POLSKA AKADEMIA NAUK · KOMITET NAUK GEOLOGICZNYCH

PAŃSTWOWE WYDAWNICTWO NAUKOWE . WARSZAWA

acta geologica polonica

Vol. 24, No. 2 Warszawa 1974

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Middle-Upper Jurassic and Lower Cretaceous biostratigraphy and sedimentology of the sub-tatric succession in the Tatra Mts (Western Carpathians)

ABSTRACT: The Middle-Upper Jurassic and Lower Cretaceous deep-sea sequence of the sub-tatric succession of the Tatra Mts consists of Toarcian-Aalenian nodular limestones, Bajocian-Bathonian radiolarites, Callovian nodular limestones, Oxfordian radiolarites, Kimmeridgian nodular limestones, Tithonian-Berriasian siliceous limestones (Biancone), and Valanginian-Barremian (Lower Aptian?) marlstones. Two maximal depth phases were observed namely the Middle Jurassic and Oxfordian ones. The carbo-silite sequence of the Upper Jurassic is characterized by distinct vertical symmetry in the distribution of nodular limestone and radiolaritic facies. The Middle Jurassic and Oxfordian (the latter in particular) depth phases were of universal character in the Tethyan troughs of the Carpathians and probably of the Alps as well. The depocenter of these sediments was probably a slope of trough. The deposition depth is considered in relation to calcite and aragonite compensation depths and based on microfacial analysis (selective solution). A sequence of calcareous avalanche turbidites (the Murań limestone) of Hauterivian-Barremian age is analysed and its conditions of sedimentation considered. Its origin was due to avalanche and turbidite current transport from distal and possibly also proximal Urgonian reef-detrital zones. On the basis of facial analysis of these redeposited sediments a direct connection of some of the sub-tatric units (Eastern Tatra Mts) with the most southerly situated Klippen Belt succession (Haligovce) is suggested. An Upper Tithonian ammonite fauna was found in the sub-tatric succession. 9 Upper Tithonian ammonite species and genera are described and 8 of them illustrated. The Lower Cretaceous ammonite fauna comprises Valanginian, Hauterivian and Barremian forms, out of which 14 are described and 7 illustrated.

INTRODUCTION

The present work embraces the problems of stratigraphy, sedimentology and palaeogeography of the Middle and Upper Jurassic and Lower Cretaceous of the so called sub-tatric succession of the High-Tatra Mts. Less attention is being paid to the Middle Jurassic then to the Upper Jurassic radiolarites and associated nodular limestones. The latter comprise the so called Upper Jurassic carbo-silite sequence (Lefeld 1969) and mark the main deepening phase in the whole Carpathians, thus being the most important and most indicative event in the Jurassic history of the region.

Chapters devoted to the Lower Cretaceous geology deal with the marlstones of the Neocomian and associated with them the so called Muraň limestones. The origin of the latter member rose many doubts and discussions in earlier times.

The localities studied are shown on the sketch-map (Fig. 1).

Investigations concerning the above poblems started in 1964 and were continued, with intervals, till 1972.

Acknowledgements. The following persons, geology students of the Warsaw University helped the author during field seasons in 1969, 1970 and 1972: Mr. Tomasz Krzywicki, Mr. Andrzej Wygralak, Mr. Andrzej Budzyk, Mr. Grzegorz Micula and Mrs. Zofia Krzysiak. To all of them the author wishes to express his cordial thanks.

Laboratory work was carried out in the Laboratory of Stratigraphy of the Institute of Geological Sciences, Polish Academy of Sciences in Warszawa.

Comparative studies were done in Czechoslovakia in 1970. Dr. K. Borza of the Geologicke Laboratorium Slovenskej Akademie Vied in Bratislava was so kind to explain to the author some stratigraphic and sedimentological problems of the West Carpathian Upper Jurassic and Lower Cretaceous geology, and guided him to the most representative exposures in the Slovakian West Carpathians, in particular to the Male Karpaty, Strażovska Hornatina, Velka nad Mala Fatra and Niżne Tatra Mts, as well as to the western sectors of the Klippen Belt. Beside that the author has visited and studied the Upper Jurassic and Lower Cretaceous sequences in the Haligovce Klippe (Pieniny Klippen Belt), the Ruźbachy (old Polish name — Drużbaki) tectonic window and the Choč Mts the latter constituting the western prolongation of the Tatra Mts

During field seasons of 1969, 1970 and 1972 the author has visited many exposures of the Czorsztyn, Niedzica and Branisko successions in the Polish part of the Pieniny Klippen Belt. Useful information about the geology of the last mentioned area was kindly communicated by Prof. Dr. Ing. K. Birkenmajer of Laboratory of the Young Structures of the Institute of Geological Sciences, Polish Academy of Sciences in Cracow.

The author wishes to express his cordial thanks to Prof. Dr. Edward Passendorfer who provided many useful information and comment during the whole time of preparing this work and offered his collection of Lower Cretaceous ammonites for determination. Thanks are also due to Mr. A. Iwanow, M. Sc., for many discussions.

Free access to the natural reserves both in the Polish and Slovakian parts of the Tatra Mts was allowed to the author by the Directors of the Tatra National Park Mr. M. Marchlewski, Vice-director Mgr. Ing. Czesław Madeyski and Director

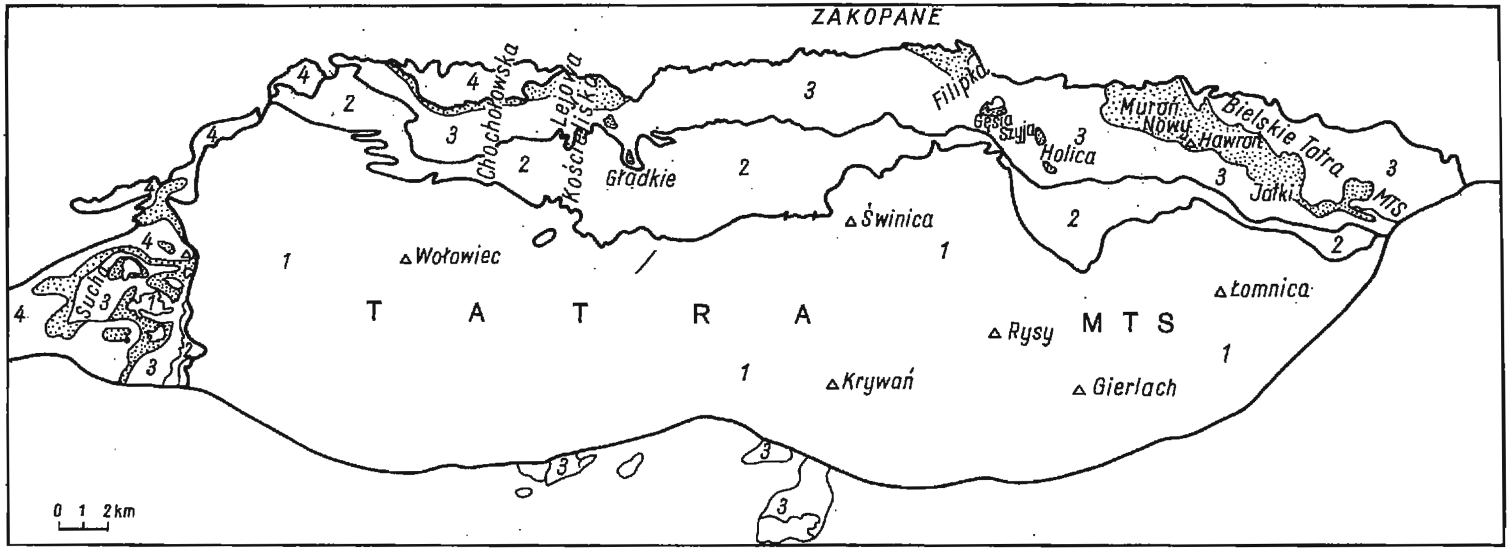


Fig. 1

Geological sketch-map of the Tatra Mts showing the main tectonic zones and the sub-tatric Jurassic and Lower Cretaceous outcrops

1 high-tatra crystalline core; 2 high-tatric zone; 3 sub-tatric zone; 4 Choč zone, stippled — sub-tatric Jurassic and Lower Cretaceous sediments

Mgr. Ing. Leon Niedzielski, for the Polish part, and by the Vyskumna Stanica Spravy Tatranskeho Narodneho Parku in Tatranska Lomnica, for the Slovakian part.

Thanks are also due to the workers of the Muzeum Tatrzańskie in Zakopane who helped the author with working place during some, chiefly bad-weather times of field work.

Chemical analyses of the sub-tatric radiolarites and limestones were done by Dr. Z. Wichrowski of the Geochemical Laboratory of the Geological Department, Warsaw University.

The Vigilev's collection of the sub-tatric Lower Cretaceous fossils, chiefly ammonites was kindly lent to the author by the Laboratory of Young Structures, Institute of Geological Sciences of the Polish Academy of Sciences, Cracow.

X-ray diffractogramms were done by Mr. M. Stępniewski, M. Sc., of the Geological Institute, Warszawa. The author is grateful to Mrs. I. Bańkowska for the preparation of Plates.

PREVIOUS WORK

The sedimentary mantle of the High-Tatra Mts (Central Carpathians) was subdivided on facial grounds, by Uhlig (1897) into the so called high-tatric zone (Hohtatrisch of Uhlig) situated directly over the Tatra crystalline core, and the sub-tatric one (Subtatrisch of Uhlig), which is thrown over the last mentioned one.

The history of investigation of the Upper Jurassic and Lower Cretaceous members of the sub-tatric succession of the Tatra Mts which are dealt with in this paper starts with Stache's (1868) findings of some Lower Cretaceous fossils.

Uhlig in his monograph on the Tatra geology (1897) proposed the name Murań limestone (Murańkalk) and regarded this member to be Urgonian. The same opinion about the age and facies of the Murań limestone was then expressed by Rabowski & Goetel (1925), and Andrusov (1931, 1959). Passendorfer (1950), on the other hand, was of the opinion that the Murań limestone represents Hauterivian as he found neither orbitolinas nor other Urgonian index-fossils in it. Borza (1957) analysed the Murań limestone petrographically but did not come to any new stratigraphic conclusion. Some data about the Murań limestone in the Polish part of the Eastern Tatra Mts are presented by Grabowska-Hakenberg (1958).

The fauna of the Neocomian marlstones of the sub-tatric succession from the Kościeliska Valley in the Western Tatra Mts was collected and determined by Vigilev (1914). He mentioned 12 ammonite species, 3 apty-
dealt with in this paper starts with Stache's (1868) findings of some
plant remains. A complete list of his fossils appears in the Palaeontological Part. Vigilev neither described nor illustrated them. He claimed only Valanginian-Hauterivian age for the marlstones of the Western Tatra Mts despite his finding of *Crioceratites emerici* Lév., a typical Barremian form.

Many Lower Cretaceous fossils, mostly ammonites were found by Passendorfer in early fifties in the Kościeliska Valley.

The sub-tatric radiolarites were petrographically analysed by Sujkowski (1932). Aside of Middle Jurassic age of the radiolarites he ascribed also upper portion of this member to the Upper Jurassic without any paleontological basis. This proved correct in the light of aptychi studies carried out by Gąsiorowski (1959) on the material from Western Tatra Mts.

In the stratigraphic scheme of Rabowski & Goetel (1925) the sub-tatric radiolarites corresponded only to the Middle Jurassic. The Upper Jurassic was hardly subdivided into red, grey and greenish limestones. In the light of aptychi studies by Gąsiorowski (*op. cit.*) the Middle and partly Upper Jurassic part of the stratigraphic scheme by Rabowski & Goetel (*op. cit.*) proved erroneous. According to Gąsiorowski the upper limit of the sub-tatric radiolarites coincides with the Oxfordian/Kimmeridgian boundary.

The application of the above mentioned stratigraphic scheme to tectonic problems led to some errors in the tectonic interpretation of the sub-tatric zone first of all in the Bielskie Tatra Mts (Sokołowski 1950), which were revealed in a paper by Lefeld (1969).

First chemical analyses of the sub-tatric radiolarites and Muráń limestone were done by Kuźniar (1913). Some others (radiolarites) were published by Krajewski & Myszka (1958).

STANDARD OF THE UPPER JURASSIC AND LOWER CRETACEOUS

The standard of the Upper Jurassic stratigraphy is that proposed by Arkell (1956). It was used, with few modifications, by Birkenmajer (1963) in the geology of the Pieniny Klippen Belt of Poland.

The standard of the Lower Cretaceous stratigraphy is applied here after Haug (1927) as it was used in the stratigraphy of the Carpathians in Slovakia (Andrusov 1959) and in the Klippen Belt of Poland (Birkenmajer 1963 — with some modifications).

The Tithonian stage is treated here together with the Berriasian according to Wiedmann (1968, 1971), because of lithologic uniformity.

MIDDLE-UPPER JURASSIC CARBO-SILITE SEQUENCE

General remarks

The radiolarites and associated nodular limestones of the Middle and Upper Jurassic are a very characteristic lithostratigraphic member of the sub-tatric succession in the Tatra Mts. They form a typical carbo-silite sequence according to Grunau's (1965) classification. General geology of that sequence is presented in Fig. 2. First nodular limestone member appears in the Toarcian there, being then followed by the Middle Jurassic

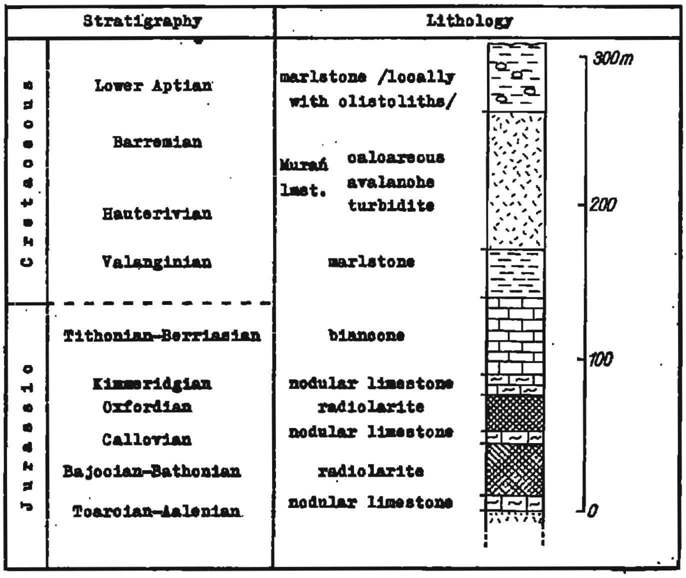


Fig. 2

General stratigraphy of the Middle-Upper Jurassic and Lower Cretaceous of the sub-tatric succession in the Tatra Mts

green radiolarites which, in turn, are overlaid by another nodular limestone, probably Callovian in age. This nodular member separates the so called "lower" green radiolarites from the "upper" ones of Oxfordian age. The latter show red radiolaritic envelopes both on their bottom and top. The sequence ends with the "upper" nodular limestones of Kimmeridgian age, which pass gradually into the Tithonian siliceous limestones of Biancone type.

Stratigraphic units versus lithological members

Aptychi studies by Gąsiorowski (1959) have revealed that the upper limit of the sub-tatric radiolarites lies about the Oxfordian/Kimmeridgian boundary. No other index-fossils are known from this carbo-silite sequence, and the only ammonites are *Hildoceras bifrons* Brug. from the Toarcian "lower" nodular limestone (Uhlig 1897, Sokołowski 1925). Higher members, mostly radiolarites, lack any fossils except rare aptychi and calcified radiolaria. There exists, however, a striking facial similarity to the coeval carbo-silite sequences of the Pieniny Klippen Belt chiefly the Niedzica and Branisko successions (Birkenmajer 1965). On this basis it was possible to correlate the particular sub-tatric Jurassic members with the better paleontologically evidenced ones of the last mentioned area (Table 1).

Table 1

Stratigraphy of the sub-tatric Middle and Upper Jurassic as compared to that of the Niedzica succession of the Pieniny Klippen Belt. After Birkenmajer (1965) and Lefeld (1969)

	Tatra Mts sub-tatric succession	Pieniny Klippen Belt Niedzica succession
Tithonian	biancone	biancone
Kimmeridgian	upper nodular limestone	upper nodular limestone
Oxfordian upper	upper red radiolarite	upper red radiolarite
	green radiolarite	green radiolarite
Oxfordian lower	lower red radiolarite	lower red radiolarite
Callovian	middle nodular limestone	lower nodular limestone
Bajocian and Bathonian	green radiolarite	crinoidal limestone

Table 2

Stratigraphy of the sub-tatric Middle and Upper Jurassic and Lower Cretaceous after Gąsiorowski (1959), Sokołowski (1925), Vigilev (1914) and author's own researches

	Western Tatra Mts	Eastern Tatra Mts
Lower Aptian and Barremian	marlstone with thin interbeds of calcareous and arenaceous turbidites /ammonites/	marlstone with Urgonian olistoliths
		Murań limestone; calcareous avalanche turbidites
Hauterivian		
Valanginian	spotted marlstone /ammonites/	spotted marlstone
Berriasian	biancone /tintinnids/	biancone /tintinnids/
Tithonian	/ammonites/ biancone	biancone
Kimmeridgian	upper nodular limestone /abundant Saccocoma/	upper nodular limestone /Saccocoma/
Oxfordian upper	upper red radiolarite	upper red radiolarite
	upper, green radiolarite	upper, green radiolarite
Oxfordian lower	lower red radiolarite	lower red radiolarite
Callovian	middle nodular limestone /partly lacking/	middle nodular limestone /partly lacking/
Bathonian and Bajocian	lower, green radiolarite	lower, green radiolarite
Aalenian and Toarcian	lower, red nodular limestone manganiferous encrinite	lower, red nodular limestone /partly lacking or other facies/

No palaeontological evidence exists so far concerning the Callovian stage in the sub-tatric succession in the Tatra Mts. Aside of the above mentioned similarities to the Niedzica succession of the Klippen Belt a possibility exists that the so called "middle" nodular limestone member of the Tatra Mts may embrace a part of the Upper Bathonian at its base and/or a part of the lowermost Oxfordian in its top.

Bearing in mind such reservations which result from a scarcity of faunal remains in the sub-tatric Middle and Upper Jurassic the stratigraphy of the analysed members is presented in Table 2.

Selected profiles

Out of many profiles studied in the field only best exposed ones are here presented. These are: in the Western Tatra Mts — sections of the eastern slope of the Lejowa Valley, in the Sucha Valley and at Gładkie Upłaziańskie, and in the Eastern Tatra Mts — sections at the southern slope of the Nowy Wierch (Bielskie Tatra Mts), and at Holica.

The section in the Lejowa Valley (Fig. 3) exhibits about 18 meters of Middle Jurassic (Bajocian-Bathonian) "lower" green radiolarites. These are greenish-gray [1] to olive-gray calcareous rocks with olive cherts. The following nodular limestone of Callovian age is 13.5 m thick. This is a typical "Ammonitico Rosso" with calcareous nodules and brownish-red matrix. Reddish-brown, small cherts occur in some nodules there. The matrix enveloping the nodules is reddish-brown (10 R 3.5/5) whereas the nodules are slightly paler. There are some thin beds of limestone devoid of nodules at the bottom of that member. The nodules are approximately 2—5 cm in size, usually longer then high, lenselike. Next member, the lower red radiolarite is 12 m thick. The rock is thinly bedded with some shale intercalations. The colour is dark reddish-brown (10 R 2/3). Cherts are seldom found in it. The upper green radiolarite 10 m thick, shows thin red radiolarite band almost in the middle. The rock is grayish-olive-green (5 GY 4/2) and does not contain cherts either.

The upper radiolarite is 4 m thick and does not differ much from its lower counterpart. It contains small reddish-brown cherts in bottom portion.

The upper calcareous member of Kimmeridgian age, unlike its counterparts in the Eastern Tatra Mts, shows only thin nodular bed among reddish-brown thin bedded siliceous limestone. Reddish colouration gradually passes into grayish one. Thickness of the upper nodular limestone in that section is less than 2 meters, which is incomparably less than in other parts of the sub-tatric succession.

Upwards the sequence passes gradually into the Tithonian Biancone, which in its upper part contains few ammonites (Berriasellidae).

[1] All colour designations according to the G. S. A. Rock Color Chart.

The sub-tatric zone of the Tatra Mts passes westward into the Choč Mts which are lower, mostly due to existence of a tectonic transversal depression there (Gorek 1950). A section in the Sucha Valley (Fig. 4) in the Westernmost Tatra differs slightly from that in the Lejowa Valley.

