of the circle (opposite directions) would lead to in absurd situation — the lack of space. Therefore I suppose that the afore mentioned convention could serve the countries associated in the Carpatho-Balcanian Geological Association as a working basis in elaboration of their common paleogeographic maps. It is better to have a real paleogeographic picture slightly deformed like in a concave mirror than have nathing.

PREVIOUS PALEOGEOGRAPHIC CONCEPTS OF THE TITHONIAN IN THE WEST CARPATHIANS

Andrusov 1959 (pp. 178—179, 218, Fig. 24) gave the following paleogeographic picture: during the Tithonian the Jurassic transgresion achieved its maximum in the Carpathians. Between the Danube river and Štramberk a belt of fringing coral reefs occured. In the area of Austrian Klippen and those of Pavlovské Vrchy Hills, as well as in Poland near Andrychów and East of Przemyśl the Tithonian transgressively overlies older formations. The shallow-water facies of Štramberk was bordered on the South by deep-water facies of Cetechovice. East of Štramberk the reef area was rimmed by somewhat deeper non — reefal facies of Bachowice on the South, then another belt with reef facies appeared (geoanticline of Andrychów) at the foot of supposed emerged land (Silesian land). From the remaining part of the West Carpathian area Andrusov mentioned the existence of Czorsztyn cordillera (ridge) and high-tatric shallow-water area (an island during the Lower Jurassic). He supposed that the area of Gemer, now practically without Upper Jurassic sediments, was covered with pelagic facies, as no traces of shallower environment had been found in the adjacent regions.


Bechowice
Inwald
Cisownice
Leszna Górna
Č. Těšín
Třinec
Nýdek
Štramberk
Trchá
NP-522
Jasenice
Skaličky
Vigantice
Karovice
Cétechovice
Koryčany
Strážovice
Klobouky
Pavlovice
Přítluky
Zaječí
Bulhary-1
Czorsztyn
Niedzica
Rogožník
Litmanová
Podbiel
Brezovica
Jurášová
Kosciеliská d.
Bobrovec
Orava
Javorinská
Široké
Ružbachy
Kyjov
Polomа
Prač
Chminianske Jakubovany
Brekov
Jasenovo
Perúbka
Oravské
Bredno
Kozinec
Záskrivianska
Stupné
Nimnica
Vieska Bezdedov
Mikušovce
Maninská tiesňava
Ďurčiná
Butkov
Vršatec
Majtín
Zliechov
Krivoklát
B. Slatiny
Č. Lehota
Valaská Belá
Petrová Lehota
Rudník
Seckov
Dubodiel
Bezovec
Trstené
Ilanovská d.
Lupčianska d.
Lipt. Teplička
Kritna
Donovaly
Kostiviarska
Drienkyňa
Košické Hámre
Chvalová
Ardanovce
Vel. Pole
Smolenická d.
Zabité
Kohatník
Hlohovec
Jedl. Kostoľany
Pernek
Kadlubek
Dev. N. Ves
0
20
40
60 km

Książkiewicz (1960, Fig. 3) sketched a large island East of Štramberk and South of Andrychów. Turbidity currents carried the detrital material into the future Těšín Limestone zone from NW, from the disintegrating reef sediments, which formed the northern border of the basin. Another existensive island emerged in the Gemer area and continued farther to the SE.

Hanzlíková & Roth (1965, pp. 8—12, Fig. 1) indicated on their paleogeographic scheme of Upper Malm the Beskydy parageosyncline with the Lower Těšín Beds as a sea gulf of tectonic origin. According to their opinion, the so-called Dębica elevation zone of Książkiewicz (1960) was only an extensive prominence of the mainland, a peninsula. They pointed out that the coral bioherms and occurrences of *Calpionella* are the northernmost ones in the whole Mediterranean realm. They suggested that the presence of boreal faunistic elements within the klippen of Pavlovské Vrchy could be explained by their immigration with a cold current streaming through Danish-Polish depression. This explanation seems to be hypothetic however.

Houša & *al.* (1963) summarized the Tithonian stratigraphy of the West Carpathian Mts. They assumed the existence of a peninsula dividing the Štramberk area from that of Pavlovské Vrchy. No paleogeographic scheme was included.

All facts concerning the Tithonian have been recently compiled in the due chapters of the Regional Geology of Czechoslovakia (Buday & *al.* 1967, Mahel' & *al.* 1967, English edition: Mahel' & *al.* 1968).

Fig. 1

Map of the selected facial indicators concerning the Tithonian of Czechoslovakia

Symbols of tectonic units: *F* — Flysch Zone, *FŽ* — Ždánice unit (transition into molasse), *FSB* — Silesian Nappe, Baška facies, *FSG* — Silesian Nappe, Godula facies, *FM* — Magura unit, *B* — Klippen Belt, *BCZ* — Czorsztyn unit, *BK* — Kysuca unit, *BP* — Pieniny unit, *BM* — Manín unit, *O* — Envelope Series, *OMK* — of Malé Karpaty Mts, *OI* — of Inovec Mts, *OŽ* — of Žiar Mts, *OT* — of Tribeč Mts, *OMF* — of Malá Fatra Mts, *OVF* — of Veľká Fatra Mts, *ONT* — of Nízke Tatry Mts, *OVT* — of High Tatra Mts, *K* — Krížná Nappe, *KZ* — Zliechov facies of Krížna Nappe, *KV* — Vysoká Series, *KB* — Belá Series, *KĎ* — Ďurčiná Series, *KH* — Humenné Series, *KD* — "Homeland" of Krížná Nappe, *CH* — Choč Nappe, *V* — Veporides, *VVB* — Veľký Bok Series, *G* — Gemerides