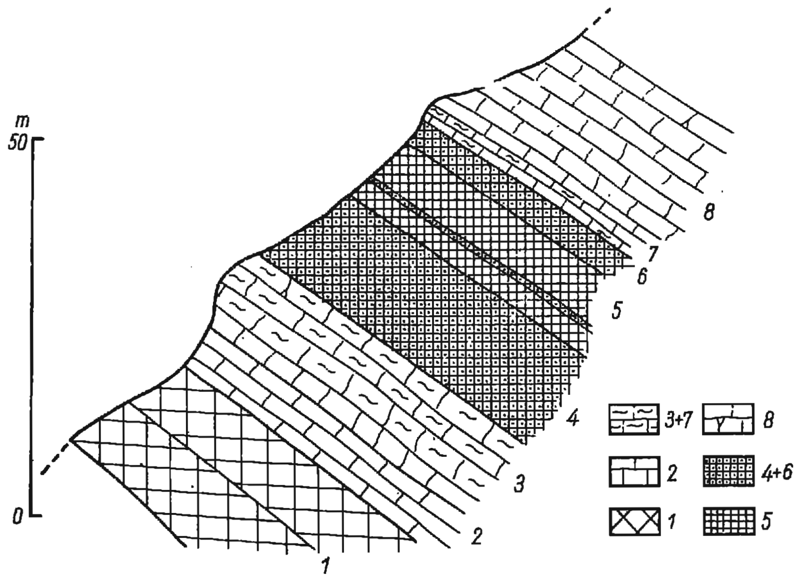


Fig. 3

Cross-section of the Middle and Upper Jurassic in a gully on the eastern slope of the Lejowa Valley

1 Middle Jurassic radiolarites and siliceous limestones; *2* limestones; *3* middle nodular limestone (Callovian); *4* lower, red radiolarites (Lower Oxfordian); *5* upper green radiolarite (lower part of the Upper Oxfordian); *6* upper, red radiolarite (upper part of the Upper Oxfordian); *7* nodular and siliceous limestone (Kimmeridgian); *8* Biancone (Tithonian-Berriasian)

The Callovian nodular limestone member separating as a rule the lower green radiolarite (Bajocian-Bathonian — *1* in Fig. 4) from the upper radiolarites is rudimentary only, thus the lower green radiolarite passes directly into the lower, red radiolarite (8 m thick) of the Lower Oxfordian (*2* in Fig. 4). The upper, green radiolarite (1.5 m thick), is covered by the upper red one which is again 6—7 meters thick. The whole Upper Jurassic radiolarite group is rather variegated in colour as many thin greenish-gray bands occur within both red members of the Oxfordian. Small reddish-brown jaspers occur in both red radiolarite members. The Kimmeridgian upper nodular limestone is poorly developed there. In the overlying Biancone of the Tithonian age one thin band of clastic turbidite occurs. This section shows similarities to the development of the Upper Jurassic carbo-silite sequence at Lučky in the Choč Mts situated farther west.

A section at Grześ (Pl. 3) in the Chochołowska Valley (Polish Tatra

Mts), the aptychi of which were analysed by Gąsiorowski (1959), shows strong resemblance to that of the Sucha Valley being, in fact, intermediate between the sections at Lejowa and the Sucha valleys.

A small tectonic scale at Gładkie Upłaziańskie discovered by Limanowski (1904) occupies a peculiar tectonic position (*see* Mapa Geologiczna Tatr Polskich, 1:10 000 sheet B2, and Kotański 1965). The sequence of that tectonic scale (at least its Upper Jurassic part) does not fit to the neighboring sub-tatric units which suggests that it was thrusted over the high-tatric zone from somewhat different source area.

The Middle-Upper Jurassic sequence at Gładkie Upłaziańskie is as follows (Fig. 5). Over the Toarcian reddish-brown encrinite there is a very characteristic bed (12 m thick) of dusky yellow-green (5 GY 5.5/2) radiolarite (Pl. 5, Fig. 2) with dusky red cherts (5 R 3.5/4). There is no nodular limestone at the base of the Oxfordian and the Callovian is probably replaced by reddish-brown radiolarite which forms uniform bed (8 m thick) together with the Oxfordian. The upper nodular limestone (7 m thick) of the Kimmeridgian is well developed. The colour is reddish-brown at base with intercalations of red and gray, and passes topward into grayish.

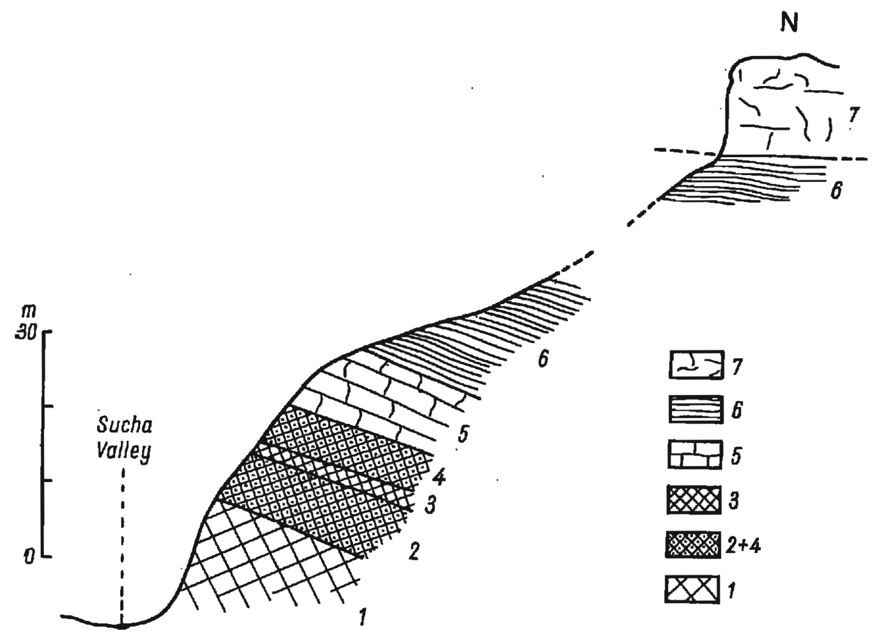


Fig. 4

Cross-section in the Sucha Valley (Westernmost Tatra)

1 lower green radiolarites (Middle Jurassic); 2 lower, red radiolarites (Lower Oxfordian); 3 upper, green radiolarites (lower part of the Upper Oxfordian); 4 upper, red radiolarite (Upper Oxfordian and possibly Kimmeridgian); 5 siliceous limestones (Biancone) (Tithonian-Berriasian); 6 marlstones (Valanginian-Hauterivian); 7 overthrusted Triassic dolomites of the Choč unit

The uppermost portion of the section is composed by the Tithono-Berriasian Biancone in its typical development.

In the Eastern Tatra Mts the sub-tatric Middle and Upper Jurassic sequences occur both in the Polish and Slovakian parts of the massif. The best exposed and longest exposures are to be found on the southern slopes of the Bielskie Tatra Mts (Pl. 2). The Hawrań unit of the Bielskie Tatra Mts continues westward into the Polish part of the Tatra Mts, in the Kopy Sołtysie area and merges under the Eocene flysch toward WNW.

South of the Bielskie Tatra Mts and Kopy Sołtysie there is a group of tectonic scales represented by the Holica- and Czerwona Skałka hills — in the Slovakian part (Pl. 1, Fig. 2), and by the Gęsia Szyja hill — in the Polish part (*see* Fig. 1).

In the Bielskie Tatra Mts a section at Nowy Wierch (Fig. 6) may serve as an example here. The Middle Jurassic olive-gray (5 Y 5/1) radiolarite containing cherts contacts directly the "upper" green radiolarite of the Oxfordian without any nodular bed inbetween. Hence the Callovian is either represented by radiolarites, or its sediments have been removed by redeposition and/or dissolution. Farther southeast, at Szalony Wierch and Jatki this member is developed in form of pseudonodular limestones. The Lower Oxfordian red radiolarite is absent as well. The upper red part of the carbo-sillite sequence is normally developed with rather thick reddish-brown (10 R 4/4) upper nodular limestone of the Kimmeridgian. The nodules are definitely lighter. The upper nodular limestone is well

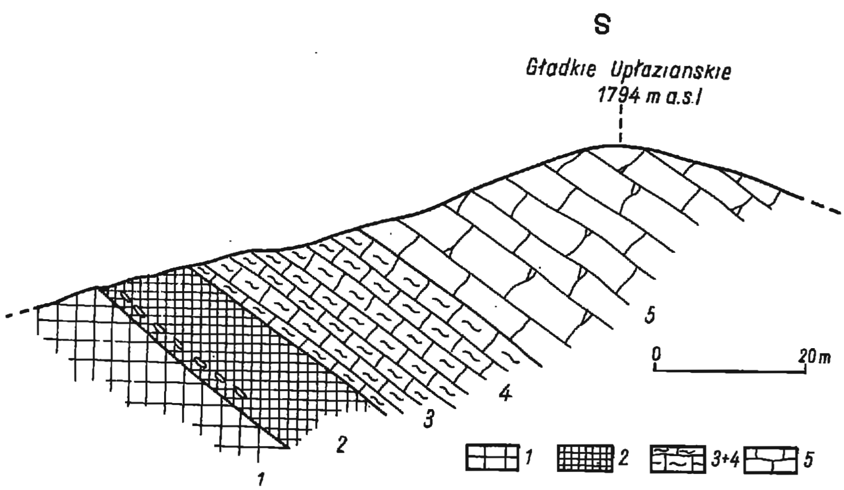


Fig. 5

Cross-section at Gładkie Upłaziańskie

1 lower, green radiolarites with dusky-red-jaspers (Middle Jurassic); 2 red radiolarites and siliceous limestones (jaspers at bottom) (Callovian and Oxfordian); 3 upper, nodular limestones (Kimmeridgian); 4 grayish nodular limestones (Kimmeridgian and Lower Tithonian); 5 siliceous limestones (Tithonian-Berriasian Biancone)

represented all over the Bielskie Tatra Mts and exhibits the greatest thickness of all sub-tatric units in the Tatra Mts. East of Nowy Wierch, near the Murań Mt., some yellowish encrinite olistoliths occur in this member.

In the Polish part, in the Filipka Valley the vertical symmetry in the Upper Jurassic radiolarites is best developed. The Callovian middle nodular limestone is typical there and contains reddish-brown cherts. Its existence there obviously implicates reddish colouration of the lower red radiolarite.

The Rużbachy (old Polish name — Drużbaki) tectonic window situated east of the Tatra Mts shows, according to Mahel (1963) a similar sequence as that of the Hawrań unit in the Bielskie Tatra Mts.

A highly reduced radiolarite sequence occurs at Holica (Fig. 7). The Liassic (most probably Pliensbachian) encrinites are overlaid by 6 m thick Toarcian haematitic dark-reddish-brown nodular limestone which has yielded *Hildoceras bifrons* Brug. (Sokołowski 1950). About 10 meters

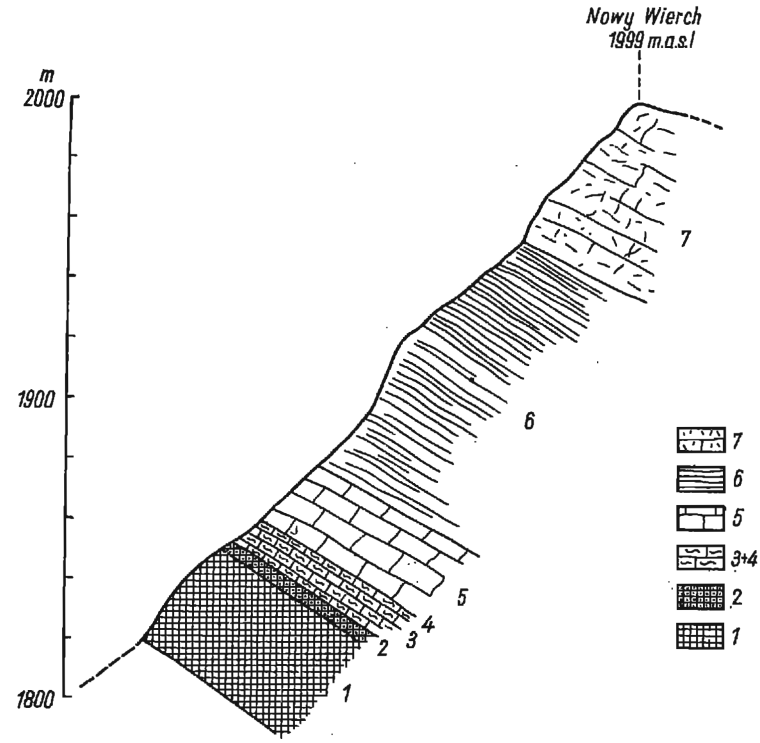


Fig. 6

Cross-section of the southwestern slope of the Nowy Wierch (Bielskie Tatra Mts)

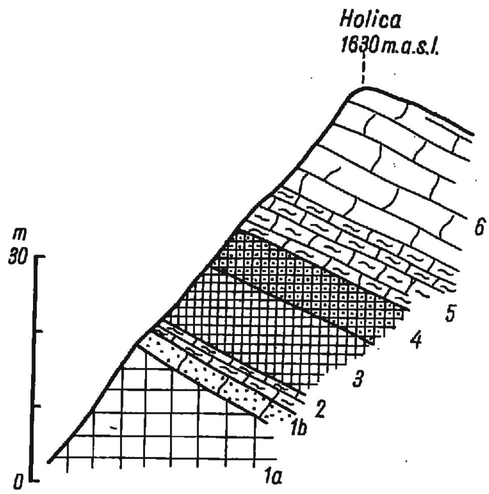
1 green radiolarites (Middle Jurassic and Oxfordian — Lower partly Upper); 2 upper red radiolarites (Upper Oxfordian); 3 upper, nodular limestone (red) (Kimmeridgian); 4 grayish, nodular limestone (Kimmeridgian and Lower Tithonian); 5 siliceous limestone (Tithonian-Berriasian Biancone); 6 marlstones (Valanginian-Hauterivian); 7 Murań limestones (Uppermost Hauterivian — Barremian)

thick green radiolarite represents probably the whole Middle Jurassic and Lower Oxfordian. The upper red radiolarite member (Upper Oxfordian) is 6 m thick. The upper nodular limestone (Kimmeridgian) is 8 m thick. In this tectonic scale the upper nodular limestone is also thicker than the lower one which is a rule in the Tatra Mts. The sequence then passes into the Tithonian Biancone which forms the peak of Holica. An almost complete vertical symmetry crops out in the neighboring Czerwona Skałka (Lefeld 1969).

Fig. 7

Cross-section at Holica (Eastern Tatra Mts)

1 spotted limestones (*a*) and encrinites (*b*) (Domerian); *2* lower nodular limestones (Toarcian); *3* green radiolarites (Middle Jurassic and Oxfordian); *4* upper, red radiolarites (Upper part of Upper Oxfordian); *5* upper, nodular limestones (Kimmeridgian); *6* siliceous limestones (Tithonian-Berriasian Biancone)



Correlation of profiles

The correlation of profiles (Figs 8—10) was done, in the lack of fossils, on purely lithological grounds. The existence of a distinct vertical symmetry in practically all sub-tatric Middle-Upper Jurassic profiles served as the main basis for the correlation. The Toarcian, Callovian and Kimmeridgian nodular limestone members seem to be most stable lithostratigraphic levels, except few cases in which their thickness is reduced partly or even completely (*e.g.* the Callovian in the Bielskie Tatra Mts). Correlation of the particular Oxfordian radiolarite horizons was more difficult because only the colour of those rocks varies in vertical profiles, and in some cases (*e.g.* Płaczliwa Skała in the Bielskie Tatra Mts, Lejowa — in the Western Tatra Mts) it is obvious that only total thickness of the Oxfordian radiolarites should be taken into account whereas the colour changes do not correspond exactly to the stratigraphy. Bearing in mind the possibility of some redeposition within the nodular limestone members the accuracy of ending and/or beginning of the nodular episodes must not fit exactly to stratigraphic units. The sub-tatric carbo-silite sequence the origin of which is, at least in part, due to dissolution processes,

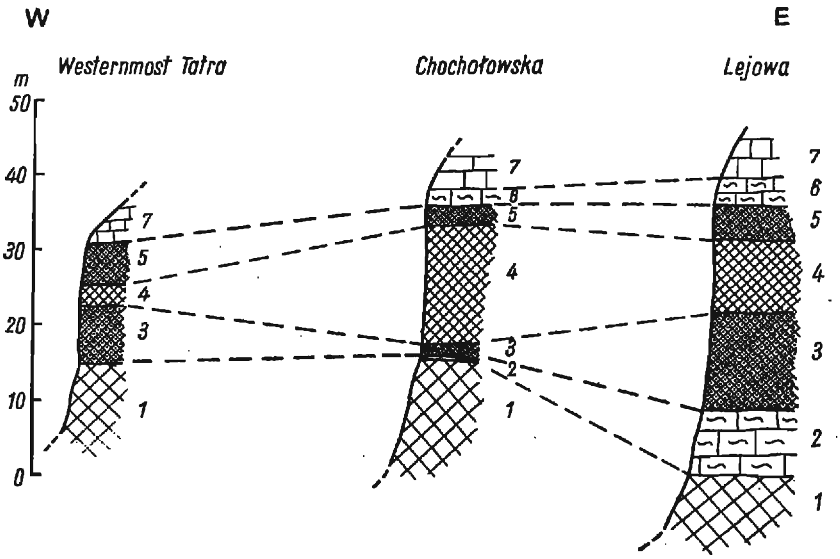


Fig. 8

Lithostratigraphic correlation of the Upper Jurassic carbo-silite sequences in the Western Tatra Mts

For lithologic explanations — see Figs 9 and 10

1 lower, green radiolarites (Middle Jurassic); *2* middle, nodular limestones and siliceous limestones (Callovian); *3* lower, red radiolarites (Lower Oxfordian); *4* upper, green radiolarites (lower part of the Upper Oxfordian); *5* upper, red radiolarites (upper part of the Upper Oxfordian, also Kimmeridgian in the Westernmost Tatra); *6* upper, nodular limestones (Kimmeridgian and Lowermost Tithonian); *7* siliceous limestones (Tithonian-Berriasian Biancone)

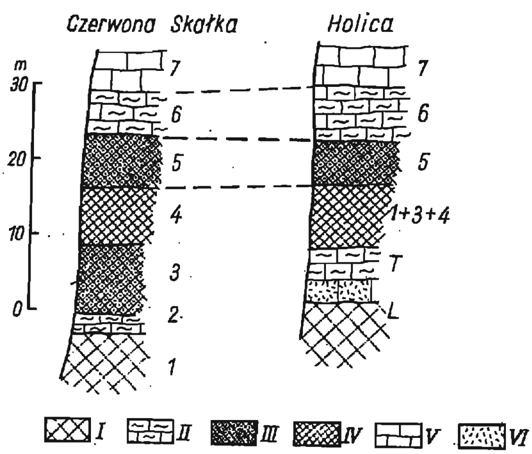


Fig. 9

Lithostratigraphic correlation of the Upper Jurassic carbo-silite sequences at Holica and Czerwona Skałka (Eastern Tatra Mts)

I radiolarites or siliceous limestones; *II* nodular limestones; *III* multicolored Upper Jurassic Oxfordian (radiolarites); *IV* upper, green radiolarites (lower part of the Upper Oxfordian); *V* siliceous limestones (Biancone); *VI* encrinites

1 Bajocian-Bathonian, *2* Callovian, *3* Lower Oxfordian, *4* lower part of the Upper Oxfordian, *5* upper part of the Upper Oxfordian, *6* Kimmeridgian, *7* Tithonian-Berriasian, *L* Liassic (Domerian), *T* Toarcian

must inevitably involve some time spans which are not represented by sediments in its lithological column. Such phenomena, however, cannot be traced using present day research methods. For instance, it is impossible to say whether the Callovian stage is represented or not in the green

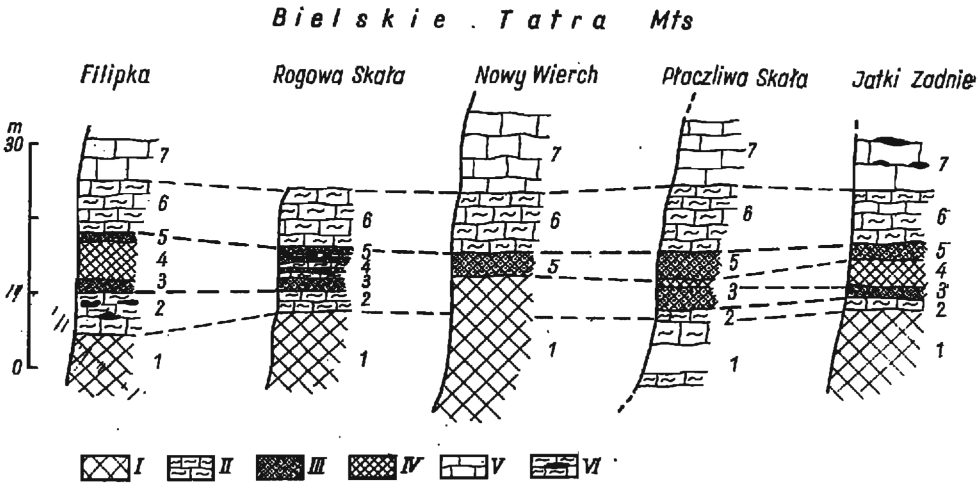


Fig. 10

Lithostratigraphic correlation of the Upper Jurassic carbo-silite sequences in the Hawrań unit (Bielskie Tatra Mts and Polish Eastern Tatra)

I lower, green radiolarites and siliceous limestones (Middle Jurassic); *II* nodular limestones, *III* red radiolarites; *IV* upper, green radiolarites; *V* siliceous limestones (Tithonian-Berriasian Biancone, at Jatki Zadnie — with cherts); *VI* middle nodular limestones with reddish-brown jaspers (Callovian, in the Filipka Valley)

1 Bajocian-Bathonian (at Nowy Wierch together with large part of the Oxfordian), *2* Callovian, *3* Lower Oxfordian, *4* lower part of the Upper Oxfordian, *5* upper part of the Upper Oxfordian, *6* Kimmeridgian (possibly with the lowermost Tithonian), *7* Tithonian-Berriasian

radiolarites of the Bielskie Tatra Mts (*e.g.* Nowy Wierch — Fig. 6) as no nodular limestone is present there. This time span maybe either replaced by the green radiolarites or an unnoticeable hiatus exists there.

Thickness relations are presented in Tables 3 and 4.

Table 3

Total thickness of the sub-tatric Oxfordian radiolarites (in meters)

Westernmost Tatra Mts	Chochołowska Valley	Lejowa Valley	Gładkie Upłaziańskie	Filipka Valley	Bielskie Tatra Mts	Holica
16	14	27	5.5	8	8	18

Table 4

Total thickness of the Upper Jurassic carbo-silite sequence in the sub-tatric succession (in meters)

Westernmost Tatra Mts	Chochołowska Valley	Lejowa Valley	Gładkie Upłaziańskie	Filipka Valley	Bielskie Tatra Mts	Holica
21.5	19.5	38	19	17	22	26.5

Stratigraphy

Lower nodular limestone — Toarcian-Aalenian

The sub-tatric carbo-silite sequence starts with the so called lower nodular limestone of Toarcian and possibly also Aalenian age, according to findings of ammonites *Hildoceras bifrons* Brug. and other forms at Holica (Eastern Tatra Mts) by Uhlig (1897) and Sokołowski (1925). Nodular character of the Toarcian maybe observed only at Holica and in the Western Tatra Mts, whereas in the Hawrań unit (both in the Bielskie Tatra Mts and in the Kopy Sołtysie area) this stage is developed in other facies (Iwanow 1973). The nodular limestones of the Western Tatra Mts are reddish-brown rocks (10 R 4.5/5) with small, slightly lighter nodules. The proportion of the matrix to nodules is relatively high. The matrix shows high admixture of crinoidal debris (Pl. 13, Fig. 1). In the Chochołowska Valley the Toarcian nodular limestones were a subject of exploitation of poor iron ores. In that area they overlie crinoidal manganiferous limestones which were analysed by Krajewski & Myszka (1958), who have also described the Toarcian rocks.

Lower green radiolarite — Bajocian-Bathonian

The nodular limestones of the Toarcian-Aalenian are overlaid by the so called lower green radiolarites of Bajocian-Bathonian age. At base these rocks are still reddish-brown but higher up they soon become dark greenish-gray (5 GY 4/1) to greenish-gray (5 GY 5/1). These relations are to be noted in the Western Tatra Mts, first of all at Grześ hill in the Chochołowska Valley where the lower green radiolarite member is about 25 meters thick, and in the Lejowa Valley (Fig. 3). Dark gray lenticular cherts occur within those rocks. Some parts (mostly top) of these rocks are rather highly calcareous and maybe regarded as siliceous limestones. These are characterized by the Bositra microfacies (Pl. 13, Fig. 2). True radiolarites show abundant radiolarian moulds usually filled secondarily with calcite (Pl. 13, Fig. 3).

In the Eastern Tatra Mts, in the Hawrań unit the lower green radiolarite member contains some encrinites either as separated layers or the crinoidal debris is dispersed throughout the limestone. In few cases, as on the southern slope of Murań, fragments of crinoid stem were found.

In the Hawrań unit, and in the Filipka Valley in particular, pyrite substance is disseminated in the spotted olive-green limestones and radiolarites of the Bajocian-Bathonian (Pl. 13, Fig. 4). In the Western Tatra Mts the rocks of the same age contain but traces of pyrite. Shales occasionally occur inbetween the radiolarite layers. At Gładkie Upłaziańskie a peculiar greenish-gray radiolarites contain reddish-brown jaspers.

Average thickness of the lower green radiolarites maybe estimated as about 15—25 meters.

Only one aptychus was found and determined by Gąsiorowski (1959) from these rocks. According to this author the lower green radiolarites are possibly younger that Lower Bajocian.

In almost all earlier elaborations (Rabowski & Goetel 1925; Sokołowski 1925, 1950) the lower green radiolarites were treated together with the upper ones and regarded as being of Middle Jurassic age. Such interpretation led to confusion and *e.g.* the chemical analysis done by Kuźniar (1913) is difficult to classify now as it may concern the Oxfordian radiolarites. The same canbe said about some illustrations by Sujkowski (1932; Pl. 10, Figs 1—2).

Middle nodular limestone — Callovian

The Middle Jurassic radiolarites are usually separated from the Oxfordian ones by the so called middle nodular limestones. So far few paleontological evidence exists about the age of this member. However, its position inbetween the Bathonian radiolarites in the bottom and the Oxfordian ones at top rises no doubts about its Callovian age. Moreover, such a nodular member (lower nodular limestone) does exist in the Niedzica succession of the Pieniny Klippen Belt and is well documented by ammonitic fauna (Birkenmajer & Znosko 1955). It is not out of question, however, that this member may embrace the Upper Bathonian at bottom and the lowermost Oxfordian at top. In few sites as *e.g.* Nowy Wierch — Murań in the Bielskie Tatra Mts this member is missing probably due to dissolution.

The rock is a typical nodular limestone reddish-brown (10 R 3.5/5) with lighter calcareous nodules. In some cases (Lejowa) the matrix is dark reddish-brown. At Filipka it is grayish-red (10 R 4/2) with dark-reddish-brown cherts. Small, partly dissolved ammonite shells are to be found in these rocks (*see* Lefeld 1969; Pl. 1, Fig. 1). At Szalony Wierch (Slovakian name — Hlupy) in the Bielskie Tatra Mts this member is developed as pseudonodular limestone. Farther south, at Jatki normally developed nodular limestone crops out. It disappears altogether at Fajksowa in the south-eastern termination of the Bielskie Tatra Mts.

As seen in thin section the rock is skeletal micrite. Some parts exhibit abundant *Bositra* shell fragments (Pl. 13, Fig. 5). In other cases *Saccocoma* ossicles, sponge spiculae, *Globochaete alpina* Lombard (Pl. 13, Fig. 6) and *Colomisphaera* cf. *carpathica* (Borza). In the Filipka Valley (Eastern Tatra Mts) a massive hydrozoan *Stromatomorpha* aff. *yokoyamai*

Yabe & Sugiyama was found in the middle nodular limestone. This form is known from the Torinosu series (Callovian-Tithonian) of Japan (Yabe & Sugiyama 1935). The Torinosu limestone in which *Stromatomorpha* was found for the first time is of Oxfordian-Tithonian age. In the tatric case only Callovian/Oxfordian boundary or lowermost Oxfordian age is possible as the overlying radiolarites are Lower Oxfordian in age. This hydrozoan shows some obliteration probably due to transportation (redeposition). It possibly derived from shallower zone and was slided down the through slope to its site of repose. It is embedded in fine, biomicritic rock containing abundant *Saccocoma* ossicles.

In the Western Tatra Mts only at Lejowa Valley is the middle nodular limestone well developed. In that site it shows microfacies with thin shells of *Bositra* (Pl. 1, Fig. 6) and almost at the boundary with the lower, red radiolarite — also the Saccocoma microfacies. In the Chochołowska Valley at Grześ only a single limestone bed (0.35 m thick) separates the Middle Jurassic green radiolarites from the Oxfordian ones. This is a micrite with abundant calcified radiolarian tests. At Gładkie Upłaziańskie the existence of the middle nodular limestone is uncertain. Only trace of it was found there in doubtful position.

Thickness of the middle nodular limestone member in the particular profiles is presented in Table 5.

Out of macrofossils only belemnoid rostra are commonly found whereas aptychi belong to rarities. Ammonite shells are frequent but invariably corroded due to dissolution, a phenomenon already noted by Hollman (1962, 1964) in the Ammonitico Rosso of the Southern Limestone Alps, and by Garrison & Fischer (1969) in the Adneth Beds of Austrian Northern Limestone Alps.

Lower red radiolarites — Lower Oxfordian

The lower red radiolarite member forms a transitional link between the Callovian nodular limestone and the Upper Oxfordian green radiolarite. Its calcium carbonate content diminishes upwards. Lower Oxfordian age is ascribed to this member by analogy to the Niedzica succession of the Pieniny Klippen Belt (Birkenmajer 1958a, 1965). The colour of the lower, red radiolarite member is closely connected with the lower nodular limestone. Obviously its reddish-brown colouration is a result of dissolution processes which continued from the time of deposition of the lower nodular member.

The particular layers of this member are 5—12 cm thick and usually intercalate with thin red shales. Under the microscope the rock shows abundant calcified radiolarian moulds (Pl. 14, Fig. 1). In few sites (Lejowa) a radiolarian-*Saccocoma* association occurs (Pl. 14, Fig. 2) which proves that the deposition had taken place there above the calcite compensation depth. Usually the Saccocoma microfacies disappears upwards. Among macrofossils only few aptychi can be found in these rocks. Chemical analysis of the lower, red radiolarite is presented in Table 6.

The lower, red radiolarite member is missing in the central and extreme eastern parts of the Bielskie Tatra Mts where both green radiolarite members form one complex.

Chemical analyses of the sub-tatric radiolarites published in earlier papers are presented in Tables 7 and 8.

Table 5

Thickness of the particular members of the Upper Jurassic carbo-silite sequence in the sub-tatric succession (in meters)

	Western Tatra Mts	Chochołowska	Lejowa	Gładkie	Filipka	Murań	Szalony Wierch	Jatki	Holica	Czerwona Skałka
Upper nodular limestone /Kimmeridgian/	5	5	6	5.5	6–7	7–8	10	7–8	8	6
Upper red radiolarite /Upper Oxfordian/	6	1	4			3.5			7	
Green radiolarite	1.5	10.5	10	5.5	8		8	3–4	8	8
Lower red radiolarite /Lower Oxfordian/	8	2.5	13							10
Middle nodular limestone /Callovian/	0.25	0.35	4–6	8	5	–	3	2.5	5	2.5

Table 6

Results of chemical analyses of the sub-tatric radiolarites and nodular limestones (in weight per cents)

No. of sample	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	MnO
1	49.01	2.50	0.07	0.63	24.48	0.18	0.09
2	83.99	1.14	trace	0.64	12.49	0.50	no data
3	84.97	1.99	trace	0.90	10.09	1.25	no data
4	47.22	1.81	0.05	0.72	25.76	0.12	0.11
5	42.21	7.31	0.16	6.28	36.99	3.45	no data
6	61.98	1.81	0.01	0.79	33.81	1.13	no data
7	26.43	3.95	0.14	1.88	30.93	1.35	0.07

Provenance of samples:

1 — lower, green radiolarite (Bajocian-Bathonian), Grześ hill, Chochołowska Valley.
2 — middle nodular limestone (reddish-brown jaspers in it) (Callovian-Lowermost Oxfordian), Filipka Valley.
3 — lower, red radiolarite (Lower Oxfordian), Filipka Valley.
4 — upper, green radiolarite (lower part of the Upper Oxfordian), Grześ hill, Chochołowska Valley.
5 — red shale in upper, green radiolarite (Oxfordian), Chochołowska Valley.
6 — upper, red radiolarite (upper part of the Upper Oxfordian), Lejowa Valley.
7 — upper, nodular limestone (Kimmeridgian), Gładkie Upłaziańskie, Western Tatra Mts.

Table 7

Chemical analysis of the sub-tatric radiolarites (after Kuźniar 1913) (in weight per cents)

	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	CaO	MgO	K_2O	Na_2O	Loss by ignition
Jasper from Czerwona Skałka	91.11	1.17	0.37	0.14	2.84	0.67	0.38	0.14	3.52

Remark: Because of that time incorrect stratigraphic scheme it is impossible to say whether this analysis refers to the Middle Jurassic or to the Oxfordian radiolarite

Table 8

Chemical analyses of the sub-tatric radiolarites (after Krajewski & Myszka, 1958). Classification into stages is author's own

No. of analysis	Rock type	Insoluble in HCl	$CaCO_3$	$MgCO_3$	Total R_2O_3
		in per cents			
1	greenish-grey radiolarite, calcareous with brownish spots /Bajocian-Bathonian/	61.63	31.21	3.82	3.22
2	greenish radiolarite with brownish spots in upper part /Bajocian-Bathonian/	62.39	31.40	3.20	2.98
3	greenish-gray radiolarite, calcareous with brownish spots in upper part /Bathonian?/	58.36	35.08	3.64	2.84
4	upper, green, massive radiolarite /Oxfordian/	73.42	24.22	1.32	0.86
5	red, platy limestone /Upper Oxfordian and/or Kimmeridgian/	42.40	26.60	21.15	0.78
6	gray, platy limestone /Kimmeridgian/	46.15	49.35	3.56	0.82

Upper green radiolarites — Upper Oxfordian

This member occupies central position in the Upper Jurassic carbo-silite sequence of the sub-tatric succession. Its thickness varies from 5 m at Gładkie Upłaziańskie up to 10.5 m in the Chochołowska Valley in the Western Tatra Mts. Such small values as 1.5 m in the Westernmost Tatra and 4 m at Jatki (Bielskie Tatra Mts) can hardly be taken into account as thickness evaluation is based entirely on the basis of the colouration of the rocks (Table 5). Simply in some sites the proportions of red to green members differ to some extent from the corresponding time units.

In such cases total thickness of the Oxfordian radiolarites rather should be taken into account, then that of the particular red and/or green members. The colour of the rocks varies from grayish-olive-green (5 GY 4/2) to light olive gray (5 Y 5.5/2).

Thin shale interbeds occur within the green radiolarites (Pl. 5, Fig. 1). Uniform development of this member in the sub-tatric succession clearly contrasts with a peculiar alternation of thin (8—10 cm) reddish cherts and pinkish, siliceous somewhat nodular limestones (20—30 cm) observed at Rogowa Skała (westernmost part of the Bielskie Tatra Mts — Fig. 11), where that type of sediment represents the whole Oxfordian.

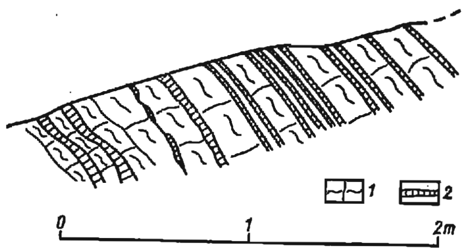


Fig. 11.

Intercalations of nodular limestone and radiolarite in the Oxfordian at the Rogowa Skała (Bielskie Tatra Mts — north-westernmost part)

1 pinkish nodular limestones, 2 reddish-brown radiolarite bands

Syndepositional or syndiagenetic olive cherts are frequently noted within the green radiolarites. They are either lenticular or form thin interbeds. As seen in thin section these rocks show abundance of radiolarian tests which are calcified as a rule. These microfossils are either oriented along the bedding planes, or dispersed at random in the rock. A combination of *Saccocoma* and radiolaria was stated in the green radiolarites at Lejowa Valley (Pl. 14, Fig. 4). In other sites, however, *Saccocoma* ossicles are seldom found in this member. A continuity of the Saccocoma microfacies throughout the Oxfordian up to the Kimmeridgian was observed in the Sucha Valley (Westernmost Tatra Mts), but even there relatively small quantities of these planktonic crinoids occur in the Oxfordian. Such a continuity of this microfacies is well known in some geoanticlinal successions in the Western Carpathians *e.g.* at Manin (Pl. 14, Fig. 6).

In fact, the "green" uniformity exists only in the Eastern Tatra Mts whereas in its western part some reddish interbeds can be observed within the upper green radiolarites which was already observed by Gąsiorowski (1959), who determined the following aptychi from that member:

Lamellaptychus ex gr. *c* Trauth?
Lamellaptychus sp. *2* ex gr. *a* Trauth

According to Gąsiorowski (1962) the upper green radiolarites represent the lower part of the Upper Oxfordian (Table 2).

Upper red radiolarites — Upper Oxfordian

The upper red radiolarites are closely connected with the upper nodular limestones of Kimmeridgian age. Macroscopically the upper, red radiolarites are identical to the lower ones. The colour of rocks is from reddish-brown (10 R 4/4) to grayish-red (5 R 3/2). Some varieties (Lejowa) are paler with dark reddish-brown cherts (Pl. 15, Figs 1—2). The following aptychi were found by Gąsiorowski (1959, 1962) in the upper red radiolarites at Grześ hill:

Lamellaptychus cf. *lamellosus* (Park.)
Lamellaptychus ex gr. *b* Trauth (with inflection near terminal point)

According to this author they probably belong to horizon *IV* in his classification. In thin sections these radiolarites reveal abundance of calcified radiolarian tests. According to Sujkowski (1932) the radiolarian skeletons occurring in the sub-tatric radiolarites belong to Nassellaria and Spumellaria. Horizontal orientation of radiolarian tests as they were laid down at the sea bottom lamina by lamina is frequently observed.

Internal molds and casts of ammonite shells but not phragmocones are occasionally found in the upper red radiolarites and associated red shales. This proves that those rocks were deposited below the aragonite compensation depth. Aptychi and belemnoid rostra belong to rarities. Thickness values of this member are given in Table 5.

Cherts in the Oxfordian radiolarites seem to bear primary character although they have probably undergone some changes in result of diagenetic processes (Pl. 15, Figs 1—2). The role of these secondary processes was probably overestimated by Sujkowski (1932).

Upper nodular limestones — Kimmeridgian

The upper, red radiolarites pass gradually into the upper nodular limestones. The latter member is much better developed in the sub-tatric succession then the middle nodular limestone and is present practically everywhere in the Tatra Mts (Pl. 4). Also its thickness is almost always greater then that of the middle nodular member (*see* Table 5). In most profiles this is a typical "Ammonitico Rosso calcaire" according to Aubouin (1964). The nodules are composed of micritic limestone. They are irregular, often flattened 0.5 up to 10—12 cm large. Their colour varies from almost blackish red (5 R 2/2) to dark reddish-brown (10 R 4/4) — matrix, and grayish-red (5 R 4/2) to pale red (10 R 6/2 and 5 R 6/2) — nodules. In few cases pale greenish colour occurs as well. The proportion of nodules versus matrix varies in vertical profile (Pl. 6, Figs 1—2).

In the Western Tatra Mts (Lejowa, Chochołowska, Sucha valleys) the upper nodular limestone shows few nodules and it is rather platy thus resembling the "Ammonitico Rosso marneuse". This change coincides with westward decrease in thickness. When observed in thin sections the nodules are buildt of skeletal micrite full with *Saccocoma* ossicles, calcified radiolarian tests and rare sections of aptychi (Pl. 15, Figs 3—4). The quantities of *Saccocoma* ossicles increase topward, from the upper, red radiolarites and attain maximum, a "bloom", in the upper nodular limestone. According to Mišik (1959) this microfacies is very characteristic in the Kimmeridgian of the Western Carpathians. Out of macrofossils only aptychi and belemnoid rostra are seldom found in these rocks. According to Gąsiorowski (1959, 1962) the following aptychi derive from the upper nodular limestone member at Grześ hill in the Chochołowska Valley:

Lamellaptychus, group C, *theodosia* (Desh.)
Lamellaptychus, group *A*:
  cf. *beyrichi* (Opp.) em. Trauth
  sp. *1* ex gr. *a* Trauth
Laevaptychus (Latuslaevaptychus) cf. *latissimus* Trauth
Laevaptychus "sp." ind.