1 — *Calpionella* limestones, *2* — *Clypeina jurassica*, *3* — *Teutloporella*, *Triploporella*, *Munieria*, *4* — algal nodules with *Girvanella* and *Marinella*, *5* — microonkolites, *6* — Characeae, *7* — *Trocholina*, *8* — corals, *9* — *Pygope*, *10* — crinoidal limestones, *11* — oolitic limestones, *12* — terrigenous clastic admixture, *13* — endostratic breccias, *14* — primary voids (internal) sedimentation, *15* — neptunian dikes, *16* — turbidity currents, *17* — their direction, *18* — red nodular limestone (Lower Tithonian), *19* — ditto conaining *Calpionella* (Upper Tithonian), *20* — chert concretions, *21* — limburgite volcanics, *22* — metamorphosed Tithonian, *23* — beds in the outcrop, *24* — pebbles from younger conglomerates, *25* — their supposed direction of transport, *26* — rock from the borehole

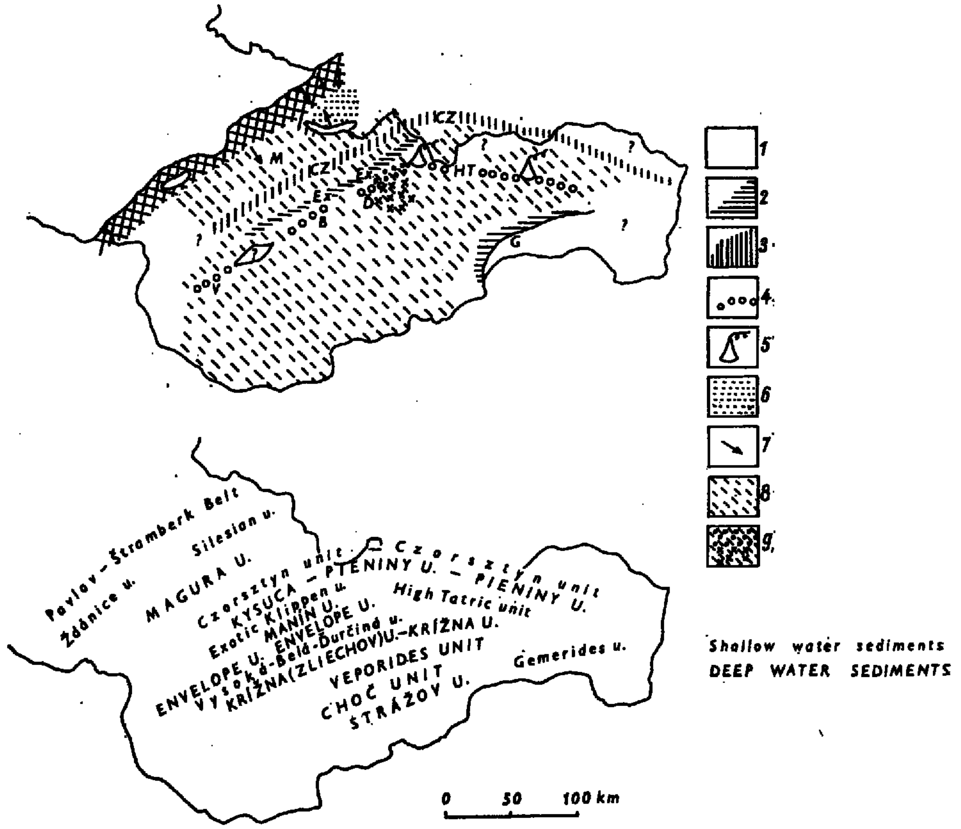


Fig. 2

Paleogeographic map of the Tithonian in Czechoslovakia

Tectonic units are placed in the same manner as they were in sedimentary area; their widths were propocionally reduced into the frame of Czechoslovak territory. Below is the referential scheme showing mutual positions of units within the sedimentary area 1 — land, 2 — shallow water sediments with Dasycladaceae, 3 — shallow water sediments with corals, 4 — submarine elevations (without Dasycladaceae and corals), 5 — volcanoes, 6 — flysch-like sediments, 7 — direction of turbidity currents, 8 — deep water sediments with *Calpionella* not differentiated, 9 — ditto with cherts, 10 — ditto without cherts

DISTRIBUTION OF SELECTED FACIAL INDICATORS

Some facial signs have been chosen and their spatial distribution traced (Fig. 1). They rendered possible to characterize several sedimentary areas (Fig. 2).

Oolitic limestone

Typical oolitic limestones occur in the area of Pavlov-Štramberk marginal elevation. At the locality Mikulov oolites deformed during the compaction of sediment have been found (Mišík 1966a, Pl. 55, 2). Oolites have been mentioned from the localities Štramberk (Frajová 1957), Leszna Góra (Książkiewicz 1971b).

Birkenmajer (1960) quoted pink oolitic limestones with *Globochaete*, derived from exotic cordillera zone of the Klippen Belt. Oolitic limestone pebbles from the Flysch Zone conglomerates are regarded as Jurassic as well, but it is not possible to determine more precisely their stratigraphical setting. Oolitic-pseudoolitic limestones are known to occur in the high-tatric cordillera region (Lefeld 1968); the oolites proper seem to be rare there as the majority of these bodies belong to microonkolites-pseudoolites, most probably of algal origin (Lefeld & Radwański 1960). The typical oolites of Pavlov-Štramberk area were formed undoubtedly in the intertidal environment.

Onkolites, algal nodules

Algal nodules of diameters up to 3 cm with *Marinella lugeoni* Pfender and *Girvanella minuta* Wethered are known only from Turold near Mikulov (Andrusov 1959). In the high-tatric cordilleran area only microonkolites occur. *Globochaete* and *Saccocoma* fragments are often present in their centres giving them a characteristic appearance. This microfacies was illustrated from NW part of the High Tatras (Lefeld & Radwański 1960; Lefeld 1968; Mišík 1966a, Pl. 63, 1—2). Borza (1970) mentioned it from the NE part of High Tatras, Javorinská Šikorá. He gave reasons for its Kimmeridgian-Tithonian age. By means of analysis of conglomerates I traced the continuation of this microfacies under the Central Carpathian Paleogene more than 50 km to the East — Pl. 1, Fig. 1 (localities Poloma, Chminianske Jakubovany; probably from there they were supplied to the Paleogene conglomerate of the Klippen Belt near Proč). Subtidal zone is generally considered as the most probable sedimentary environment for onkolites. It is noteworthy that Dasycladaceae were never found in this microfacies, they had been evidently lacking on the high-tatric Tithonian shoals.

Dasycladaceae

Clypeina jurassica Favre is known in the Pavlov-Štramberk area from Inwałd (Książkiewicz 1971a); I found it in the samples from the borehole Tichá NP-522 (the material was kindly offered by Dr. Jurková). The pebbles from the Central Carpathian Paleogene near Brezovica, Orava, containing *Clypeina jurassica* Favre were probably derived from exotic cordillera emerged near the margin of the Klippen Belt (Mišík & *al.* 1968). Occurrences in the form of pebbles from Aquitanian conglomerates, locality Chvalová (Mišík 1966a, Pl. 62, 1—2) represent a shallow--water facies fringing the Gemer land (Pl. 1, Figs 3—4). The paleontological determination and stratigraphical setting were confirmed by Dr. Dragastan (Bucharest). Fenninger & Holzer (1970) put the zone with *Clypeina jurassica* to the Lower Tithonian of the Eastern Alps and the zone of *Clypeina jurassica* and *Bankia striata* into the Upper Tithonian respectively. According to some authors *Clypeina jurassica* Favre displays a wider stratigraphic range (Kimmeridgian-Valanginian) and for final conclusion new finds of index fossils are needed.

Teutloporella remesi Steinmann is well known from Štramberk (Andrusov 1959). *Munieria* sp. and *Actinoporella podolica* Alth were quoted from the Tešín Limestone (Cisownica, Leszna Góra) by Książkiewicz (1971b). *Teutloporella socialis* Praturlon is known from Inwałd (Książkiewicz 1971a) and in association with *Teutloporella obsoleta* Carozzi from the pebbles of Upohlav conglomerates, loc. Stupné, *i.e.* from an exotic cordillera of the Klippen Belt (Bystrický & Borza 1964).

The depths of 10—20 m are considered as a proper environment for Dasycladaceae. In the Štramberk area they occur in association with coral debris. Whether

Dasycladaceae were bound to the lagoonal backreef facies, as for instance in the Triassic of the Eastern Alps (Ott 1966), is not known.

Characeae

They were found only in pebbles from Albian conglomerates, loc. Nimnica (Borza *in* Samuel & *al.* 1972), derived from exotic cordillera of the Klippen Belt. Their stratigraphical range is Upper (Jurassic (?)). They may be considered as an indicator of extremely shallow-water conditions, probably a brackish facies analogous to Purbeckian.

Trocholina

The characteristic association *Trocholina-Clypeina* is present in marginal sediments of the Gemer land (Pl. 1, Fig. 4) and at the locality Tichá. Hanzlíková (1965) quoted *Trocholina* from Mikulov, while Książkiewicz (1971a) illustrated abundant sections from Inwałd. He compared that rock with bahamite but in the real bahamite the organic remains are far more seldom than in the mentioned rocks from Inwałd. *Trocholina* is considered as a shallow-water dweller.

Crinoidal limestones

They were described from the Czorsztyn succession of Poland, *e.g.* Niedzica, Rogoźnik (Birkenmajer 1960). From the central part of the Váh river valley Began (1969, p. 61) mentioned dark red crinoidal limestones with fragments of Calpionella limestone. In the high-tatric succession at Osobitá crinoidal limestones have been ascertained by Kotański & Radwański (1959). In Humenské pohorie Mts (loc. Porúbka) they have been found by Kullmanová (oral communication). In Vysoká--Belá-Ďurčiná area (series of the same name) their presence is supposed at some localities, *e.g.* Ďurčiná (Malá Fatra Mts). Crinoidal limestones are attributed to depths of some tens of metres.

Brachiopods Pygope

Genus *Pygope* represents the most frequent brachiopod in the Tithonian of West Carpathians. According to Siblík (1964) it is generally accepted that the majority of Paleozoic and Mesozoic brachiopods lived on shoals and their adaptation to greater depths took place but in Tertiary. Recent brachiopods occur down to depth of 5000 m (littoral zone excluded). One third of species is capable to bear considerable depth differencies. Rogoźnik coquina limestone with abundant *Pygope diphya* Col. represents undoubtedly a shallow-water environment as well as the occurrences at Štramberk. A neritic environment is attributed to crinoidal limestones with *Pygope* from Osobitá, High Tatras (Kotański & Radwański 1959). On the other hand, *Pygope* was found within the Calpionella limestones in Strážovská hornatina Mts (Michalik, oral communication), *i.e.* in a definitely deeper environment. Perhaps it would be possible in the future to trace some areas of smaller depths indicated by brachiopods, in the frame of pelagic Calpionella facies.

Calpionella limestones

They contain almost exclusively pelagic microorganisms: Tintinnidae, ***Chitinoidella, Cadosina, Stomiosphaera*** (for details *see* Borza 1969) and ***Globochaete***, calcified radiolarians, ***Nannoconus***, globigerins and planctonic crinoid ***Saccocoma***. Nekton is represented by aptychi and fish scales. Rare benthonic elements-echinoderm articles, arenaceous foraminifers — may be considered as allochthonous as well as single quartz grains of silt cathegory. The rock contains 3—15% of insoluble residue, mainly clay minerals. *Calpionella*-bearing limestones are regarded as sediments of considerable depths (Colom 1955). The same may be attributed to the West Carpathians where they represent the most wide-spread facies, being present in all areas of supposed troughs and subordinately on some submarine elevations. Only in the Czorsztyn geoanticlinal succession the Calpionella limestones display signs of shallow-water environment. Pink and yellowish limestones with *Calpionella alpina* Lorentz contain synsedimentary erosion surface above which tiny intraclasts of Calpionella limestone occur (they probably correspond to submarine hiatuses identified by Birkenmajer 1958); primary voids with internal sedimentation were observed, too.