They belong to subhorizon VI_1 (undifferentiated) thus pointing to Upper Kimmeridgian and Lower Tithonian (Gąsiorowski 1962). In fact, it seems highly probable that the upper nodular limestone of the sub-tatric succesion may embrace a part of the Lower Tithonian as well.

Olistoliths in the upper nodular limestone

At the southern slope of the Murań Mt. (Bielskie Tatra Mts) few slabs of yellowish encrinite were found in the upper nodular limestone (Fig. 12). The slabs, up to 1.5 m long, are flat and subangular in shape

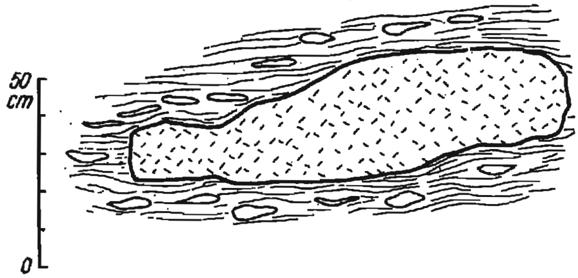


Fig. 12
Encrinite slab embedded in the upper, nodular limestone (Kimmeridgian), Murań Mt. in the the Bielskie Tatra Mts

and are completely wrapped by the nodular limestone. It maybe easily observed that the matrix of the nodular limestone has adapted to the slabs during the deposition. Such yellowish encrinites are absolutely alien to that nodular environment. Presumably the encrinite olistoliths glided down the basin slope from another milieu. Gravitational sliding is the cause usually ascribed to such phenomena by many authors (Marchetti — *in* Jacobacci 1965, Broquet 1970). Olistoliths are well developed in the Jurassic of Sicily and were first described from that island by Italian geologists (*see* literature *in* Broquet, *op. cit.*,). Olistostromes associated with radiolarites are mentioned by Grunau (1965) from the Oman Mts (Oman). Flysch type sediments embedded within Ammonitico Rosso limestones were reported from the Umbro-Marchigiano Basin (Central Italy) by Colacicchi & Pialli (1971). Exotic blocks in the lower nodular limestone (Bathonian-Callovian) of the Niedzica succession (Pieniny Klippen Belt) were described by Birkenmajer & *al.* (1960).

Colour of the radiolarites and nodular limestones

The colour of the sub-tatric radiolarites and associated nodular limestones varies from dark reddish-brown (most common particularly in the matrix of nodular limestones) to pale red in all "red" members, and from dark greenish-gray to olive-gray in the "green" radiolarite members. No special studies were done concerning the Fe_2O_3/FeO ratio versus colouration of the rocks in question, except three samples for which the weight per cents of Fe_2O_3 and FeO were calculated. Namely a sample of lower, green radiolarite (Bajocian-Bathonian) from the Chochołowska Valley (analysis No. 1 at Table 6) shows 0.09 per cent of Fe_2O_3 and 0.54 of FeO. Its colour is light olive-gray (5 Y 5/2). Upper, green radiolarite (Oxfordian) from the Chochołowska Valley shows 0.40 of Fe_2O_3 and 0.32 of FeO (analysis No. 4 at Table 6). Its colour is the same as that of the lower, green radiolarite. The upper, nodular limestone (Kimmeridgian) from the Gładkie Upłaziańskie exhibits 1.11 per cent of Fe_2O_3 and 0.77 of FeO with dark reddish-brown colour (10 R 2/4). These data seem to support Grunau's supposition (1965) that higher ferric iron content causes darker red hues in the rocks, but the scarcity of chemical data does not allow to draw serious conclusions. Stability of colour symmetry in vertical profiles of the carbo-silite sequence as well as of the colour along the strike of beds over long distances was stated in the sub-tatric succession. This suggests primary character of rock colours in the carbo-silite sequence. Similar opinion was expressed by Birkenmajer & Gąsiorowski (1961) about the colour character of the radiolarites and associated nodular limestones of the Pieniny Klippen Belt.

It seems quite obvious that the red radiolarites of the Oxfordian which are enveloped by the nodular limestone members owe their reddish-brown colour to the haematite matrix derived from the latter environment. On the contrary, in cases where the middle nodular limestones are missing (*e.g.* Nowy Wierch in the Bielskie Tatra Mts and Holica), the radiolarites exhibit only greenish-gray colour varieties. Alternation of green and red colour was observed in sites where the carbo-silite rocks were laid down definitely above the calcite compensation depth (*e.g.* Lejowa). Such a reccurrency of red colouration among the usually green radiolarites maybe explained by the proximity of the deposition site of nodular limestone facies.

It is generally accepted that the colouration of the red nodular limestones in the Alpine Jurassic comes from haematite (Hallam 1967). The same is argued about the reddish-brown Alpine radiolarites (Grunau 1965). According to the last mentioned author (*after* van Houten — *in* Nairn 1961), the red colour derived from washing the red upland soils into the eu- and miogeosynclinal basins of the Tethys under tropical and subtropical climatic conditions during the upper Jurassic times. In such case, however, one might expect either uniform distribution of lateritic material over the ocean due to the action of currents, or continuously parallel to the trough position of the denuded land area. In fact, such situations seldom occur in nature and we deal with some changes in red colour in horizontal sense. Thus, another explanation is needed to explain uniform horizontal colouration of the Carpathian radiolarites. It seems most probable that the horizontal uniformity of the red colour in the sub-tatric radiolarites and associated nodular limestones is primarily due to extensive dissolution processes on the sea floor below and/or above the calcite compensation depth which led to enrichment in haematite matrix. Also redeposition of some quantities of nodules may account to some extent for such an enrichment. Hence, it is rather the depth of deposition which maybe occunted for the colour of the rocks in the sub-tatric carbo-silite sequence. According to Grunau (1965) the green colour of the "green" radiolarites maybe caused by the existence of chlorite. Sujkowski (1932) mentioned radiolarian tests preserved in green chlorite in the sub-tatric radiolarites. Nevertheless, this mineral is seldom found in these rocks.

Mean sediment accumulation rates

The calculation of the mean sediment accumulation rates was done separately for the Oxfordian radiolarites and for the whole Upper Jurassic carbo-silite sequence. It seems most probable that the Upper Jurassic radiolarites of the sub-tatric succession are confined to the Oxfordian (with some part of the Kimmeridgian, Gąsiorowski 1959). The duration of the Oxfordian was taken as 6 millions years (Howarth 1964). The calculation was based on the approximated primary thickness of sediments *i.e.* the thickness of the rocks plus 15 per cent which was lost in result of compaction (Garrison 1967). The calculated data are presented in Tables 9 and 10.

Table 9

Accumulation rates of the sub-tatric Oxfordian radiolarites

	Sucha Valley	Chochołowska Valley	Lejowa Valley	Gładkie Upłaz.	Filipka Valley	Bielskie Tatra Mts
Thickness of rocks	16.0	14.0	27.0	6.0	10.0	8.0
Original thickness of sediments	18.4	16.1	31.05	6.9	11.5	9.2
Accumulation rate /in Bubnoff units/	3.06	2.68	5.17	1.15	1.92	1.53

Table 10

Accumulation rates of the Upper Jurassic carbo-silite sequence of the sub-tatric succession

For definition of the Bubnoff Unit — see Fischer, 1969
Duration of the Oxfordian — 6 millions years
Duration of Callovian, Oxfordian and Kimmeridgian — 16 millions years (Holmes — Symposium. 1964 — *see* Howarth 1964)

	Sucha Valley	Chochołowska Valley	Lejowa Valley	Gładkie Upłaz.	Filipka Valley	Bielskie Tatra Mts
Thickness of rocks	21.50	19.50	38.00	19.0	21.0	22.0
Original thickness of sediments	24.72	22.42	43.70	21.85	24.15	25.30
Accumulation rate /in Bubnoff units/	1.55	1.40	2.70	1.37	1.51	1.58

The duration of deposition of the Upper Jurassic carbo-silite sequence comprising the Callovian, Oxfordian and Kimmeridgian stages was taken as 16 millions years (Howarth 1964). The duration of the Bajocian and Bathonian during which the "lower" green radiolarites were deposited was taken as 10 milions years.

It is remarkable that highest rates were calculated for the rocks of the Lejowa Profile in the Western Tatra Mts where the radiolarites are most calcareous of all in the Tatra Mts (*see* Tables 6 and 8). Values from the Sucha, Chochołowska and Filipka valleys and from the Bielskie Tatra Mts seem to be most representative althought they are higher then those ones calculated for the Ruhpolding Radiolarite of the Austrian Alps by Garrison & Fischer (1969). The Bajocian-Bathonian green radiolarites of the sub-tatric succession at Grześ hill in the Chochołowska Valley are 22 m thick which corresponds to about 25.3 m of original sediment (15 per cent compaction added). The corresponding accumulation rate was about 2.53 m/million year. It is not out of question, however, that the Ruhpolding Radiolarite of the Eastern Alps does not represent the whole Lower Tithonian and, in such case, the duration time of its deposition should have been shorter, hence the rates of its deposition more easily comparable to those of the Tatra Mts.

Stratigraphic distribution of microfossils

The skeletal remains preserved in the rocks of the Middle-Upper Jurassic carbo-silite sequence in question belong entirely to planktonic microfossils. These are: radiolarians, stomiosphaerids, protoglobigerinas, ossicles of *Saccocoma* and possibly of other planktonic crinoids, and thin possibly in part — juvenile shell fragments of *Bositra* (=*Posidonia*) (Pls

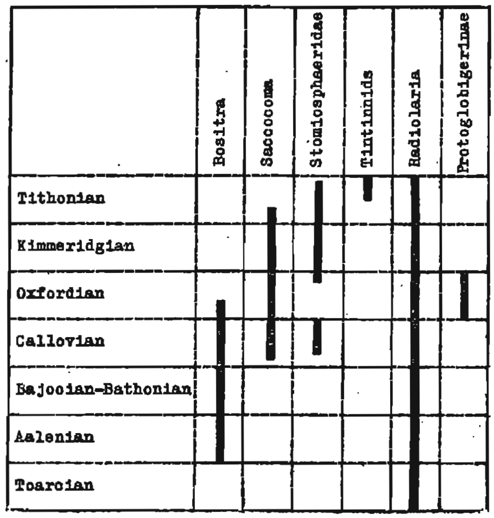


Table 11
Distribution of microfossils in calcareous facies of the sub-tatric Middle-Upper Jurassic

13—15). Their stratigraphic distribution in the sub-tatric Jurassic is presented in Table 11. The *Bositra* shell fragments are common in the sub-tatric red and green nodular limestones and shales of Aalenian, Bajocian-Bathonian, Callovian and Oxfordian age (Pl. 13, Figs 2 and 5). In the Aalenian this microfacies is most common and is associated with crinoidal debris. In the Lower Oxfordian it is associated with radiolarians. This

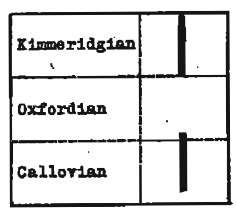


Table 11a
Discontinuous distribution of *Saccocoma* ossicles in the sub-tatric Oxfordian radiolarites

microfacies was probably widespread over various depths in the Tethyan realm. The presence of the Bositra microfacies *per se* cannot be regarded as an indicator of any marine environment as these thin pelecypod shells were easily transported by oceanic currents over great distances. In the case of the sub-tatric Jurassic its association with deep marine environment rises no doubt. This microfacies was not observed in the radiolarites.

According to Borza (1969) such remains of juvenile pelecypod shells occur also in the Oxfordian and Lower Kimmeridgian of the Slovakian West Carpathians. *Saccocoma* ossicles are abundant in the middle nodular limestones of the Callovian, and higher up in the Kimmeridgian (Pl. 13, Fig. 6; Pl. 15, Figs 3—4). In the Western Tatra Mts a continuity of this microfacies was noted (Lejowa Valley), where *Saccocoma* is to be found in the Oxfordian micrites as well although in smaller quantities (Pl. 14, Fig. 4). In other parts of the area, however, a remarkable gap exists in the vertical distribution of the *Saccocoma* ossicles which, most probably, is due to dissolution below the calcite compensation depth. Such a case is illustrated in Table 11*a*. In the area of the Bielskie Tatra Mts this microfacies was first studied by Mišík (1959). It is known to occur in the high-tatric zone of the Polish Tatra Mts as well (Lefeld & Radwański 1960).

Stomiosphaerids which were thoroughly studied in the area of the Polish Cieszyn Silesia by Nowak (1968) also occur in the sub-tatric succession. Aside of their occurrence in the Tithonian and Berriasian some specimens of *Colomisphaera* cf. *carpathica* (Borza) were found in the middle nodular limestone of Callovian — lowermost Oxfordian age in the Filipka Valley (Eastern Polish Tatra Mts). In the light of this find, that species can hardly be regarded as index form, and is rather indicative for some pelagic facies.

Radiolaria occur throughout the whole Middle-Upper Jurassic carbo-silite sequence in the sub-tatric succession. State of preservation of their tests in usually bad. In most cases their tests are calcified, in some cases — they are partly infilled by chalcedony, and partly — by calcite. Opaline or chalcedony filled molds are seldom found (*see* Sujkowski 1932; Pl. 10, Fig. 2). It was observed that relatively larger quantities of radiolarian tests occur in the green radiolarites then in both red radiolarite members. This radiolarian "bloom" in the green radiolarites (Pl. 14, Figs 3 and 5) is probably a result of enrichment due to intensive dissolution processes of calcium carbonate about or below the calcite compensation depth (Garrison & Fischer 1969).

The radiolaria of the sub-tatric succession were not paleontologically studied. According to Sujkowski (1932) who has separated them from the sub-tatric radiolarites using chemical methods they belong to Spumellaria and Nassellaria. Because of bad state of preservation determination to species is impossible.

Protoglobigerinae were found only in the Oxfordian radiolaritic limestone at Rogowa Mt. in the Bielskie Tatra Mts. According to Colom (1955) Protoglobigerinae belong to pelagic forms of Globigerinae. Their stratigraphic range in the Slovakian Western Carpathians is from the Callovian up to the Kimmeridgian (Borza 1969).

Vertical symmetry in the Upper Jurassic carbo-silite sequence

One of the most spectacular characters of the sub-tatric Upper Jurassic carbo-silite sequence is its vertical symmetry in the particular profiles. This phenomenon was first observed in the Pieniny Klippen Belt (Niedzica succession) by Birkenmajer & Gąsiorowski (1961). In the sub--tatric succession the symmetry consists of the red, so called "middle" nodular limestones of probable Callovian age, lower red radiolarites (Lower Oxfordian), green radiolarites, upper red radiolarites (Upper Oxfordian) and upper red nodular limestones (Kimmeridgian) (Lefeld 1969). Using letter symbols for simplicity this symmetry maybe shown as follows:

upper nodular limestone	A
upper red radiolarite	B
green radiolarite	X
lower red radiolarite	B
middle nodular limestone	A

In some sites, particularly in the Eastern Tatra Mts, the middle nodular limestone is missing and in such cases the green radiolarites of the Middle Jurassic directly contact the green radiolarites of the Oxfordian. Such a "reduced" symmetry maybe expressed like that:

upper nodular limestone	A
upper red radiolarite	B
upper green radiolarite	X
lower green radiolarite	X

The reduced symmetry is clearly unilateral as red members occur only on one side (top) of it. Taking into account the complete carbo-silite sequence of the sub-tatric succession which starts with the Toarcian-Aalenian lower red nodular limestone the scheme will be:

upper nodular limestone	A
upper red radiolarite	B
upper green radiolarite	X
lower red radiolarite	B
middle nodular limestone	A
lower green radiolarite	X
lower red nodular limestone	A

In few sites there are thin red radiolarite beds separating the lower nodular limestone of the Toarcian-Aalenian from the lower green radiolarite of Bajocian-Bathonian age.

Some deviations from the above schemes occur, particularly in the Western Tatra Mts *e.g.* at Lejowa Valley where thin red interbeds occur within the upper green radiolarites. Such minor irregularities do not change much the main symmetric scheme. As it comes from the above schemes the upper part of this symmetry is always present thus it is better developed. This phenomenon was observed in the Alps already by Steinmann (1925). The same situation exists in the Klippen Belt of Poland where the upper part of such vertical symmetry can be observed in the Niedzica, Czertezik, Haligovce and Branisko successions (Birkenmajer & Gąsiorowski 1961, Birkenmajer 1965). A complete symmetry occurs there only in the Niedzica succession (Birkenmajer & Gąsiorowski, *op. cit.*). Complete symmetry in the sub-tatric succession was stated only in the Lejowa Valley (Western Tatra Mts), at Czerwona Skałka and in the both eastern and western extremities of the Bielskie Tatra Mts (Eastern Tatra Mts), whereas the central part of the last mentioned area shows only a partial, "reduced" symmetry without the middle nodular limestone member (*e.g.* Fig. 6). Similar apparent "unity" of both green radiolarite members exists in the Chochołowska Valley where only insignificant thin (15 cm) bed of grayish-brown siliceous limestone separates the lower green radiolarites from the upper ones. Such profiles most probably, ware taken into account in establishing the first stratigraphic schemes of the sub-tatric succession in which radiolarites were assigned only to the Middle Jurassic (Rabowski & Goetel 1925). Such a reduced sequence of the Tatra Mts maybe tentatively compared to the Branisko succession of the Klippen Belt, at least in respect of its Upper Jurassic members. A complete symmetry is comparable to that of the Niedzica succession of the Pieniny Klippen Belt. The nomenclature applied by Birkenmajer & Gąsiorowski (1961) to the latter succession was also used in this paper.

It is worth of note that the existence of red radiolarite members is closely connected with the presence of the nodular limestones. In all sites where the latter are missing the red radiolarites are lacking as well. This indicates that the red radiolarites owe their reddish-brown stain from the processes which acted during the sedimentation of the nodular limestones. They maybe regarded as "impure" radiolarites, whereas the green ones constitute pure radiolaritic facies. Birkenmajer & Gąsiorowski (1961) regarded the Oxfordian green radiolarites of the Klippen Belt (Niedzica, Haligovce and Branisko successions) as the central members of the vertical symmetry. This member may correspond to a maximum depth of the basin according to the last mentioned authors (*op. cit.*). In cases of absence or scarcity of nodular limestones the thickness of the green radiolarites always rises at the expense of the red radiolarite members. This maybe observed both in the sub-tatric succession in the Tatra Mts, and in the Pieniny Klippen Belt of Poland (Birkenmajer 1965, Table 1). On the contrary, sequences with well developed „border" zones of nodular limestones show but thin central radiolaritic members. This is the case with the Niedzica succession of the Klippen Belt (Birkenmajer & Znosko 1955, Birkenmajer 1965). In extreme cases the whole Upper Jurassic sequence maybe represented entirely by nodular limestones as it is the case with the geoanticlinal Czorsztyn succession of the Klippen Belt. The Czorsztyn Limestone of that succession (Birkenmajer 1963) comprises stages from the Callovian up to the Kimmeridgian inclusively, thus covering the time span of the carbo-silite sequence in question.

Undoubtedly the existence of vertical symmetry in the sub-tatric Upper Jurassic denotes a definite regularity in the basin development. Its similarity to some successions of the Pieniny Klippen Belt (the Niedzica succession in particular) is marked by the following characters:

1. Insignificant lateral facies changes.
   The radiolarite horizons are of similar thickness and facies over the whole Tatra Mts. The same can be said about the nodular limestone beds bordering them with some exception of the middle nodular member (Callovian) which is the most inconstant member, and in some sites is missing altogether.
2. Small thickness of the radiolarites.
   The pertinent data are given in Tables 3, 5 and 9.
3. Persistence of rock colouration over the whole sub-tatric zone of the Tatra Mts. The radiolarites and associated nodular limestones are reddish-brown to greenish-gray and again reddish-brown with few deviations. According to Birkenmajer & Gąsiorowski (1961) the colouration of the Klippen Belt radiolarites is of primary character and was connected with the depth of the basin. The same may be supposed about the sub-tatric rocks.
4. Poor fossil content.
   Only few aptychi and very rare rostra of belemnoids occur in the sub-tatric radiolarites. Ammonite molds and imprints are seldom encountered, and only in the red radiolarites. Usually abundant radiolarian tests are preserved, as a rule, in form of calcified molds.
5. Lack of land-derived material except few finest dust enclosed in thin shale interbeds among the radiolarites.
6. Lack of sedimentary structures.
   There are no hieroglyphs and the fossils are nonoriented.
7. Lack of volcanic material.
   Volcanic material was stated neither in the Tatra sub-tatric zone nor in other Central Carpathian massifs (Križna unit) in the Upper Jurassic (Andrusov 1959).

Basalts connected with the Jurassic radiolarites were observed in Bukowina (Eastern Roumanian Carpathians) by Zapałowicz (*fide* Sujkowski 1932). The latter area, however, is quite distant from the Tatra Mts.

Certainly such a symmetrical distribution of facies may be interpreted in many ways. Among others, the schemes proposed by Garrison & Fischer (1969, Figs 19—21) maybe applicable. Out of those figures, their Fig. 21 seems to be most realistic one, as it assumes that the compensation depths have remained roughly the same from the Jurassic to the present. Such an approach to the problem is applied in this paper as well. Recent oceanographic data show that no evident depression of the compensation depth took place in the Pacific during most of the Tertiary (Riedel & Funnel 1964). Changes of the compensation depths due to possible bottom ocean water temperature changes were probably of minor scale at least in respect of magnitudes important to the geological processes. An increase of calcite production by the plankton during the Jurassic as postulated by Garrison & Fischer (1969) was probably much more gradual and started presumably much earlier although the first stages of its development are unnoticeable so far. It seems improbable that it might have had much influence on the that time compensation depths. On the other hand, an increase of total amount of calcium carbonate in the Tethyan troughs really existed but was probably mostly due to a rather mechanical supply down the basin slopes. This is proved by some features observed in the nodular limestones as *e.g.* slumping processes (Garrison & Fischer 1969, Bernoulli 1971; and this paper, p. 299). Combination of these processes together with dissolution highly obscures the view, particularly so that we are unable to evaluate proper dimensions of all of them.

Aside of all the above considerations some palaeogeographic data concerning the Upper Jurassic history of Eastern and Central Europe seem to help in solving the problem. In the Polish Lowland a maximum of Jurassic transgression was reached during the Oxfordian (Samsonowicz *in* Samsonowicz, Książkiewicz & Rühle 1965), and a shallowing tendency took place in the same area at the Oxfordian/Kimmeridgian boundary (Kutek 1969). These facts strikingly coincide with the upper part of the vertical symmetry in the sub-tatric and Niedzica and Branisko successions of the Inner Carpathians in which the radiolarites pass upwards into the nodular limestones. In the result of those changes which took place over vast areas of Europe outside the Tethys, the deepest zones of the latter have expanded considerably. Thus it was the surplus of water resulting from rise of sea-level rather then subsidence which was primarily responsible for the Upper Jurassic (Oxfordian) deepening phase. This view is dealt with in detail farther on in this paper, in the chapter on palaeogeography.

If the above coincidence of palaeogeographic events is correct the following scheme of facial development in the sub-tatric succession is proposed (Fig. 13). In this scheme each radiolaritic unit is accompanied laterally by nodular limestone facies. The lower part of the symmetry marks probably not only the deepening tendency in the basin but also an outward expansion of the nodular limestone zone. The deepening phase is marked by an expansion of radiolaritic facies, and the subsequent shallowing tendency — by a return of nodular facies (Kimmeridgian), which terminates the vertical symmetry. The vertical straight line indicates the position of the analysed sub-tatric succession in the basin. As it comes from this scheme the sub-tatric deposition had taken place presumably on a slope of a geosynclinal trough. This fits well to the abundance of nodular limestone zones and slumping phenomena recorded in some of such basins. Such a position in the basin supports also the view expressed by Aubouin (1964) about slope position of the Ammonitico Rosso facies in geosynclines. Similar argumentation maybe applied to the Middle Jurassic radiolaritic phase. The Toarcian-Aalenian lower nodular limestones began the "Période de vacuité" of Aubouin (1967) simultaneously being a transitional facies toward the radiolaritic sedimentation of the Bajocian-Bathonian. A symmetry similar in character seems to occur in the Jurassic of the Transdanubian Central Mountains in Hungary (Konda 1971). The radiolarites of Süd Tessin in Switzerland are also bordered with limestones containing cherts (Bernoulli 1960).

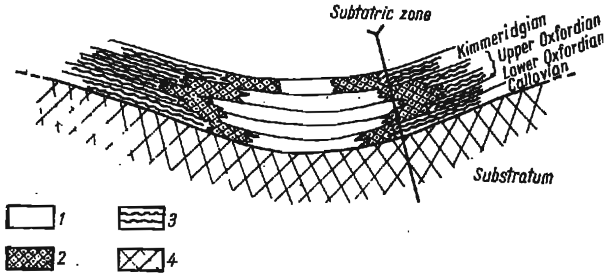


Fig. 13

Estimated deposition scheme of the sub-tatric Upper Jurassic carbo-silite sequence in the Tatra Mts. The Oxfordian expansion of the radiolarite facies marks the maximum depth phase in the Carpathian part of the Jurassic Tethys (not to scale)
1 green radiolarites, 2 red radiolarites, 3 nodular limestones, 4 substratum (Middle Jurassic)

Role and character of nodular limestones

The nodular limestone members play a role of transitional facies in the sub-tatric succession. Their bordering character in all the analysed profiles rises no doubts. The Toarcian-Aalenian lower nodular limestones form a transition from the Liassic spongiolitic and crinoidal facies toward the Middle Jurassic radiolarites. The upper nodular member is transitional from the Oxfordian radiolarites to the Tithonian-Berriasian Biancone siliceous limestones. The role of the middle nodular member (Callovian) is less clear. In the succession in question this member separates the lower radiolarites (Bajocian-Bathonian) from the upper ones. According to the scheme cited above (Fig. 13) it should correspond to a shallowing episode. This seems to coincide roughly in time with the appearance of stromatolithic horizons at the decline of the Callovian in the Polish Jura Chain (Szulczewski 1968). As it was already said, the middle nodular limestone is an inconstant horizon in the sub-tatric succession and in some sites is missing altogether. Presence of three nodular calcareous horizons suggests that the deposition in the sub-tatric zone had oscillated about the compensation depths of the Middle-Upper Jurassic times. Traces of dissolution are very impressive in the nodular limestones in the Tatra Mts. Many examples of dissolution of ammonite phragmocones are known as *e. g.* in the middle nodular limestone (Callovian) of Płaczliwa Skała, Bielskie Tatra Mts (Lefeld 1969; Pl. 1, Fig. 1). Such phenomena are well known from many Alpine limestones of „Ammonitico Rosso" type (Giannini & *al. 1950* — *fide* Cressman 1962; Lucas 1955a; Hollmann 1962, 1964; Szulczewski 1965; Garrison & Fischer 1969). It should be pointed out, however, that the sub-tatric nodular limestones differ considerably from those ones described by Hollmann (1962, 1964), Sturani (1969) and Szulczewski (1965) as clastic material, stromatolites and burrows of lithofags are absent in them. The common feature is their texture resulting in both cases from dissolution processes. Association with radiolarites excludes their origin on geoanticlinal highs. The upper nodular limestones in the Bielskie Tatra Mts (Pl. 6, Figs 1—2) show vertical zonation into parts with more, densely packed nodules (central part in Fig. 1) interbedded with parts showing less nodules and more matrix (bottom and top of block, same figure). This maybe due either to differentiation of dissolution processes, or to pulsative character of carbonate sediment supply due to slumping or slow creeping down the basin slope, or both factors combined. Slumping was a major factor in the deposition of this type of sediment in the sub-tatric succession as it is proved by the presence of obliterated specimen of hydrozoan *Stromatomorpha* (see p. 293) an organism obviously derived from a photic zone and subsequently slumped down into the nodular environment. Another evidence is the existence of encrinite slabs embedded in the upper nodular limestone (*see* p. 299). It is quite possible that in some cases the inflow of calcareous material might have exceeded the actual dissolution rate. In all reverse cases, as *e.g.* the both red radiolaritic members of the vertical symmetry, the final product of sedimentation was radiolarian ooze mixed with haematitic mud, the latter most probably a residue after dissolution of carbonates. In exceptional cases as *e.g.* on the Bermuda Apron where the carbonate sediments were deposited rapidly by turbidity currents to depths of 4515 m, even the aragonite and high-magnesian calcite, have been preserved in sand-size fraction, but have been removed by dissolution in intercalated carbonate silt and ooze (Friedman 1965). Thus preservation of carbonates at great depths depends, among other factors, on the rapidity of sediment inflow (*e.g.* creeping, sliding, turbidity currents etc.) to the depocenter, the normal depository conditions of which invariably lead to an almost complete dissolution of carbonate matter (basin starvation).

Role and character of radiolarites

Farther increase of the dissolution rate (due *e.g.* to a general depening of the basin) resulted in sedimentation of green radiolarites which as a rule, are devoid of haematitic tint. This member occupies central position in the sub-tatric carbo-silite sequence. In most sites in the sub-tatric zone the green radiolarites have been laid down below the calcite compensation depth. In the Western Tatra Mts, however, some red intercalations in this member as well as preserved ossicles of *Saccocoma* prove that the deposition there has undergone between the calcite and aragonite compensation depths. Those rocks maybe defined rather as siliceous limestones because their calcium carbonate content is high (*see* Table 6). Judging from their central position in the profiles it seems obvious that the green radiolarites represent the maximum depth in the sub-tatric succession. This is particularly so in such profiles as *e.g.* the central part of the Bielskie Tatra Mts (Fig. 6), where both green radiolaritic members form one unit. Their thickness there does not exceed 30 m thus being comparable to that of the Ruhpolding Radiolarites of the North-Eastern Alps (Trauth 1950, Garrison & Fischer 1969). In most sites, however, these two green radiolarite members are separated by the middle nodular limestones and lower red radiolarites. It is noteworthy that the red radiolarites contain few iron oxides (*see* Table 6) despite their strong reddish-brown colouration. Garrison & Fischer (*op. cit.*) are probably correct in saying that the radiolarites are a kind of insoluble residue. Also in the case of the sub-tatric radiolarites the dissolution rate was most probably highest of all in the carbo-silite sequence in question.

Problem of the source of silica in the radiolarites

The source of silica in the radiolarites is a difficult and long discussed problem. In the case of the sub-tatric radiolarites as well as in the Alpine ones the problem is whether all the silica came from the dissolution of radiolarian skeletons, or other source was also supplying it. The problem was thoroughly discussed by Aubouin (1965) and Garrison & Fischer (1969). Many authors maintain that silica in the radiolarites comes from submarine volcanic sources (Khvorova 1968), but this is not the case with the Inner Carpathians as no such a source existed there during the Bajocian-Oxfordian times when the Carpathian radiolarites were formed. This was already pointed out by Birkenmajer & Gąsiorowski (1961). On the other hand, some eruptive rocks associated with Jurassic radiolaritic shales were reported from the Eastern Carpathians by Slavin (1972), and Zapałowicz (*fide* Sujkowski 1932). Some Alpine Upper Jurassic radiolarites (*e.g.* at Arosa and Klosters) are possibly associated with a volcanic activity (Grunau 1959).

The problem whether the silica can be inorganically precipitated in the sea or not was discussed by many, among others by Siever (1962), Bien & *al.* (1958), Cressman (1962) Berger (1970), Krauskopf (1956), Berner (1971), Degens (1965), Grunau (1965), Calvert (1968) and Pettijohn (1957). Majority of them agree that silica cannot be inorganically precipitated in the sea except perhaps in some few near-volcanic environments (Berner, *op. cit.*). But there is no general aggreement in this question (Degens, *op. cit.*). Dissolution as a process playing decisive role in the formation of the radiolarites was long pointed out by many authors (Correns 1950, Heim 1958, Grunau 1965, Aubouin 1967, Hudson 1967, Berger 1968, Berner 1971, and others). Heim's (*op. cit.*) conclusion was that radiolarites are a residue after complete dissolution of carbonates. These processes were obviously active during the formation of the rocks of the sub-tatric carbo--silite sequence. Thus the silica both of the radiolarites and nodular limestones maybe regarded as a residue after the dissolution of carbonates. Partial removal of carbonate substance from the sub-tatric radiolarites may, among other factors, account for their slow deposition. In the opinion of Berger (1970), basin to basin circulation could have played an important role in transport of silica by bottom currents. Under the thalassocratic marine conditions of the Upper Jurassic times water circulation must have been extensive. Thus an inflow of silica derived from distant sources (organic and/or even volcanic) was quite possible.

It should be pointed out here that also the sub-tatric nodular limestones contain large quantities of radiolarian tests (Pl. 15, Fig. 3; Pl. 13, Fig. 6) and relatively large quantities of silica (Table 6, *see also* Hallam 1967). Dissolution of such carbonate rocks must have furnished considerable amounts of silica into the environment. The dissolution may possibly account also for another kind of residual type of sediment namely the thin shale interbeds occurring inbetween the radiolarite layers. Such shaly intercalations among the Oxfordian radiolarites of the Branisko and Niedzica successions of the Klippen Belt were interpreted by Birkenmajer & Gąsiorowski (1961) as a result of deposition from suspension of dust clouds. Aside of such a possibility the shale interbeds being residues after dissolution of primarily more calcareous sediments represent probably large time spans. An example from the Chochołowska Valley which was chemically analysed (Table 6, analysis No. 4) still shows high CaO content.

From the above considerations it maybe concluded that the silica in the Middle-Upper Jurassic sub-tatric radiolarites derived partly from the dissolution of radiolarian skeletons, and partly is a residue after dissolution of carbonates. Volcanic source is excluded unless some basin to basin circulation has been possible during those times from some distant areas.

Inferred depth of deposition of the radiolarites

The depth of deposition for the sub-tatric radiolarites maybe estimated as lying about or slightly below the calcite compensation depth of the Oxfordian times in the Eastern Tatra Mts (central part of the Bielskie Tatra Mts, Eastern Polish Tatra Mts in particular), and between the aragonite and calcite compensation depth of those times for the western part of the Tatra Mts. This is reckoned from the state of preservation of various skeletal particles in the radiolarites and siliceous limestones. Ammonite phragmocones are never preserved except very few casts (Lejowa Valley). Ossicles of the planktonic crinoids *Saccocoma* are preserved in the Oxfordian radiolarites and siliceous limestones only in the Western Tatra Mts. They are lacking in those rocks in the Eastern Tatra Mts.

Evaluation of the more or less accurate position of the Upper Jurassic compensation depth is rather risky and it should not be compared directly to the present day oceanographic data. The actual compensation depth in the world oceans lies approximately at depths of 4000 meters below sea level (Berner 1971). The position of lysoclines *i.e.* the curve lines marking the compensation depth of the world oceans varies (*see* Berger 1970, Fig. 8) from 2800 m down to 5000 m below sea level and depends, among other factors — on latitude. The present latitude of the Tatra Mts is slightly more than 49° latitude north. The Jurassic latitude for that massif calculated on the basis of paleomagnetic data (Irving 1964) should be about 28° north which is roughly the latitude of the present day area situated south of the Mediterranean Sea (overthrust of the sub-tatric zone not calculated). Lysocline curves for both Pacific and Atlantic Oceans of to day markedly rise toward the Equator and particularly so inbetween latitudes 20—5° north (Berger, *op. cit.*, Fig. 8). If this was the case with the Upper Jurassic Tethys the inferred compensation depth of those times should be placed inbetween, say, 4500—2700 m below sea level. In this warm oceanic basin the solution might proceed more rapidly then in cold oceans of to day (Hudson 1967). Thus the radiolarites might have been deposited about the minimal of the above mentioned depths (3000 m or so). Another caution was given by Heath (1969) who observed that the calcite compensation level has risen from depth of more than 5200 m since of the Oligocene to the present day 4700 m in the equatorial Pacific. This, certainly, cannot be indiscriminately transferred to the Upper Jurassic Tethys, nevertheless, it gives and idea of the changes which obviously did occurred in all ancient oceans, and irreversibly escaped our observation. Slightly higher carbonate content of the sub-tatric radiolarites as compared to that of the Alpine ones (Grunau 1959) suggests that they might have been deposited on smaller depths than their Alpine counterparts.

TITHONIAN-BERRIASIAN

The upper nodular limestones of the Kimmeridgian gradually pass upwards into the carbonate rocks of the Tithonian. The latter rocks are not dealt with in detail here as special paper will be devoted to the Tithonian of the Tatra Mts in future.

Because of their uniformity with the Berriasian rocks this member is treated here as Tithonian-Berriasian following Wiedmann's proposal (1968, 1971).

The basal part of the Tithonian is developed as grayish nodular limestone (*e.g.* at Gładkie Upłaziańskie) still characterized by abundance of *Saccocoma* ossicles. Higher up the character of the rocks becomes less and less nodular and more and more siliceous. The colour is light olive gray (5 Y 6/1 to 5 Y 5/2). Petrography, chemical content (*see* analysis below) and microfossils show that this rock is closely comparable to the Biancone (or Maiolica) facies.

Chemical analysis of the Biancone-type micritic limestone of the Tithonian — Gęsia Szyja — Eastern Polish Tatra Mts (in weight per cent):

SiO_2	10.52
Al_2O_3	1.27
TiO_2	0.01
Fe_2O_3	1,14
CaO	84.68
MgO	1.87

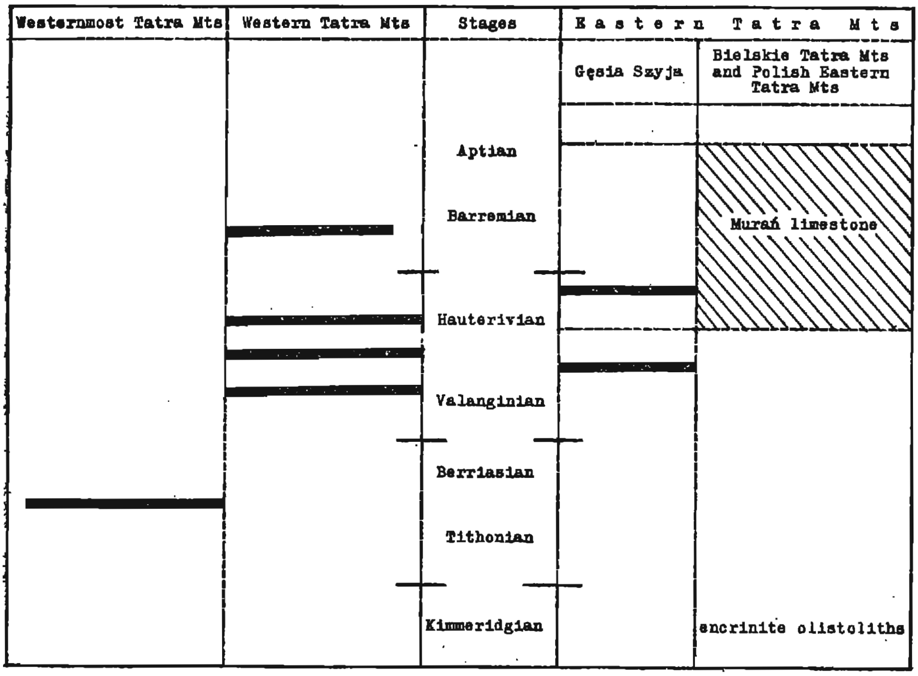
Another chemical analysis of Tithonian-Neocomian limestone from Dolna Mičina (Upper Hron Basin — Central Slovakia) was mentioned by Čepek (1970).

The Tithonian-Berriasian sequence is about 50—80 m thick and consists of layers 8—30 cm thick with few thin shale intercalations. In some profiles (*e.g.* Jatki in the Bielskie Tatra Mts) olive cherts occur in these Biancone limestones, some of which were recently analysed by Mišík (1973). As seen in thin section the rock is fine micrite with abundant Tintinnidae (in middle and upper part of the profile) and radiolaria (Pl. 15, Figs 5—6; Pl. 16, Figs 1—3 and 4). The radiolarian tests are usually calcified. Various types of radiolarian preservation are illustrated and described by Mišík (1973). Since the radiolarian tests of the sub-tatric Biancone are calcified as a rule, the silica of the micritic matrix may derive at least in part, from the dissolution of them.