Corals

They occur in the Pavlov-Štramberk area and the Czorsztyn area. Biohermal limestones and organoclastic limestones, originated by disintegration of coral bioherms, and characterize the whole area of Pavlov-Štramberk marginal elevation. They are represented by Ernstbrunn Limestone and the analogous Štramberk Limestone. According to Andrusov (1959) the Štramberk Limestone was formed by disintegration of fringing coral reefs almost at the place of their growth. Frajová (1959) described coral colonies with the diameter of 3 m in growth position. Eliáš (1966) also affirmed that the well-known locality Kotouč near Štramberk was a coral reef of 500 m in thickness. But Houša (1961) considers these occurrences as subaquatic herms, mounds of detrital material removed from bioherms. In his opinion no important subsidence occurred there. He proved the Valanginian age of the red Kopřivnica Limestone, previously regarded as Tithonian. It is of transgressive nature and forms neptunian dikes — infilling of fissures in the Štramberk Limestone. Eliáš & Stránik (1963) suppose that all occurrences of the Štramberk Limestone, including the Kotouč hill, are olistolites, blocks slided down from marginal elevation of the Silesian geosynclinal area into the deeper part of the basin, where the deposition of dark shales with intercalation of dark grey limestones and grey sandstones was taking place. These so-called Kotouč Beds originated under euxinic conditions. Big blocks of the Štramberk Limestone are frequently bordered with tilloid conglomerates which served as an evidence of their olistolitic nature. The lack of lateral transitions from massive biohermal limestones into bedded ones seems to be in favour of this suggestion. It is interesting to compare, that the same fact led to the same explanations of the genesis of coral and algal biohermal limestones in the Paleogene of the West Carpathians (so-called Myjava-Žilina Belt).

Spatial distribution of the Štramberk Limestone as pebbles in various conglomerates was revised by Eliáš (1966). They are limited only to the Baška facies of the Silesian unit and in the western part of the Subsilesian one. They are lacking in southern parts of the Silesian unit and in the Magura unit. Their occurrences in the Silesian unit are derived from the Baška cordillera, since the distribution area of the Silesian cordillera is characterized by typical pelagic Tithonian facies.

Coral biohermal facies in the Czorsztyn succession, middle part of the Váh valley, was rarely mentioned up to now. Andrusov (1945, pp. 27—28) quoted the facies of grey aphanitic or fine-grained limestones with scarce corals and pelecypods; he determined *Lima (Plagiostoma) paradoxa* Zittel. Their stratigraphical setting should be Tithonian, a higher horizon than the Rogoźnik coquina limestone. He found two localities: West of Krivoklát near Pruské (Drienová Hora) and small klippen in the surroundings of Maríkova. Borza (1960) gave a brief note about the limestone of the so-called "Štramberk-type" between Krivoklát and Maríkova. He characterized them as non-stratified and indistinctly stratified limestones with *Lima (Plagiostoma) paradoxa* Zittel. According to him they contain Tintinnidae of Tithonian and Neocomian age.

I found biohermal facies with corals and pelecypods at the following localities: 1) Vršatec, saddle above parking place, 2) Mikušovce, the klippen near the village, upper tectonic scale, 3) Drienová Hora above Krivoklát (locality mentioned already by Andrusov 1945). Their stratigraphical setting may be deduced from the following facts. In the outcrops at Vršatec, first klippen from the village Vršatecké Podhradie, they lay upon the red crinoidal limestones of Bathonian age. Close to the ruins of the Vršatec castle (SW from the road) the crinoidal limestones of Dogger are penetrated by abundant neptunian dikes with the infilling of pink, frequently laminated micritic limestones, seldom with corals and pelecypods. Coral biohermal limestones are probably overlain by pink and yellowish Calpionella limestones, which also contain small primary voids with internal sedimentation and small corals (outcrop in the roadcut). At all three lacalities the Czorsztyn Limestone is missing (in the klippen Mikušovce it is of reduced thickness and only in the lower tectonic scale). I suppose that the coral biohermal limestones are a partial stratigraphic equivalent of the Czorsztyn Limestone. As they do not contain Tintinnidae, the age from Kimmeridgian to Middle Tithonian seems to be the most appropriate. They are white, grey or pink, the bedding is lacking. Out of macrofossils beside coral (clusters up to 20 cm) the thick-valved pelecypods are abundant, *Chlamys* sp., *Plagiostoma* sp. — according to Andrusov (1945) *Lima (Plagiostoma) paradoxa* Zitt.; thick spines of cidarian echinoids (mainly at the locality Mikušovce) and big gastropods and calcareous sponges were also found. In thin sections their considerable recrystallization is visible. The structure is mostly organoclastic. Beside corals they contain fragments of tiny bryozoans, sessile nubecularian foraminifers, microforaminifers with organic tests, rarely *Spirillina* sp., *Patellina* sp., echinoderm articles, spines of echinoids, fragments of pelecypods, ostracods, *Cadosina* sp., small gastropods, hydrocorals, calcified radiolarians and sponge spicules (filled with roughly radial calcite aggregates). Indistinct tiny pellets probably of accretionary origin and sometimes also interclasts of the same character are present. Clastic quartz of silt and fine-grained sand cathegory represents a rare admixture.

These limestones contain the typical biohermal sign — primary voids lined with reef-tufa ("Evinospongia structure"). The voids have a size of some cm, they are filled most frequently with red micrite, sometimes laminated (alternation of calcisiltite and calcilutite); they are almost always devoid of organic remains in spite of their abundance in the surrounding limestone. An initial cementation of radiaxial calcite mosaic whose growth was interrupted by internal sedimentation of limy mud may be observed (Pl. 2, Figs 1—2). Wavy stromatolites were found exceptionally but the shrinkage pores are missing in them. At the locality Krivoklát (Drienová Hora) a selective replacement of corals was found; chalcedony replaces only drusy cement of corallites, meanwhile septa and micrite of the groundmass are almost untouched by silicification. Thickness of these limestones is at least 30 m. Their aspect differs considerably from the Štramberk Limestone.

Neptunian dikes

Neptunian dikes at Štramberk were registered by Houša (1961). There are fissures and voids filled by green-grey marly rocks and limestone breccias. From the Czorsztyn succession, locality Rogoźnik they were mentioned by Birkenmajer (1958, 1963). The neptunian dikes under the ruins of the Vršatec castle are probably also of Tithonian age (*see* above). In the area of Vysoká-Belá-Ďurčiná elevation I found thin neptunian dikes at the locality Pernek (Pl. 1, Fig. 2).