Saccocoma microfacies predominates in the Lower Tithonian, but in few sites (Jatki Zadnie — Bielskie Tatra Mts) a mixture of Saccocoma and Calpionella microfacies was observed. Throughout the sub-tatric zone in the Tatra Mts the Biancone is pure pelagic fossiliferous micrite without trace of detrital material. The only site where thin inlier of clastic turbidite material was noted in the Tithonian is the Sucha Valley in the westernmost part of the Tatra Mts (*see* Table 12).

Table 12

Distribution of turbidite horizons in the sub-tatric Upper Jurassic and Lower Cretaceous



Tintinnid assemblages encountered in the sub-tatric Tithonian and Berriasian are presented in Table 13. They were determined on the basis of papers by Colom (1948), Borza (1969), Remane (1964) and Remane (*in* Hegarat & Remane 1968). An ammonite fauna, so far unknown from the sub-tatric Tithonian was found in the Chochołowska and Lejowa valleys in the Western Tatra Mts. This fauna consists predominantly of representatives of the genus *Berriasella* (about 90 per cent). This assemblage indicates uppermost Tithonian age. The tintinnids associated with these ammonites are illustrated (Pl. 17, Figs 1—4). It is remarkable that crassicollarias very seldom occur there. In majority of the analysed profiles the tintinnids are the only index fossils, hence only these microforms served for stratigraphic correlation. The tintinnid assemblages seem to be persistent throughout the sub-tatric Biancone. Minute algae *Globochaete alpina* Lombard and Stomiosphaeridae (Pl. 16, Figs 5—6) occur in varying quantities in the Tithonian-Berriasian.

Table 13

Tithonian-Berriasian and Valanginian tintinnid assemblages in the sub-tatric succession of the Tatra Mts and the position of the Upper Tithonian ammonite fauna

Eastern Tatra Mts			Western Tatra Mts	
Bielskie Tatra Mts	Holica-Czerwona Skałka	Gęsia Szyja		
		Tintinnopsella carpathica	Hauterivian	
Calpionellopsis simplex C. oblonga Tintinnopsella carpathica		Calpionellopsis oblonga Tintinnopsella longa T. maxima C. oblonga T. carpathica T. longa C. simplex	Valanginian	Tintinnopsella carpathica T. longa Calpionellopsis oblonga, Amphorellina subacuta C. darderi, Remaniella cadischiana, T. carpathica T. longa, Lorenziella cf. hungarica
	Remaniella cadischiana T. carpathica Calpionella alpina C. elliptica Lorenziella cf. plicata	Calpionellopsis simplex C. oblonga Tintinnopsella carpathica	Upper Berriasian	Remaniella cadischiana C. simplex, C. cf. darderi Crassicollaria brevis
	Calpionella alpina C. elliptica R. cadischiana T. carpathica Crassicollaria parvula	T. longa, T. carpathica R. cadischiana Calpionella elliptica	Middle Berriasian	Calpionella alpina, C. elliptica Calpionellopsis oblonga, Cal. simplex T. carpathica, T. colomi
			Lower Berriasian	
Lorenziella cf. plicata Crassicollaria parvula Cr. massutiniana Calpionella alpina T. carpathica	C. alpina, C. elliptica Cr. parvula, Cr. brevis T. carpathica	Calpionella alpina C. elliptica Crassicollaria brevis Cr. parvula	Upper Tithonian	Tintinnopsella carpathica Calpionella alpina C. elliptica ammonite fauna with Berriasella
			Middle Tithonian	Calpionella alpina C. elliptica
Saccocoma microfacies			Lower Tithonian	Saccocoma microfacies

In the Kościeliska Valley (Western Tatra Mts) a reddish horizon was found in the Tithonian-Berriasian by Guzik (1959) and Sokołowski (1959). In fact, this is a micritic limestone with strong haematitic tint. It looks like "Ammonitico Rosso" *in statu nascendi* as minute portions of the rock are being separated by haematite as to form initial "nodules". There are many stylolites stained with haematite as well. Tintinnid assemblage of this rock points to Middle Berriasian. Possibly this event maybe correlated with late Jurassic submarine erosional breaks in the Pieniny Klippen Belt (Birkenmajer 1958b).

The sub-tatric siliceous limestones correspond both in facies and stratigraphic position to the Oberalm Beds of the Eastern Alps. The latter formation was described by Flügel & Fenninger (1966) and by Garrison (1967). First electronmicroscopic studies of the Carpathian Tithonian limestones were done by Borza & Harman (1970).

LOWER CRETACEOUS MARLSTONES

The marlstone complex of the sub-tatric Lower Cretaceous is a direct depositional continuation of the Tithonian-Berriasian Biancone. In most profiles the stratigraphic boundary between the Berrasian and Valanginian coincides with that in the lithology. The siliceous limestone deposition of Biancone type ends about that boundary and marly sedimentation starts with the Valanginian. At Gęsia Szyja (Polish Eastern Tatra Mts) some recurrent intercalations of Biancone and marlstones occur at the Berriasian/Valanginian boundary.

The geology of the Neocomian marlstones of the sub-tatric succession in the Tatra Mts was studied by Stache (1868), Uhlig (1897) and Vigilev (1914). The works by Stache and Uhlig are now of historical value only. Stache found some fossils, mostly ammonites, which were then cited by Uhlig (*op. cit.*). Some important Lower Cretaceous fossils were collected by Russian emigrant, meteorologist Vigilev (*op. cit.*), who cited over twenty specific and generic names. His conclusion about the age of the marlstones, based on those fossils, was that these rocks represent Valanginian-Hauterivian. Aside of many ammonites pointing to that age he found one cast of *Crioceratites emerici* Lév. an obviously Barremian form. Nevertheless, he did not decide to accept that age for the sequence.

The best preserved specimens of the Vigilev's collection (stored in the Geological Museum of the Polish Academy of Sciences in Cracow) are here illustrated and described for the first time.

The rocks are olive- to light olive gray (5 Y 3/2 to 5 Y 5/2) marlstones.

Their chemical analysis done by Kuźniar (1913) is as follows (in weight per cent):

$Al_2O_3 + Fe_2O_3$	4.74
$MgCO_3$	2.37
$CaCO_3$	81.05
matter insoluble in HCl	11.34
total	99.50%

An X-ray analyse of a marl sample from the Kościeliska Valley (Western Tatra Mts) has shown that calcite is the main component with subordinate quartz quantities and a little of feldspar, mica and possibly kaolinite (Table 14). As, the rock contains more than 10 per cent of insoluble matter, it should be classified as clayey limestone (Teodorovitch — *fide* Bissel & Chilingar, 1967). The insoluble matter is represented by finest detrital fraction.

The marlstones are usually spotted. Spots and stripes are darker then the rock, thus the latter superficially resembles the Lower Jurassic "Fleckenmergel". In fact, those are discontinuous pyrite laminae which, when seen in thin section, show aureoles. The pyrite laminae maybe due to decay of organic matter on the sea floor, being then preserved in fine, impure lime mud. Chert bands occur in the marlstones as normal intercalations. Microscopically the rock is fine micrite with finest skeletal calcite admixed in various proportions (scarce as a rule). In some cases few elongated skeletal particles show orientation parallel to planes of deposition. The Neocomian marlstones constitute a monotonous, almost nondifferentiated sequence in the whole sub-tatric zone. The only "event" is a huge complex of avalanche calcareous turbidites of the Murań limestone which overlies the marlstones in the eastern part of the Tatra Mts. In the western part, only some relatively thin interbeds of sandstone (Pl. 19, Fig. 6) and detrital limestone turbidites (Pl. 19, Fig. 1) occur within the sequence. The latter (Pl. 19, Fig. 1) are comparable to some varieties of the turbidites of the Murań limestone in the Bielskie Tatra Mts.

Total thickness of the marlstone sequence is difficult to evaluate as the upper part of the complex in the Western Tatra Mts is disturbed in result of tectonic movements. In the Kościeliska Valley it maybe estimated as being about 100—150 m thick. In the eastern part, in the Bielskie Tatra Mts the marlstone complex is about 80—120 m thick. The whole marly sequence is strongly affected by cleavage. In result of that casts of ammonites are frequently elongated and flattened.

The Lower Cretaceous marlstones are characterized by the following features:

1. Horizontal and vertical lithologic uniformity throughout the entire sequence.
2. Scarcity of skeletal calcitic particles.
3. Lack of detrital material except finest impurities.
4. Presence of chert bands and nodules.

5. Presence of microlenses of pyrite, giving a "Fleckenmergel" appearance to the rock.
6. Presence of thin turbidites (both clastic and carbonate — Western Tatra Mts), and a thick complex of avalanche turbidites (Murań limestone — Eastern Tatra Mts).

In the light of the above characteristics the deposition of the marlstones had taken place most probably in an open sea with steady inflow of finest detrital material.

According to Passendorfer (1961) the Lower Cretaceous marlstones of the sub-tatric succession represent sediments of rather deep sea. In fact, the existence of cherts maybe regarded as a symptom of deep-sea

Table 14

Results of X-ray analyses

Plane distances (*d*) and intensities of reflexes (*I*) of two sub-tatric samples and numerical standards

Sample 1		Sample 2		Quartz *		Calcite **		Other
d	I	d	I	d	I	d	I	
10.0	6	10.0	2					mica
7.1	4	7.1	2					kaolinite
4.98	2	4.98						mica
4.48	2	4.48						kaolinite
4.25	12	4.25	4	4.26	35			
3.85	3	3.85	6			3.86	12	
3.55	2							kaolinite
3.34	100	3.34	25	3.34	100			
3.20	2	3.19	3					feldspar
3.03	71	3.03	100			3.03	100	
2.84	2	2.84	2					
2.57	2	2.57	2					
2.49	6	2.49	8			2.50	14	
2.46	4	2.46	2	2.46	12			
2.28	11	2.28	12	2.28	12	2.29	18	
2.23	3			2.24	6			
2.12	4	2.12	2	2.13	9			
2.09	6	2.09	9			2.10	18	
1.99	3	1.98	2	1.98	6			
1.93	3	1.93	5			1.93	5	
1.91	8	1.91	11			1.91	17	
1.87	7	1.87	11			1.88	17	
1.82	7	1.82	4	1.82	17			
1.67	2	1.67		1.67	7			
1.62	2	1.62	3			1.63	4	
1.60	3	1.60	5			1.60	8	
1.54	4	1.54	2	1.54	15			

Sample No. 1 — red shale in the green radiolarite (Oxfordian), Grześ hill, Chochołowska Valley (Western Tatra Mts).
Sample No. 2 — Neocomian marlstone, Kościeliska Valley.
Numerical standards according to the X-ray Diffraction Cards, American Society for Testing and Materials (ASTM), Philadelphia, 1970
* 5-0490, ** 5-0586
X-ray diffractogramms were obtained on Rigaku Denki Co., Ltd. diffractometer

depository conditions as sediments of that type occur entirely in geosynclinal successions in the Central Carpathians (Andrusov 1959). The finest detrital material has probably been laid down by vertical settling (from suspension). It was probably brought into the basin by currents, as no other symptoms indicate proximity of a land mass. The tranquility of sedimentation was seldom interrupted by scanty inflow of carbonate clastic material (carbonate turbidites), and of quartz clastic material (sandstone beds).

The highest horizons represent most probably Lower Aptian as marlstones of that age overlie the Murań limestone in the Bielskie Tatra Mts. In the West, in the Choč Mts (Slovakia) the top parts of this complex contain Albian-Cenomanian foraminifers (Kantorova & Andrusov 1958).

The beginning of inflow of finest detrital material to the sub-tatric basin seems to coincide in time with the beginning of deposition of the Upper Cieszyn Shales in the Outer Flysch Carpathians (Książkiewicz 1951).

THE MURAŃ LIMESTONES

The name "Murań Limestone" was introduced to geological literature by Uhlig (1897). By this name he designated a thick sequence of calclithites overlying the Neocomian marlstones in the Bielskie Tatra Mts. For many years the origin of this carbonate sequence was obscure and its age — highly controversial. Uhlig (*op. cit.*) and later Rabowski & Goetel (1925), and Andrusov (1931, 1959, 1970) ascribed Urgonian *i.e.* Barremian--Aptian age to them whereas Passendorfer (1950) suggested Hauterivian — Lower Barremian age. Sokołowski (1950) reviewing the opinions concerning the age of the Murań limestones has pointed out that no paleontologic evidence was provided so far to solve this problem.

Descriptions of these limestones were presented by Uhlig (*op. cit.*), Kuźniar (1913), Passendorfer (1950), and Borza (1957).

Geographical setting and geometry

The Murań limestones form picturesque cliffs on peaks (Murań, Nowy Wierch, Szalony Wierch, Jatki) and north-eastern slopes (Nowy, Hawrań, Płaczliwa Skała) of the Bielskie Tatra Mts (Pl. 1, Fig. 1; Pl. 2, Fig. 2). They occur as well in the eastern part of the Polish Tatra Mts north of the Kopy Sołtysie area fromwhere they merge northwestward under the Eocene flysch of the Podhale Basin.

Eastward they split into two thinner units separated by marlstones (Fajksowa).

They attain largest thickness (about 100 m) at Murań Mt. (Borza 1957). Similar values were noted in the Polish part where at Łężny Potok they attain not less than 80 meters. The sequence which is buried under the Podhale Paleogene shows probably comparable thickness.

The geometry of the primary limestone body is difficult to decifer as the outcropping complex is but a morphotectonic remnant within the sub-tatric succession of the Tatra Mts being sharply eroded from all its sides, except the northern one which is hidden under the Paleogene.

At the top of the Murań Mt. a marlstone sequence over 30 m thick, overlies the main complex of the Murań limestones (Fig. 14). The marlstones contain some limestone interbeds as well as some Urgonian biocalcolistoliths embedded in the topmost portion of the marlstone sequence.

The total length of the exposed complex is about 11 km in the Bielskie Tatra Mts and over 1 km in the Polish part of the Tatra Mts. The limestone belt is 2—3 km broad.

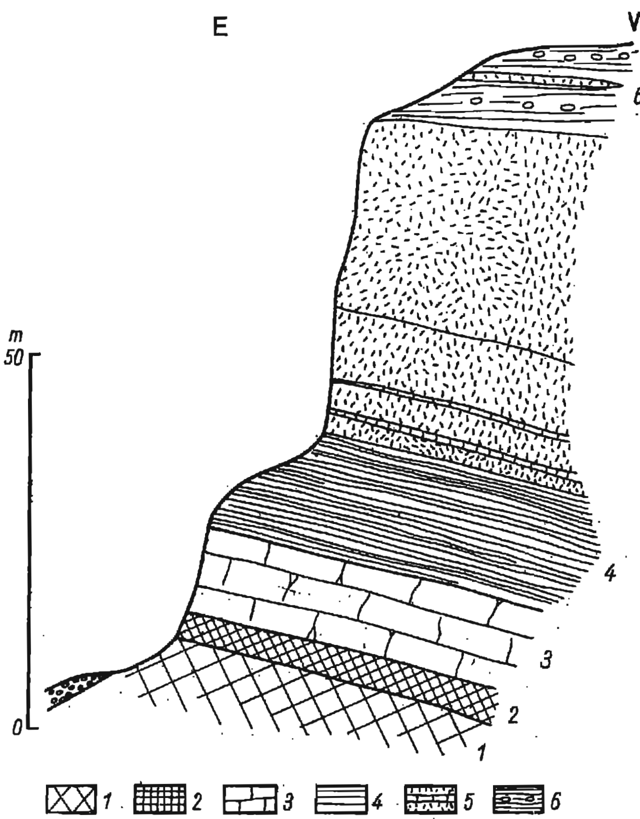


Fig. 14

Cross-section of the eastern cliff-wall of the Murań Mt. above the Nowy creek

1 radiolarites and nodular limestones (Middle Jurassic), 2 radiolarites and nodular limestones (Oxfordian-Kimmeridgian), 3 siliceous limestones (Tithonian-Berriasian), 4 marlstones (Valanginian-Hauterivian), 5 avalanche calcareous turbidites (the Murań limestone — Upper Hauterivian-Barremian), 6 marlstones with olistoliths (Lower Aptian)

Petrographic description

The Muraň limestones represent several varieties of avalanche calcareous turbidites [2]. The most common type is a lithobiocalcisiltite and lithobiocalcarenite. This is a fragmental carbonate rock composed of fine-intra- and extraclasts of micritic limestones, pellets etc. embedded in sparry calcitic cement (Pl. 18, Fig. 5). Average particle size is 100—200 microns but some largest ones may attain even 600 microns in diameter. Intraclasts form about 60 per cent of the total volume of the rock (Borza 1957). The proportion of intra- and extraclasts versus sparry calcite varies, but types with densely packed clasts are most common. Some varieties exhibit micritic cement instead of sparitic one (Pl. 19, Fig. 5). Micrites with relatively small quantity of skeletal fragments seldom occur. Presence of plagioclase grains was noted in these rocks by Mišik (1966). Among extraclasts most common are fragments of oolitic micrites (Pl. 18, Fig. 4) and isolated oolites which, in many cases are broken. Oolites are strikingly similar to those ones of the high-tatric Valanginian (Lefeld 1968; Pl. 7, Fig. 5 and Pl. 8, Fig. 1). In few cases micrites with tintinnids (Tithonian-Berriasian) were also observed. Smaller intraclasts are rounded to ellipsoidal whereas larger ones are frequently broken, subangular (Pl. 18, Fig. 1) or sharp-edged (Borza 1957). In fact, it is sometimes difficult to decide whether the pellet-like particles should be classified as intra- or extraclasts. It is obvious that a part of the fragmental micritic material has been introduced into the depocenter from some more or less distanced sources. In the light of that, these avalanche turbidites are polygenic (heterogenic) *sensu* Aubouin (1959) in character. Superficial coatings over pelletal and other micritic particles were observed by Borza (1957), who described the Muraň limestone petrographically. It should be mentioned that micrograph similar to those of the Muraň limestones was presented by Remane (1970) from the Tithonian of the Sub-Alpine Chains of France (Remane's Plate 5, Fig. 1).

Breccias are seldom found in the Muraň limestones. Their matrix is of encrinite character as a rule. Clastic fragments are sharp-edged (up to 2—3 cm in diameter). Rarity of breccias coincides well with the relations observed in modern carbonate turbidites of the Tongue of the Ocean near the Bahama Banks (Rusnak & Nesteroff 1964).

What concerns the fossil content, there are (usually few) foraminiferal tests of textularia-type and miliolids as well as such skeletal fragments

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[2] The term avalanche turbidite is introduced here according to suggestion by Prof. Dżułyński, who was critical about the term "Fluxoturbidite" (Kuenen 1958) originally used for designation of slumped and graded turbidites in the Polish Flysch Carpathians (Dżułyński, Książkiewicz & Kuenen 1959). A critique of the last mentioned term was also rendered by Walker (1967).

as crinoidal ossicles and echinoid spines; and pelecypod shell chips. All these, except tests of foraminiferas, bear fragmentary character and are recrystallized as a rule (Passendorfer 1950). In some cases larger crinoidal stem fragments (3—5 cm long) were noted (*e.g.* at Nowy Wierch). At Jatki Przednie larger concentrations of crinoidal stem debris occur within the Murań limestones. More and more fossils are to be found upward the section. These are Urgonian—derived chips of rudistids, hydrozoans (Pl. 20, Fig. 6), corals (Pl. 20, Fig. 2) and algal fragments and serpule (Mišik 1966). Some rocks are full of unidentifiable pelecypod shell fragments. Most probably such types of rocks were named "Caprotinen-kalk" by Uhlig (1897). They are common at Głośna Skała near Płaczliwa Skała and at Murań and Rogowa Skała. In the topmost parts of the complex strongly damaged tests of orbitolinas are seldom found. Like the bulk of the carbonate clastic material, they have undergone reworking and redeposition thus their preservation state is bad. The Urgonian fossils found in the olistoliths embedded in the top marlstones on the Murań Mt. are incomparably better preserved (Pl. 20, Figs 1 and 3—5).

As most of the material in the Murań limestones derives from shallower (predominantly Urgonian) facies these rocks maybe named allodapic limestones (Meischner 1964).

Chemical analyses of the Murań limestones were performed by Kuźniar (1913) and Martin (*in* Borza 1957).

The rock from Fajksowa analysed by Kuźniar showed the following composition:

Al_2O_3 + Fe_2O_3	0.27%
$CaCO_3$	96.76
$MgCO_3$	0.89
parts insoluble in HCl	1.74
total	99.66

The analysis of Martiny is as follows:

SiO_2	0.30%
R_2O_3	0.30
CaO	55.03
MgO	0.49
Na_2O	0.18
loss by ignition	43.60
total	99.90

The last mentioned analysis comes from a sample taken at Hlupy (Szalony Wierch — in Polish nomenclature). It should be mentioned here that the rock when split exhibits a bituminous odour. Megascopically the

Murań limestones are dark fragmental carbonate rocks. On weathered surfaces, they resemble the Urgonian Schrattenkalk of the Alps although they are darker than the latter. This was probably one of the main reasons why the Murań limestones were previously classified as Urgonian by many authors. The colours are medium gray (N 5) to olive-black (5 Y 2/1).

Sedimentation of the Murań limestones

Beginning of deposition

The sedimentation of the Murań limestones started with thin partly discontinuous interbeds and lenses within the Neocomian marlstones (Figs 15, 15*A*, 15*B*). First inflow of carbonate clastic material has lead

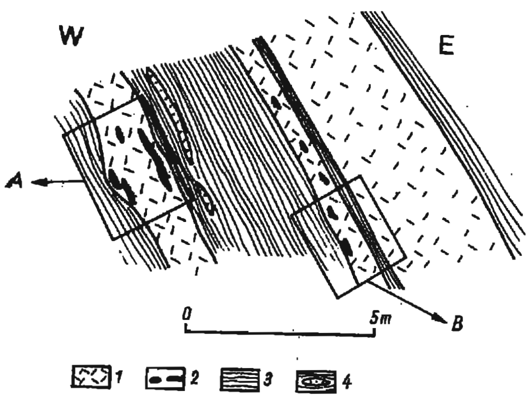


Fig. 15

Beginning of deposition of the Murań limestones. Fajksowa (eastern part of the Bielskie Tatra Mts)

1 calcareous turbidites, 2 cherts in calcareous turbidites, 3 marls, 4 small lenses of calcareous turbidites within marls

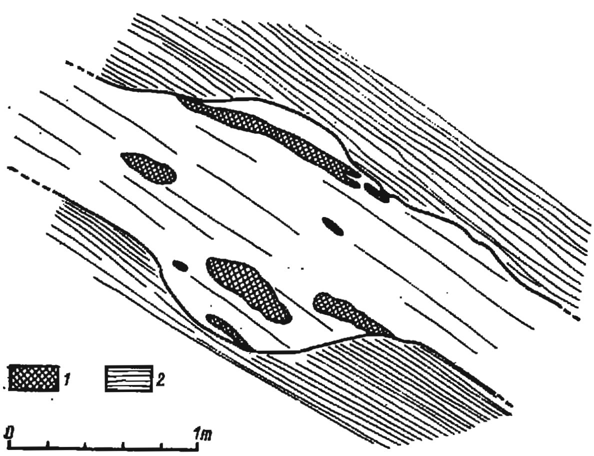


Fig. 15*A*

A groove in Neocomian marlstone filled by calcareous turbidites with cherts. Fajksowa down interbeds only 1—2 cm thin. Lense-like deposition (Fig. 16) clearly shows that at the very beginning, the tongues of clastic material brought into the depocenter were thin and neither reached far into the basin, nor did they cover the entire marly basinal floor. In some sites grooves occur

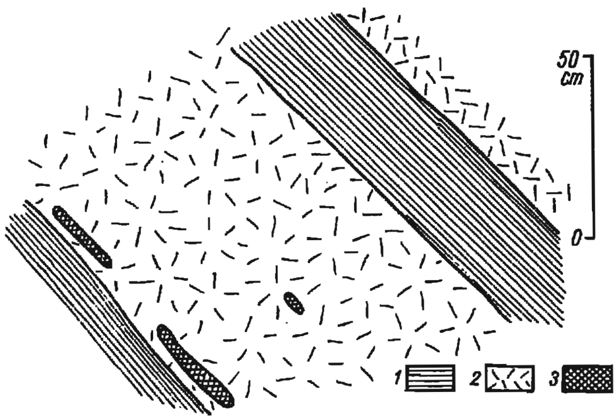


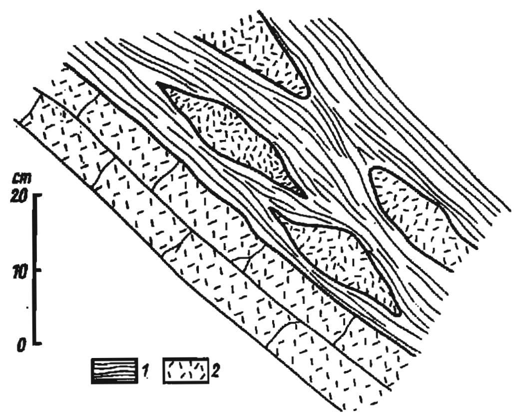
Fig. 15*B*

Thickness proportions of marlstones to initial carbonate turbidites and position of cherts. Fajksowa, Bielskie Tatra Mts
1 marls, 2 calcareous turbidites, 3 cherts

in marlstones which are filled with lithocalcisiltite (Fig. 15*A*). They have been probably eroded by the turbidity currents carrying the carbonate

Fig. 16

Lense-like deposition of calcareous turbidites in marlstones. Fajksowa — Bielskie Tatra Mts
1 marlstones, 2 turbidite carbonate material



clastic material. Higher up thicker and thicker carbonate interbeds appear and the entire sediment becomes biolithoclastic. These biolithocalcisiltites and calcarenites form the main complex of the Murań limestones which is so remarkable in the morphology of the Bielskie Tatra Mts.

The main complex

The large thickness (about 100 m) of the main complex is due to a rapid increase of sedimentation rate. The material of the Murań limestone derives from redeposition of bio- and lithoclastic particles coming from the adjacent higher situated parts of the basin. In its top part considerable amounts of Urgonian—derived material clearly shows that some distal zones of Urgonian reefal structures have undergone destruction and, in effect, redeposition of their carbonate clastic material. On the steep walls of the Murań Mt. (Bielskie Tatra Mts) one may see that the complex hardly shows any bedding. In its bottom part thin (5—8 cm) chert bands suggest some bedding when observed from a distance, but higher up, no bedding occurs at all. However, some thicker beds may be seen elsewhere in the complex (*e.g.* Głośna Skała near Płaczliwa Skała). The bulk of the Murań limestones shows neither sedimentary structures nor any segregation of the carbonate clastic material.

Smaller than that of the Bielskie Tatra Mts but still fairly large mass of the Murań limestone crops out in the Polish part of the Eastern Tatra Mts in the Kopy Sołtysie area (Grabowska-Hakenberg 1958). At Łężny Potok in a deep gully one may observe at least 80 m of the Murań limestone complex which is virtually the same as that one at Murań. In result of a system of faults which thrusted the whole Hawrań unit down about 150 m in relation to Mały Murań and about 700 m in relation to Murań, the complex at Łężny Potok is only partly exposed. There are some marl and calcareous turbidite interbeds at the beginning of the section, *i.e.* above the sub-tatric Biancone with tintinnids (Grabowska-Hakenberg 1958, Fig. 3). Higher up there is a uniform block of massive calcareous avalanche turbidites of the Murań limestone (Pl. 19, Fig. 2). Grabowska-Hakenberg (*op. cit.*) mentions *Olcostephanus astierianus* (d'Orb.) from the top marls below the main mass of the Murań limestone there.

Graded bedding which is a characteristic feature of carbonate turbidites (Rusnak & Nesteroff 1964) was noted in some sites. This is usually simple, normal bedding with grain size diminishing upwards. The particular cycles are 6—10 cm thick, exceptionally up. to 0.5 m thick (*e.g.* at Fajksowa). More then a half of each cycle is composed of fine lime clastic material. The tops of graded cycles are usually eroded, and possibly partly reduced in thickness due to erosive action of subsequent turbidity currents. Such phenomena are well known from recent oceanographic researches (Ericson & *al.* 1961). At the bottom part of the Murań limestone at Rogowa Skała (western part of the Bielskie Tatra Mts) some topmost portions of graded cycles show few animal borings filled with coarser material of the subsequent graded cycle. These borings are round in section and 1—1.5 cm in diameter. Their presence may point to a temporary stop, or retardation of deposition. Similar borings were observed in the graded sequence of the Urgonian distal facies in the high-tatric succession of the Tatra Mts in the Bobrowiecka Valley (Lefeld 1968, Fig. 1).

Cross-bedding was never observed in the Murań limestones but in one site (Fajksowa) cross lamination exists in the marlstones. It points to a transport of material from the southeast but, of course, cannot serve as a basis for any serious conclusion. Isolated skeletal fragments (*e.g.* crinoidal ossicles) are to be found within the bottom parts of marlstones containing turbidite calcareous material (top part of the Murań limestone complex). It seems that at least a part of the suspended matter has been deposited together with the marls which followed the deposition of the Murań biolithocalcisiltites.

Chert bands and nodules occur mainly in the bottom part of the complex (Pl. 7, Fig. 2) and are easily observable from a distance giving layered appearance to the Murań limestones. Detailed observations at Niżnia Hawrań (Bielskie Tatra Mts) showed that they are associated with the top parts of beds, less frequently with their bottom parts (Fig. 17).

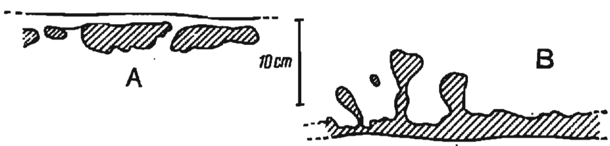


Fig. 17

Position of cherts relative to beds of calcareous turbidites. Niżnia Hawrań — Bielskie Tatra Mts

Less and less cherts are to be found toward the top of the complex. This phenomenon is probably connected with topward increase of sediment accumulation rate of the biolithocalcarenites (bioclastic turbidites).

According to Borza (1957) radiolarian tests were the source of silica for these cherts. Under the microscope the rock shows voids after radiolarian tests embedded in chalcedonic aggregates. The cherts are virtually the same as those found in the underlying marlstone, which suggests that possibly the cherts were attribute constituents of the basinal marly deposition prior to the beginning of the inflow of turbidites.

Top marlstones

The main complex of the Murań limestones at the Murań Mt. is overlaid by marlstones which contain Urgonian bioolistoliths (Fig. 18). The marly sequence there is over 30 m thick and contains an interbed of biolithocalcarenite in its middle part. This limestone bed wedges out quickly northeastward. Abundant Urgonian bioolistoliths occur in the topmost part of the marlstone. This is the youngest member of the subtatric succession in the Tatra Mts. The redeposited Urgonian olistoliths are 5 to 40 cm in size. The rock is identical with the Urgonian facies of the high-tatric zone (Lefeld 1968). Minor limestone lenses (interbeds) occur elsewhere in the marlstones. Few badly preserved belemnoids were found in the marlstones below and above the limestone wedge. Poorly preserved fragment of a small ammonite, most probably belonging to the Pulchellidae family was found almost at top of the marlstones. On this faint basis it maybe supposed that the top marlstones at Murań are not younger then the Aptian (possibly Lower Aptian).

A new genus of hydrospongia named *Murania* (after the Murań Mt.) was described for the first time from the redeposited Urgonian olistoliths there (Kaźmierczak 1974). The Urgonian bioolistoliths at Murań contain many well preserved fossils among which some specimens of *Orbitolina lenticularis* Blumenbach were collected (Pl. 20, Fig. 4). This find documents the age both of the top marlstones and of the Murań limestones. Sections of *Pianella* (= *Salpingoporella* Pia — Praturlon & Radoičič 1967) as well as other undeterminable Dasycladaceae (Pl. 20,

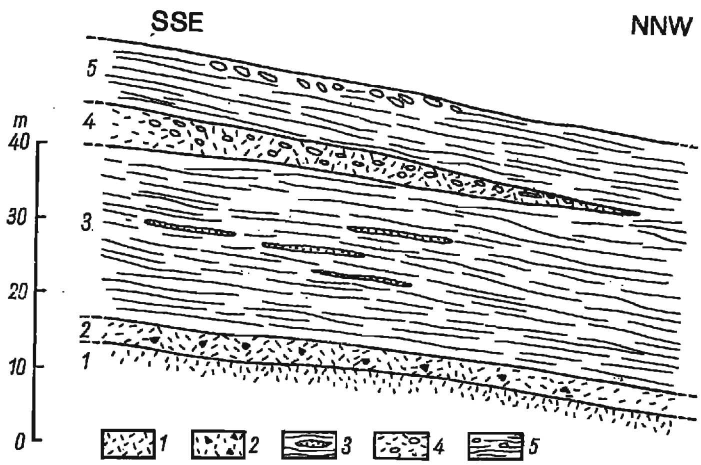


Fig. 18

Cross-section of the Lower Aptian sediments overlying the Murań limestone on the top meadow of the Murań Mt., Bielskie Tatra Mts.

1 avalanche calcareous turbidites — proper Murań limestone (Barremian); 2 same but with abundance of Urgonian—derived microfossils like Miliolidea, Orbitolina, Pianella, etc.; 3 marlstone with thin interbeds of turbidites; 4 larger wedge of calcareous turbidites of the Murań limestone type, with olistoliths of typical Urgonian limestones; 5 top marlstone with Urgonian olistoliths at top

Figs 1 and 3) can also be found. Beside that there are sections of corals (*Stylosmilia* sp. — Pl. 20, Fig. 2) and some bryozoans? (Pl. 20, Fig. 5), and fragments of sclerosponges (Pl. 20, Fig. 6). The final episode of redeposition of the Urgonian olistoliths took place in the sub-tatric succession not earlier than during the Lower Aptian.

In the eastern part of the Bielskie Tatra Mts the Murań limestones are overlaid by marlstones as well but no fossils were found there so far.

Younger members of the sub-tatric succession *i.e.* Albian and Cenomanian do not occur in the Tatra Mts and are known only from the Orava area (Kantorova & Andrusov 1958).

Sedimentation rate of the Murań limestones

Since marlstones accompany the Murań limestone both from its bottom and top it seems reasonable to suppose that the sedimentation rate of those marls was nearly constant throughout their period of deposition. On the other hand, the sedimentation rate of the redeposited carbonate clastics of the Murań limestone showed accelerations and retardations and was incomparably quicker than that of the marls. In fact, there is no reason to claim that the marly deposition had stopped during the sedimentation of the avalanche turbidites. It may be rather supposed that the fine clastic material which led to marly deposition was continuously supplied to the environment during the time of their sedimentation. Hence the biolithocalcisiltites of the main complex should be regarded as a combination of both sediment types. In sites where the inflow of carbonate clastic material was smaller as *e.g.* at Fajksowa (extreme east of the Bielskie Tatra Mts), the two main beds of the Murań limestone are separated by marlstone, which proves that the marly deposition did not stop at that time.

The upward increase of the sedimentation rate of the carbonate turbidites was probably controlled by an increase in thickness of the reef-detrital facies in the Urgonian of the geoanticlinal source area.

The bulk of the material came from a distal reef-detrital facies as it is shown by dark colouration of the carbonate clastic particles and their fineness as well as scarcity of larger reefal organisms such as hydrozoans, colonial corals and algae. Nevertheless, some Urgonian olistoliths preserved among the top marlstones at the Murań Mt. undoubtedly derive from a proximal reef facies. Possibly the sedimentation of those olistoliths marks the most intense destruction phase of the Urgonian detrital facies in the source area.

Avalanche turbidites in the Western Tatra Mts

Carbonate clastic interbeds

Few rather thin intercalations of biolithocalcisiltites occur in the Neocomian marlstones in the Western Tatra Mts, in the Kościeliska and Chochołowska valleys (Pl. 7, Fig. 1). In both localities the marlstone sequence contains some quartz sandstone interbeds as well (Fig. 19).

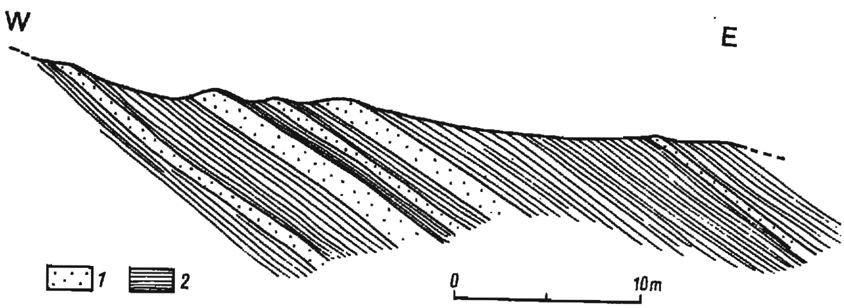


Fig. 19

Interbeds of quartz sandstone turbidites in the Neocomian marlstones — Kryta creek, a tributary to the Chochołowska Valley — Western Tatra Mts

1 sandstone, 2 marlstone

The biolithocalcisiltites contain micritic intraclasts averaging in size 50—200 microns with less abundant larger particles up to 0.6 mm (Pl. 19, Fig. 1). Cement is sparry calcite or micrite. Occasional glauconite grains (200—300 microns) were observed in some thin sections from the Kościeliska Valley. Sections of echinoid spines and biserial foraminiferal tests occur elsewhere in thin sections. Unidentified echinoderm ossicles are also numerous. Fragments of aptychi are seldom found. These rocks strongly resemble some varieties of the Murań limestone of the Eastern Tatra Mts and undoubtedly represent a kind of carbonate turbidites. Their material was subject to redeposition but in that particular case the source area (or areas) were more distant than those of the Eastern Tatra Mts. This is proved by their relatively small thickness.

Sandstone interbeds

Few layers of quartz sandstone or coarse siltstone occur within the marlstone series in the Kościeliska and Chochołowska valleys in the Western Tatra Mts.

As observed in thin section these rocks are fine-grained quartz sandstones of average grain size 150—300 microns with occasional glauconite grains (Pl. 19, Fig. 6). The rock strongly resembles some types of flysch sandstones, but in this case the cement is calcareous.

Because of scarcity of outcrops it is impossible to determine the geometry and source area of these sandy interbeds.

Lower Cretaceous turbidites in other Central Carpathian massifs and in the Pieniny Klippen Belt

Lower Cretaceous carbonate turbidites similar to those described from the sub-tatric succession of the Tatra Mts occur in some other Central Carpathian massifs such as Mala Fatra, Tribeč, Niske Tatra Mts, Choč Mts and the Manin unit of the Strażowska Hornatina Mts (Mahel 1968). Together with Dr. Borza I was able to visit several outcrops of the Lower Cretaceous sequences in the Strażowska Hornatina Mts and in the Mala Fatra Mts in 1970. A thick detrital limestone series occurs near Butkov in the Manin unit. This series represents most probably carbonate avalanche turbidites somewhat connected with an Urgonian source area. Some rock varieties are similar to distal reef facies of Urgonian type, which is quite obvious in the light of the proximity of the Urgonian limestones in the Maninska Użina (Mišik 1957, Andrusov 1959). Outcrops at Fačkov, Rajecka Lesna (Fryvald), Turie and Lietavska Svinna in the Mala Fatra Mts (Western Slovakian Carpathians) represent several varieties of carbonate detrital facies more or less related to some Urgonian structures. For example, the detrital limestone at Fačkov shows many affinities to the Murań limestone (Pl. 18, Fig. 6). At Turie detrital, dark limestone with occasional chert bands is interbedded with marlstones of Aptian age. Limestone intercalations among marlstones at Lietavska Svinna are slightly lighter in colour and their weathered surfaces resemble the alpine Schrattenkalk. In all those cases the rocks are lithobioclastic and possibly represent slumped beds which suggests avalanche turbidite origin.

In the Central Carpathians of Eastern Slovakia the so called limestone of Brekov (Barkokalk of Paul 1870 — *fide* Andrusov 1959) seems to represent calcareous turbidite sequence possibly somewhat connected with the Urgonian of Humenne.

In the Pieniny Klippen Belt Lower Cretaceous carbonate clastics of similar type are known to occur in the Haligovce Klippe south of the Pieniny Gorge (Andrusov 1959, Pl. 32). The sequence there is about 40 m thick (Birkenmajer 1959), and overlies the "Biancone"-type limestone of Tithonian-Hauterivian age. In thin section the rock is more or less skeletal micrite with micritic intraclasts of similar grain size as in typical Murań limestone (Pl. 19, Fg. 3). Autigenic quartz grains are frequent in these rocks. Skeletal particles are mostly echinoderm debris. In general aspect the Haligovce detrital limestone seems to be finer clastic rock than the Murań limestone. Its position in the primary depocenter was probably more distal then that of the latter. Also in this case the bioclastic material derives from redeposition, possibly from some Urgonian formations.