Endostratic breccias

The registered occurrences are surprisingly rare till now. In Pavlov-Štramberk area localities Jasenice and Skaličky (Frajová 1959), in the Czorsztyn succession, locality Czorsztyn (Birkenmajer 1958, 1963), in the Pruské succession, locality Medné (Andrusov 1945, but extended up to the Neocomian by Borza 1969, p. 20). In the core mountains they were found only in the Tithonian of the Križná Nappe (Belá Series) at the locality Čierna Lehota, Strážovská hornatina Mts (Kullmanová, oral communication).

Open-space structures

Primary voids achieving some dm in diameter were described from Štramberk by Houša (1964). They are filled with laminated sediment in which as much as five generations may be distinguished (the last one belongs already to the Valanginian). The top of all voids was overgrown by stromatolites. In the coral biohermal limestones of the Czorsztyn succession at Vršatec I found primary voids up to 20 cm in diameter lined by macroscopically striking reef-tufa (Evinospongia structure"). Some smaller voids display "initial rim cement", whose growth was interrupted by internal sedimentation (Pl. 2, Figs 1—2). The infilling is pink or white, often laminated, without organic remains. Small primary voids occur there also in the Calpionella limestones. Usually they display irregular shape but some of them remined dissolved fragments of shells. They are filled by a different sediment containing tiny accretionary pellets.

Terrigenous admixture

Pebbles of Tithonian limestones from the conglomerates of the Ždánice unit, loc. Kyjov, contain fragments of phyllites what was mentioned already by older authors (Andrusov 1959). Similar fragments of phyllites and gneisses from another close locality between Zaječí and Přítluky were found by Pícha & Hanzliková (1965). They indicate an emerged land nearby. Sandy terrigenous admixture was not systematically studied except for some areas. In the Těšín Beds in some sites more than 30% of clastic quartz admixture was ascertained by Eliáš (1970). He supposed than in the tectonic scale of Tul the clastic material was transported from the Silesian cordillera. Single sandy grains of quartz are present in the majority of shallow-water facies, single silt grains also in the Calpionella limestones. They are somewhat more frequent in Vysoká-Belá-Ďurčiná zone. Notions referring to this topic are scarce; only in the future it will be possible to exact the location of emerged island within the area of the mentioned elevations.

Turbidites

Intercalations of turbidites are known from the Lower Těšín Beds and Těšín Limestone of Godula facies (Eliáš 1970), at the localities: Třinec, Nýdek, Karpentná, Český Těšín and Konská. According to that author their material was derived from the Baška cordillera, from NW. He found also flute marks and erosional troughs. From the localities Cisownica and Leszna Góra similar turbidites were described by Książkiewicz (1971b). He determined the direction of transport from N and NW. These turbidites are sign of tectonic instability in the adjacent elevation area. Intercalations of turbidites in the environment of carbonate pelagic facies were described from the locality Kurovice, Magura unit (Benešová & *al.* 1968, Mišík 1968,

p. 222). These intercalations with graded bedding often combined with lamination form 3—5% of the total thickness and display the character of allodapic limestones (Meischner 1964).

Volcanic admixture

Limburgites and their tuffs are known from the NW part of High Tatras (high-tatric series). Their Tithonian age was proved by Kotański & Radwański (1959). Pebbles of Calpionella limestone with pyroclastic admixture including fragments of limburgites (Pl. 2, Figs 3—4) were found by us at the locality Poloma. It may be concluded, that the Tithonian with volcanites continues under the cover of the Central Carpathian Paleogene 50 km to the East of the previously known occurrences.

Red nodular limestones

Czorsztyn Limestones of that nature ranges locally up to the Middle Tithonian, and is characterized by *Chitinoidella* and *Cadosina* association (Borza 1969) loc. Vršatec, Litmanová, Rudník. In some series of the Klippen Belt the red nodular limestones persisted till the tintinnid zone of the Upper Tithonian. That was recorded from the Czorsztyn succession by Birkenmajer (1960), from the Pruské succession loc. Medné and from the Manín Series lic. Belušské Slatiny by Borza (1969) and from locality Petrová Ves by Kullmanová (oral communication). This is not valid for all localities there, *e.g.* in Manínska úžina the Calpionella limestones are indistinctly nodular or not nodular at all and their colour is grey. It is probable that in the core mountains the highest horizon of red nodular limestones mainly in the Križna Nappe with Saccocoma microfacies (mainly Kimmeridgian) belongs to the lower part of the Tithonian. Their microfauna is not so abundant and so well preserved as in the analogous rocks of the Klippen Belt and the revision of profiles was not performed yet. Therefore, only those localities in which red nodular limestones persisted up to the Upper Tithonian and contain *Calpionella*, were recorded at the map: Jasenová and Oreské in Humenské pohorie Mts (Kullmanová, oral communication) and the locality Frývaldská dolina in Ďurčiná Series. Red nodular limestones are considered as the sign of condensed sedimentation, submarine solution on submarine elevations like seamounts (Jenkyns 1971) or on the cordilleras of Briançon type, or at the slopes of geosynclinal furrows, respectively (Aubouin 1964).

Thickness of sequences

Maximum subsidence displayed the Těšín area ("Beskydy parageosyncline"); the thickness of Kotouč facies is estimated as 500—600 m (Eliáš 1970), that of the Lower Těšín Beds as 300—400 m. Biohermal facies of the Štramberk Limestone is, according to Andrusov (1959, p. 153) 250 m, according to Roth (1962) about 500 m; it indicates a compensative subsidence. The analogous Ernstbrunn Limestone shows only 100—120 m of thickness. The shallow-water Tithonian of the Czorsztyn unit is estimated in average as 35 m (Andrusov 1954, p. 28). The same is valid for the biohermal facies in this series. Obviously no marked subsidence took place there. The estimations of thickness concerning the pelagic facies of the Calpionella limestones diverge considerably, since the Tithonian and Neocomian merge into a macroscopically undivisible sequence. Alleged thickness of 150 m for the Pieniny Succession of the Klippen Belt (Houša & *al.* 1963, Tab. 2) seems to be exaggerated. At the stratigraphical columns of Borza (1969) the thickness of the Tithonian in the

Kysuca succession near Brodno is 40 m, in the Manín Series loc. Manín Gorge 60 m. In the Križná Nappe of the core mountains it varies according to my observations in the range of 15—30 m. This area corresponds to the conditions of a "starved basin".

FINAL REMARKS

In this facial and paleogeographic outline of the Tithonian in the Czechoslovak Carpathians the following areas were distinguished:

1. Most widespread is the pelagic Calpionella limestone of deeper water origin (for its characteristic — *see* Borza 1969, Mišík 1966, etc.).

2. Along the margins and within the deposition area of the pelagic zone the following elevations may be discerned: near the W and NW margin of the Carpathian geosyncline a belt with shallow-water sedimentation occurred, the so-called Pavlov-Štramberk area with coral and algal bioherms. In Pavlovské Vrchy it involves the Klentnice Beds with predominance of claystones in the lower part (deposited under euxinic conditions), in the upper part — with predominating limestones. Further shallowing led to the origin of regressive reefs (Houša & *al.* 1963, Hanzliková 1965) — Ernstbrunn Limestone; its analogue is the Štramberk Limestone. According to Andrusov (1959) they represented fringing reefs. From other littoral facies oolitic limestones are characteristic. The existence of land in the proximity is proved by terrigenous admixture, fragments of phyllites and gneisses at the locality Zaječí and Strážovice, as well as by the Jurassic limestone pebbles from Eocene and Aquitanian (Pícha & *al.* 1966). How far the sea penetrated into the subsiding marginal belt of the Bohemian Massif, now covered by the Neogene of the Carpathian fore-deep, will be known after publishing of boring results. In the northern part of the Pavlov-Štramberk area the belt of bioherms was doubled and divided by a deep-water area. Only in Pavlov-Štramberk elevation both corals and Dasycladaceae were found.

3. Near the SE margin another shallow-water area, adjacent to the Gemer island occurred. Due to the subsequent denudation its existence may be proved only from pebbles in the Tertiary conglomerates (Pl. 1, Figs 3—4). It is not possible to estimate its extension. Direct evidences of the emerged land, as for instance the terrigenous admixture in the Tithonian limestones, were not found. In the whole territory of the Gemerides not a single outcrop of Tithonian occurs. The single locality mentioned previously from Budikovany near Rimavská Sobota (Foetterle 1867, Marková 1959) was convincingly shifted into Upper Triassic (Borza & *al.* 1965). Andrusov (1959, p. 218) explained the lack of Jurassic in the Gemerides by erosion only, since in the SW continuation, in Hungary a deep-water facies of Upper Jurassic is known. But the evidence of shallow-water marine facies (Mišík 1966a; *see* Pl. 1, Figs 3—4) indicates that substantial part of the Gemerides was emerged during the Tithonian,

though the extension of land was not so large as in reconstruction by Slavin (1956).

Amidst the proper West-Carpathian geosyncline the following four elevations occurred: Czorsztyn, Exotic (Klippen), High-Tatric, Vysoká--Belá-Ďurčiná.

4. The Czorsztyn cordillera was the longest of them; it may be traced along the whole West Carpathians. It contains varied shallow--water facies. Birkenmajer (1963) designated the Tithonian of the Czorsztyn succession with a collective term Dursztyn Limestones. In their lower part he cited-red Calpionella limestone, pink Globochaete limestone, red crinoidal Falsztyn Limestone and red Rogoźnik coquina. In the upper part — white Calpionella limestone, white Globochaete limestone, crinoidal Falsztyn Limestone and white Rogoźnik coquina. The deposition was condensed in some places (red nodular limestones), also breaks due to the marine current activity are documented by hiatuses and hard--grounds (Birkenmajer 1958). In the middle part of the Váh valley coral bioherms occurred (Pl. 2, Figs 1—2). Even Calpionella limestones display some shallow-water signs there as, for instance open-space structures. The lack of Dasycladaceae seems to be a striking feature of the Czorsztyn elevation. Possible existence of emerged islands cannot be directly proved by terrigenous admixture.

5. Exotic cordillera of the Klippen Belt is detectable in the middle part of the Váh valley and in Orava. It is characterized by Dasycladaceae--bearing limetones found as pebbles in the Upper Cretaceous conglomerates (Bystrický & Borza 1964) and the Paleogene ones (Mišík & *al.* 1968). It is not excluded, that emersions took place with the formation of brackish facies with Characeae, analogous to Purbeckian (such pebbles were found by Samuel & *al.* (1972).

6. High-tatric cordilleran area with volcanites is characterized by a microonkolitic (pseudoolitic) microfacies with Globochaete and *Saccocoma*. Lefeld & Radwański (1960) and Lefeld (1968) placed it in Tithonian--Valanginian while Borza (1970) in Kimmeridgian-Tithonian. It is known only from the High Tatras; its continuation to the East till the foothills of the Branisko Mts was recently traced by means of pebbles in the Paleogene conglomerates (Pl. 1, Fig. 1). From the NW part of the High Tatras the occurrences of the Tithonian limburgite and tuffs are known (Kotański & Radwański 1959). Their pyroclastic admixture was now found in the Calpionella limestones from pebbles in Paleogene conglomerates at the locality Poloma, 80 km to the East (Pl. 2, Figs 3—4). It is probable that the high-tatric elevation was rimmed by a fault, along which the limburgite lavas ascended. The connection with basic volcanites of the Carpathian Ukraine is not excluded.

7. Submarine elevation zone Vysoká-Belá-Ďurčiná rendered preliminary few evidences (rare neptunian dikes, higher admixture of

quartz grains, intercalations of crinoidal limestones). Neither corals nor Dasycladaceae are known.

In the frame of basic, most widely distributed pelagic facies of deeper water with *Calpionella*, some areas of second order may be distinguished:

a) Calpionella limestones without chert concretions, *e.g.* Križná Nappe in Malá and Vel'ka Fatra Mts.

b) Calpionella limestones with abundant radiolarian chert concretions — *e.g.* Envelope unit (formerly "Šipruň Nappe") of Malá and Vel'ka Fatra Mts; Kysuca-Pieniny succession (known as "Hornsteinkalk" of older authors). The spatial distribution of both subfacies *a,b* was not systematically studied. Data from the literature are not reliable because they were traced in general as Tithonian-Neocomian. The striking differentiation into chert-bearing Envelope unit and not-cherty Križná Nappe like in Malá and Vel'ka Fatra Mts (Mišík & Rakús 1964) was not established in the Tithonian of other core mountains. This peculiar distribution of radiolarian plankton in the frame of otherwise uniform pelagic facies needs explanation.

c) The Těšín area with clastic sedimentation of the Lower Těšín Beds and Těšín Limestones, *i.e.* marly limestones with *Calpionella*, claystones, detritic limestones, sandy limestones, conglomerates (Beskydy parageosyncline — Hanzlíková & Roth 1965). It contains typical carbonate flysch with turbidites (Eliáš 1970, Książkiewicz 1971b). The environment of deeper water is claimed also for the Kotouč Beds of the Baška facies with submarine slump bodies, although no *Calpionella* were referred from them.

d) Turbidites as intercalations in pelagic limestones of the Magura unit were found at the locality Kurovice only (Benešová & *al.* 1968).

e) Red nodular limestones of Middle and Upper Tithonian were found not only within elevation zones (Czorsztyn, Vysoká-Belá-Ďurčiná) but also in some sites within the areas ranged here into pelagic realm (Manín Series, Humenské pohorie Mts). Perhaps they indicate locally restricted elevations of the sea bottom. Additional studies are needed.

For completeness, it is to be mentioned that the Tithonian sediment of the Veporides, and of the Križná Nappe in its "homeland" near Banská Bystrica and in the NE part of the Tribeč Mts as well as the Tithonian of some Envelope series (*e.g.* southern part of the Inovec Mts) were epizonally metamorphosed. All occurrences are supposed to belong originally to the pelagic limestones (perhaps with *Calpionella*) without chert concretions, then to the basic facies.

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ZARYS PALEOGEOGRAFII TYTONU KARPAT CZECHOSŁOWACKICH

(Streszczenie)

W tytonie Karpat Czechosłowackich wyróżniono i omówiono szereg stref sedymentacyjnych: 1) strefę rowów podjednostki cieszyńskiej z marglami pelagicznymi z *Calpionella*, charakteryzującą się także obecnością turbiditów oraz maksymalną subsydencją; 2) strefę brzeżną W-NW Pawłowskie Kopce — Štramberk z koralami i Dasycladaceae; 3) SE brzeżną strefę gemerską z wapieniami z Dasycladaceae; 4) płytkowodną strefę osadów z koralami serii czorsztyńskiej; 5) płytkowodną strefę egzotyczną wapieni z Dasycladaceae Pienińskiego Pasa Skałkowego; 6) serię wierchową Tatr z wulkanitami, oraz 7) strefę geantyklinalną Vysoká-Belá-Ďurčiná.

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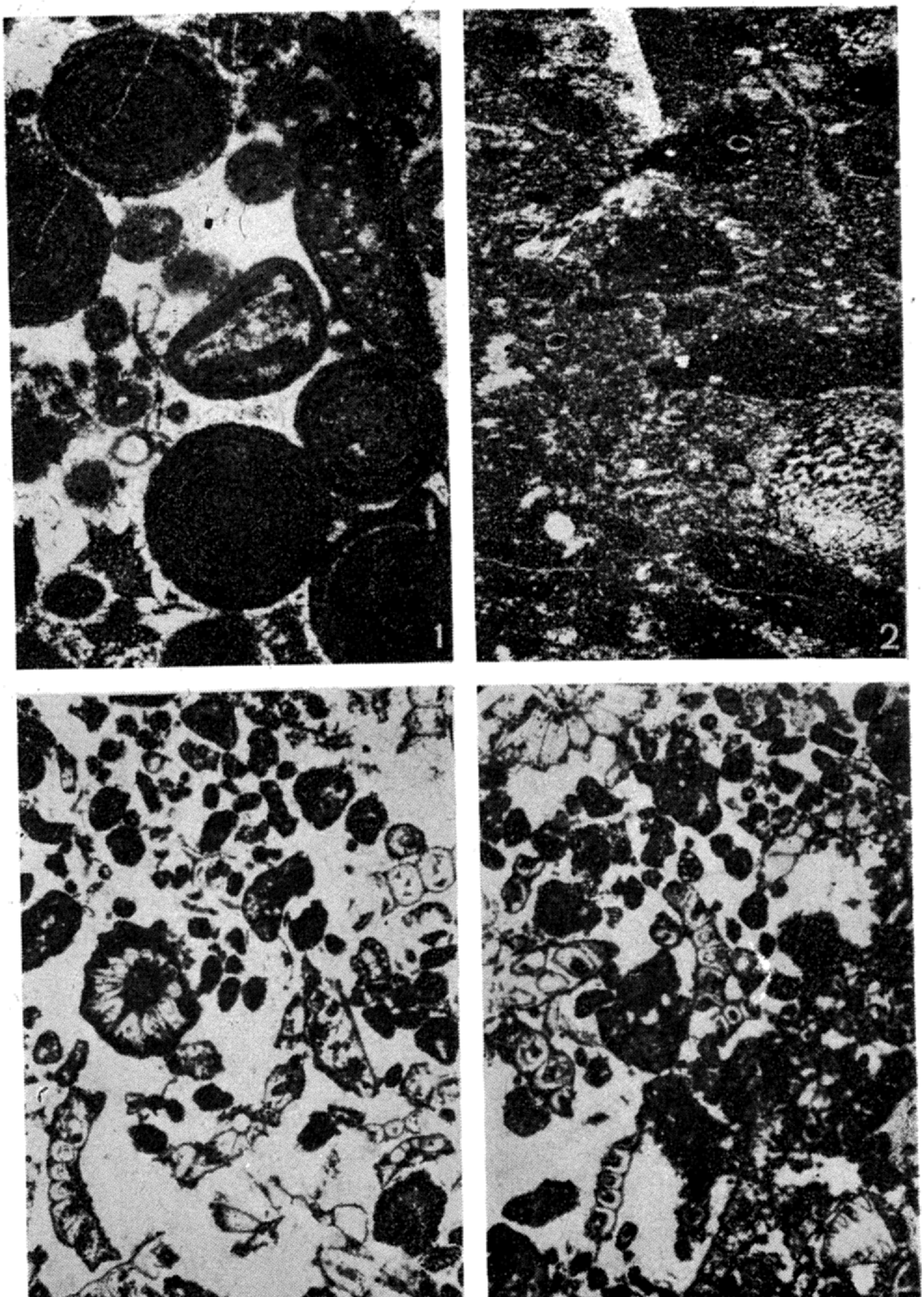
Bratislava, Gottwaldovo nam. 2, Czechosłowacja
Bratysława, w listopadzie 1972 r.



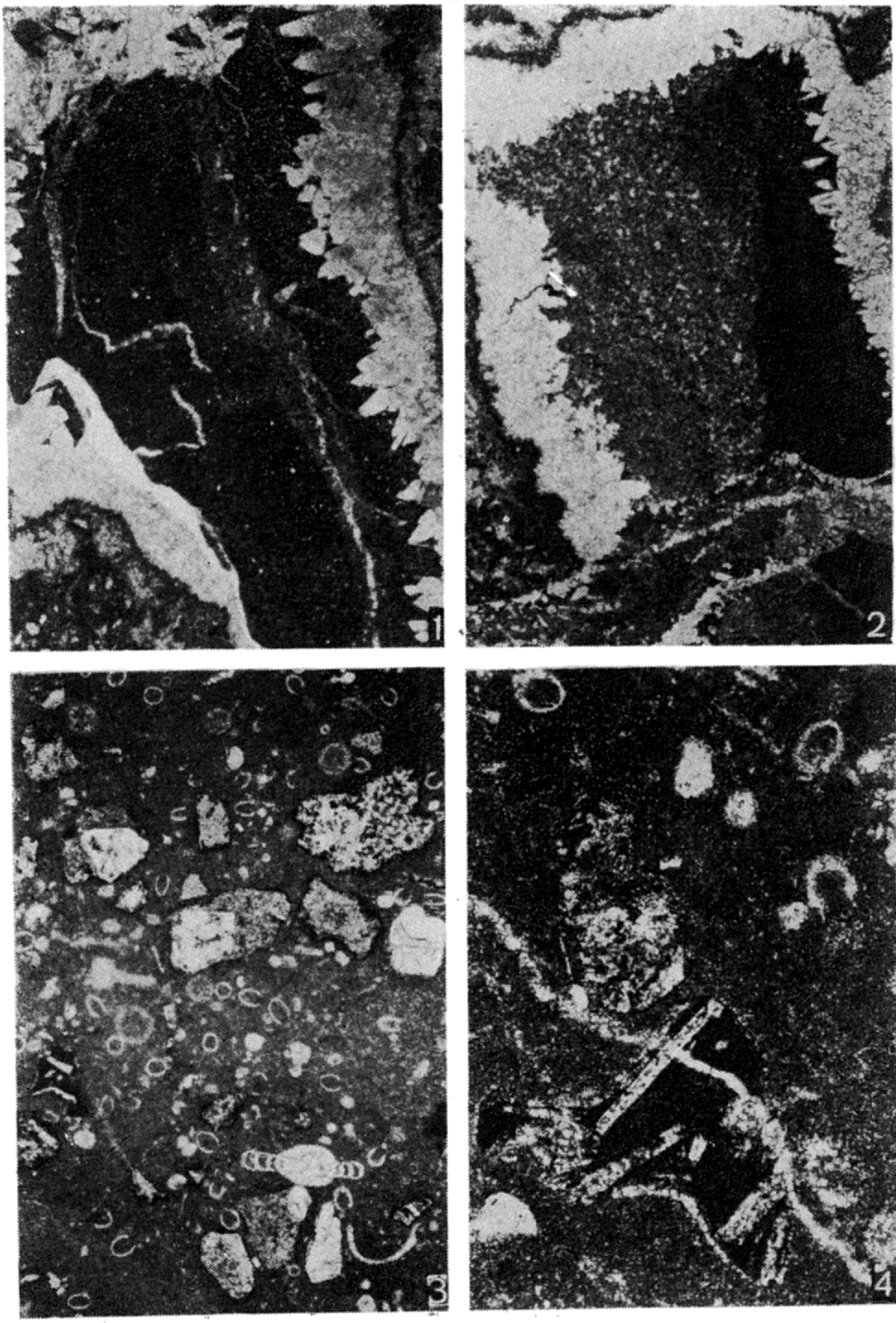
1 — Microonkolitic limestone with *Saccocoma* (in the centre). Kimmeridgian-Tithonian. Pebble from the Paleogene conglomerates, Klippen Belt, loc. Proč, Eastern Slovakia. No. 3557. × 43.

2 — Intramicrite with *Calpionella* and crinoidal ossicles — infilling of a neptunian dike in Jurassic limestones. Vysoká Series (Lower Subtatric Nappes), quarry near Pernek, Malé Karpaty Mts. No. 2629. × 43.

3 — Limestone (intrabiosparite) with *Clypeina jurassica* Favre — Tithonian of the Gemerides unit. Pebble from the conglomerates of Aquitanian age. Chvalová near Rimavská Sobota. × 14.

4 — Ditto. Association of *Clypeina* and *Trocholina*. × 12.

All photographs by L. Osvald



1 — Primary void ("open-space structure") lined with prismatic cement (orthosparite) the growth of which was stopped by internal sedimentation (allomicrite). Biohermal limestone, Tithonian of the Czorsztyn Series, Klippen Belt, loc. Vršatec. No. 5212. × 12.
2 — Ditto. No. 5212. × 12.
3 — Pyroclastic admixture (lithoclasts of basic volcanites) in *Calpionella* — bearing limestone. Tithonian of the High-Tatric unit. Pebble from conglomerates of Central Carpathian Paleogene, loc. Poloma, Levoča Mts. No. 4329. × 43.
4 — Ditto. No. 4329. × 136.

All photographs by L. Osvald