Another bioclastic "Urgonian-derived" member of the Klippen Belt is the Niżna limestone in the Orava area (Scheibner 1967). This rock is definitely coarser than the Haligovce limestone and is composed of fragments of corals, calcareous algae, brachiopods, pelecypods and orbitolinas (Pl. 19, Fig. 4). Coarse bioclastic material and abundance of larger skeletal fragments of large Urgonian fossils suggest that the redeposited material came to that site from a proximal Urgonian facies. Also in this case the source area remains unknown. Contrary to Scheibner's view (*op. cit.*) the Kysuca succession at Niżna is not of shallow water character but represents a fragment of a trough (possibly a slope of it) which is proved by the presence of radiolarites in the Oxfordian and redeposited material in the Barremian-Aptian member. The Niżna limestone contains also some particles of older limestones as *e.g.* Tithonian clasts with tintinnids.

Carbonate turbidites are also known from the Outer Carpathians. The Cieszyn limestone of Upper Tithonian — Berriasian age represents redeposited flysch sequence (Książkiewicz 1960, 1971). Redeposited carbonate Tithonian sediments with graded bedding and slumping were reported from the Kurovice Klippe of the Četechovice zone in Moravia (Czechoslovakia — Benesova, Eliaš & Matejka 1968).

Restoration of sedimentary environment

The Murań limestones owe their origin first of all to the proximity of an Urgonian source area. Poor, usually fragmentary state of preservation of the Urgonian fossils suggests that a distal reef facies was probably the source area, and its piling up, and consequent instability of submarine slopes have caused slumping and turbidity currents that transported the carbonate clastic material down the basin slope. The existing data do not allow to suggest any direction of transport of this material, although the petrography of the intraclasts points to the high-tatric zone. As it was already said, the bulk of the material was transported and laid down in result of slumping and only small part of it was deposited from suspension in form of graded cycles. The bottom portions of the Murań limestone due its origin most probably to redeposition of the Hauterivian and also possibly the Valanginian (oolitic limestones) rocks. In the high-tatric zone of the Tatra Mts denudation of carbonate material has began most probably during the Hauterivian (Lefeld 1968). Those denudation processes were then intensified during the Barremian-Aptian times when the

Urgonian reef structures developed over many Central Carpathian highs (geoanticlines). Thus it may be assumed that considerable volumes of reef detrital material was being piled up around such structures. The course of events during the deposition of the Murań limestones is presented in Table 15. The sedimentation resulting from action of slumping and turbidity currents was comparatively rapid. Each time the turbidity currents scoured the freshly deposited fine clastic material of the top parts of graded cycles. Upward increase in number of Urgonian-derived fossils in the Murań limestones suggests intensification of gradational processes in the Urgonian reef structures over the highs, and piling up of the surrounding bioclastic material.

Table 15

Deposition scheme of the Murań limestones and top marlstones with Urgonian olistoliths

Stage		Phase of deposition
Lower Aptian		marly deposition with occasional slumping of Urgonian olistoliths
		main redeposition phase,
Barremian		sedimentation of the main complex of the Murań limestones
Hauterivian	Upper	beginning of carbonate clastic redeposition
	Lower	marly sedimentation with chert bands

Preservation of the Urgonian fossils in the Murań limestones offers some hints about the transport conditions. Large *i.e.* voluminous fossils such as colonial corals, hydrozoans and calcareous algae bear traces of striping but are relatively well preserved inside, whereas the small ones, such as *e.g.* orbitolinas are completely devoid of their external layers and even their reticulate zone is obscured. This was probably the reason why orbitolinas escaped the attention of many geologists in previous years. Large but comparatively thin pelecypod shells are preserved entirely in form of isolated chips.

Much better preserved are Urgonian fossils in the olistoliths occurring in the top marlstones at the Murań Mt. The rock pieces containing them are strikingly similar to typical Urgonian rocks of the high-tatric succession. Undoubtedly in this case the redeposition reached a proximal (reef-detrital) slumping source which is also suggested by light colouration of those olistoliths.

In the present author's opinion the high-tatric Urgonian structures *(sensu lato)* were the source area for the bulk of the carbonate clastics of the Murań limestone. Some minor components of the Murań limestone like *e.g.* oolites, most probably come from the high-tatric succession as well. By negation it can be said that the source area was not situated to the east of the Bielskie Tatra Mts as a decrease of thickness and splitting of the main complex into several thinner beds is to be observed in this direction. It may be looked upon toward SSW of the present-day Hawrań unit.

A quite different image may be seen in the Western Tatra Mts where only thin interbeds of carbonate turbidites exist. Undoubtedly that area was far more distant from a source area. Beside that some other sources have existed and supplied quartz clastic material to form the sandstone interbeds there. Presence of Barremian ammonites in the marlstones of the Western Tatra Mts proves that the marly deposition continued there till the Barremian and possibly till the Lower Aptian.

In the Choč Mts which are the western prolongation of the Tatra Mts some intercalations of weakly arenaceous organodetrital and microconglomeratic limestones occur within the marly sequence (Mahel 1968). The origin of those rocks maybe related to that of the interbeds in the Western Tatra Mts.

The Lower Cretaceous (Aptian) microconglomeratic, dark limestones of the Butkov zone in the Manin unit may represent, in the present author's opinion, at least in part, a distal detrital reef zone, and in part — redeposited sediments of the Urgonian structures of that unit.

Also in the high-tatric succession of the Tatra Mts some portions of the distal reef facies bear character of turbidites (graded cycles in the Bobrowiecka Valley — Lefeld 1968).

A widespread development of the Urgonian reef structures during the Barremian-Aptian times over many geoanticlinal highs in the Central Carpathian geosyncline caused concentrations of detrital organic material which in turn gave origin to redeposition by slumping and turbidity currents into the adjacent troughs. A relatively large thickness of the Murań limestones in the Eastern Tatra Mts and the state of preservation of Urgonian-derived fossils seem to indicate that this complex represents a proximal turbidity zone in relation to the Urgonian source area, and was laid down over the middle part of the trough slope. The distal turbidites may be represented *e.g.* by the Lower Cretaceous clastics of the Ružbachy (Polish name — Drużbaki) horst (Mahel 1963). These relations are illustrated on the scheme (Fig. 20).

Recapitulation of the main sedimentary features of the Murań limestone

The Murań limestones is characterized by the following features:

1. Simultaneous sedimentation of marls and biolithocalcisiltites out of which the former was continuous throughout the Valanginian--Aptian times, and the latter one superposed onto the former and represented much quicker deposition (greater sedimentation rate with possible upward acceleration).
2. Presence of chert bands and nodules which, most probably, are the attribute component of the underlying marlstones.
3. Graded bedding which usually shows eroded upper portions of cycles which are sometimes drilled.
4. Scouring of the bottom (direct substratum) of the turbidites.
5. Slump structures containing Urgonian olistoliths within the marlstone beds on top of the complex.
6. Abundance of intra- and extraclasts, the existence of which is due to redeposition from source areas.
7. Rapid increase in thickness within the area of the Bielskie Tatra Mts and adjacent Polish Eastern Tatra Mts (the Hawrań unit).
8. Slumped (gravity displaced) material prevails over the graded one.
9. Increasing quantites of Urgonian fossils upward the section.
10. Decreasing frequency of chert bands in the same direction.
11. Scarcity of carbonate pelite (*comp.* Unrug 1963).

PALAEOGEOGRAPHY

Middle-Upper Jurassic carbo-silite sequence

The facial analysis of the sub-tatric Middle and Upper Jurassic carbo-silite sequence presented above clearly shows that two distinct deepening phases and reverse shallowing of the basin took place. These two phases are separated by a smaller episode of the middle nodular limestone member or probable Callovian age. The Upper Jurassic (Oxfordian) deepening phase shows better developed vertical symmetry of facies then the Middle Jurassic (Bajocian-Bathonian) one.

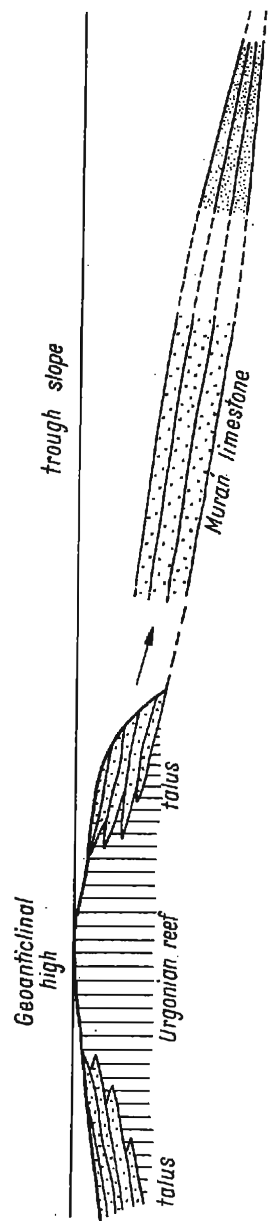


Fig. 20

Scheme of presumed relations between the Urgonian reef complex, its talus (reef-detrital facies), proximal (in this case — Murań limestone), and distal turbidites

An almost perfect symmetrical distribution of nodular limestone and radiolarite members in the Upper Jurassic carbo-silite sequence proves that:

1. The course of palaeogeographic events must have been a regular one, which is also supported by the uniformity of facial development in horizontal sense.
2. The deposition during the Callovian-Oxfordian-Kimmeridgian times was not disturbed by land-derived clastic sediments thus pointing to remoteness of land masses.

The estimated sediment accumulation rates for that sequence (*see* Table 9) suggest an extremely slow deposition. The sequence in question is undoubtedly a good example of sediments laid down during a "période de vacuité" (Aubouin 1967). These are typical "leptogeosynclinal" deposits *sensu* Trümpy (1955). Lack of even smallest traces of volcanism, and high carbonate content of the radiolarites suggest that they represent miogeosynclinal rather then eugeosynclinal depository conditions in the Carpathian geosyncline.

According to consideration on pages 307—309 and a scheme of deposition (Fig. 13) the sub-tatric carbo-silite sequence was probably laid down on a slope of a trough. Spacial isolation resulting from tectonic overthrusts does not allow to restore the primary basin floor morphology, thus nothing can be said about deeper (if any?) parts of that basin. Changes in basin floor morphology caused by geosynclinal tectonic movements (deepening) were usualy mentioned as the main cause of the deep-sea radiolarite deposition in the sub-tatric Jurassic (Passendorfer 1961). Although such an explanation cannot be excluded, at least in part, another approach to the problem is here proposed. The development of the sub-tatric Upper Jurassic carbo-silite sequence coincided in time with a major thalassocratic period in the Mesozoic era (Hallam 1971). The maximum of the Upper Jurassic transgression in East-Central Europe, among other territories also in the Polish Lowland, had taken place during the Oxfordian (also a part of the Callovian included — Samsonoowicz *in* Książkiewicz, Samsonowicz & Rühle 1965). In result of a major transgression the bathyal and abyssal zones in the Tethys have expanded considerably. In consequence immense land areas were covered by the epicontinental seas thus making any land remote from geosynclinal basins. The surplus of oceanic water has caused rise of the compensation depth relative to the existing basin floor morphology, and in result of it — spread of bathyal and abyssal zones. A retreat of the sea recorded in the Kimmeridgian sediments in the Polish Lowland (Kutek 1969) seems to be reflected also in development of the upper nodular limestones (relative shallowing) in the sub-tatric carbo-silite sequence as well as in some other Inner Carpathian successions. Synchronic character of these events during the Oxfordian-Kimmeridgian history of the Inner Carpathians is to be observed among others in the Pieniny Klippen Belt (Niedzica succession in particular — Birkenmajer & Znosko 1955, Birkenmajer 1965). Similar coeval vertical symmetry seems to occur in the Transdanubian Central Mountains of Hungary (Konda 1972) and in the Haghimasul Mare and Haghimasul Negru sections of the Haghimas mountains in Romania (Preda 1973). Upper Jurassic (Callovian-Oxfordian) age has been ascribed to red and green jaspers of the Czywczyn Mts (Eastern Carpathians) on the basis of analogy to the Hagilmasul Mare section of Romania (Pazdro 1934). Upper Jurassic radiolarites are known to occur also in the Eastern Carpathians (Ukrainian SSR — the Tissalskaya zone in particular, Vialov & *al.* 1960). It is a well known fact that many Alpine radiolarites are of Upper Jurassic age (Trümpy 1960, Grunau 1965).

Lithologic sequence and facial development of the Middle and Upper Jurassic members were taken as the main criterion to distinguish the particular successions in the Pieniny Klippen Belt of Poland (Birkenmajer 1957). In the present author's opinion the same criterion should be applied to most (if not all) Inner Carpathian successions. The facial development of the Middle and Upper Jurassic members in the Inner Carpathians is highly indicative primarily in respect to the depository position of a given succession in a basin. According to Mahel (1960) the Jurassic period maybe looked upon as the culmination of geosynclinal stage in the West Carpathian geosyncline. A good example of furrow stage in the Križna unit of the Upper Hron Basin (Central Slovakia) is presented by Čepek (1970). Another example maybe the Pieniny succession in the Klippen Belt which is characterized by radiolarite deposition without bordering nodular limestone members (Birkenmajer 1958a, 1960). The successions deposited on basin (trough) slopes as *e.g.* the Niedzica, Haligovce of the Klippen Belt, and the sub-tatric one of the Tatra Mts show complete or almost complete vertical symmetries, similar or identical to that one described in this paper.

The Oxfordian maximum of thalassocratic period in the Carpathians seems to be also reflected in the existence of nodular limestones in some geoanticlinal successions as *e.g.* the Czorsztyn one of the Klippen Belt and the western part of the high-tatric succession of the Tatra Mts. In the case of the former it is the so called Czorsztyn Limestone representing Callovian-Oxfordian and Kimmeridgian stages (Birkenmajer 1963). At Mikušovce in the Vah River valley (Western Slovakia) some Mn ores and cherts occur in the Oxfordian part of the Czorsztyn nodular limestone (Andrusov — *fide* Krajewski & Myszka 1958). This type of sedimentation may reflect at least considerable retardation of deposition (Birkenmajer 1963). Similar traces of Mn were noted already by Neumayr (*fide* Birkenmajer, *op. cit.*) in the nodular Czorsztyn limestone in the Babierzówka and Stankowa klippes of the Pieniny Klippen Belt in Poland. In the high-

-tatric succession of the Tatra Mts at least a part of the nodular limestones seems to correspond to the Oxfordian (Passendorfer 1951, Szulczewski 1965). In the outer klippen belt of the Western Carpathians Oxfordian nodular limestones are known to occur at Četechovice (Czechoslovakia) where they contain a mixture of European and Mediterranean ammonite faunas (Andrusov 1959). All these examples point to synchronism of the Upper Jurassic maximum depth phase in the Western Carpathians.

Similar line of argumentation maybe applied to the Middle Jurassic depth phase. Radiolarites or siliceous limestones are known not only from the sub-tatric succession but also from the broadly termed Križna units of Central Slovakia (Čepek 1970), Šiprun succession of the Mala Fatra Mts (West of the Tatra Mts, in Slovakia) and from the Nedzov one (South-westernmost Slovakia — Andrusov 1959). Middle Jurassic nodular limestones are known to occur in the Manin succession (Western Slovakia — Mišík 1957). Hence also in this case the Middle Jurassic depth phase seems to be synchronous in many Western Carpathian units.

Local differentiation of sea floor morphology (*e.g.* deepening of troughs) could not possibly account for such synchronous phenomena. The persistence of sea floor morphology without major changes throughout the Middle-Upper Jurassic and Lower Cretaceous times seems to be reflected in the fact that only over the radiolarite-bearing sequences the calcareous turbidite formations were deposited during Late Neocomian times (Table 16). This question is dealt with later on in this chapter. Nevertheless, some local tectonic changes *i.e.* depressive movements or upheavals in relation geoanticlinal high versus basin might have occurred in the Carpathian geosyncline and possibly speeded up the action of turbidity currents which transported the material down the basin slopes. This was probably the case with the transport of encrinite slabs embedded in the upper nodular limestones of the Bielskie Tatra Mts (*see* p. 299).

Middle Jurassic volcanic phenomena are unknown from the Tatra Mts, nor from other Inner Carpathian massifs. Volcanic activity of that age is known from such remote areas as the Caucasus (Zesashvili — *fide* Stratigrafia USSR, Jurayskaya sistema, 1972), Crimea (Muratov & *al.* — *fide* Stratigrafia USSR, Jurayskaya sistema, 1972), and Northern Italy, near Verona (Sturani 1969) and Sicily (Fabiani 1930, Trevisan 1937). Volcanic tuffs of possible Jurassic age were cited from the Eastern Carpathians by Świderski (1938).

Tithonian-Berriasian Biancone

The Tithonian-Berriasian Biancone facies of the sub-tatric succession represents probably an equalization of deep marine conditions over vast areas in the West Carpathian geosyncline as this facies is common in

Table 16

Deposition phases in the sub-tatric succession during the Middle-Upper Jurassic and Lower Cretaceous times

Stage	Lithostratigraphic member	Phase
Lower Aptian	marlstone	cease of redeposition processes
Barremian /possibly also a part of the Hauterivian and Lower Aptian/	Muraň limestone /calcareous avalanche, turbidites/ /only Eastern Tatra Mts/	maximum of redeposition
Hauterivian Valanginian	marlstone	termination of the "période de vacuité"
Berriasian Tithonian	b i a n c o n e	compensation of deep oceanic facies
Kimmeridgian /partly also the Lowermost Tithonian/	upper nodular limestone	shallowing phase
Oxfordian /possibly a part of Kimmeridgian/	red, upper green and again red radiolarites	II-nd maximum of deepening
Callovian	middle, nodular limestone	intermediate shallowing phase
Bathonian Bajocian	lower, green radiolarite	I-st maximum of deepening
Aalenian Toarcian	lower, nodular limestone	beginning of deepening phase

many Inner Carpathian successions. The state of preservation of ammonites (only casts) and microfossils (tintinnids and radiolaria) proves that this kind of sediment was laid down below the aragonite and above the calcite compensation depths of Tithonian-Berriasian times. Garrison (1957) assumes abyssal depths for the Oberalm Beds of the Austrian Northern Alps, which sediments seem to be comparable to the sub-tatric Biancone.

Colom (1955, 1967) also regards the Biancone facies as sediment of deep (but not abyssal) Tethyan oceanic realms.

Only one thin turbidite interbed was found in the Biancone of the Westernmost Tatra (Sucha Valley) which proves that occasionally some detrital material was being brought into the basin, presumably from the West.

Lower Cretaceous marlstones

The deep marine conditions continued during the Valanginian through Barremian and even possibly Lower Aptian times. The only innovation was an inflow of finest detrital material which produced marly character of the sediments. In the western part of the Tatra Mts some usually thin intercalations of calcareous and quartz clastic turbidites show that occasional transport by turbidity currents from adjacent areas had taken place there.

The Murań limestones

The sedimentation of calcareous turbidites was much more intense in the Bielskie Tatra Mts (Eastern Tatra Mts) where thick sequence of the Murań limestone was laid down. The turbidite deposition has probably started during Hauterivian times (possibly Upper Hauterivian) as it may be observed at Gęsia Szyja where first turbidite intercalation occurred prior to the last find of *Tintinnopsella carpathica* Murg. & Filip. Sedimentation of the Murań limestone was most intense during the Barremian when Urgonian reefs have flourished over many Central Carpathian highs (Andrusov 1959, 1970; Lefeld 1968). Some diversification of the sea floor morphology probably took place in the geosyncline as gradual upheaval (shallowing tendency) is to be noted in the high-tatric succession of the Tatra Mts starting from the Valanginian through Hauterivian up to the Barremian-Aptian (Lefeld, *op. cit.*). Development of the Urgonian reefs on geoanticlinal highs caused piling up of reef-derived detrital material in the proximal and distal Urgonian zones. This, in turn, led to instability of slopes down which avalanches of carbonate clastics slided into the basin. Occasional turbidity currents took part in the transportation of the detrital material and caused graded bedding in the sediments. Existence of chert bands within the Murań limestone suggests that the depocenter was rather a deep one (at least in relation to the upheaved highs). Deposition of avalanche turbidites has ceased about the end of Barremian, and gave way to another marly deposition. Some Urgonian olistoliths, however, still were transported down the basin as it maybe observed on the top meadow of the Murań Mt. (Fig. 18).

The sub-tatric succession of the Bielskie Tatra Mts seems to continue eastward in the Rużbachy (old Polish name — Drużbaki) horst in the Slovakian Spisz where according to Iwanow (oral information) a Liassic sequence is identical to that of the Hawrań unit of the Bielskie Tatra Mts. Possibly the dark-grayish organodetrital limestone member overlying the Tithonian-Berriasian at Rużbachy (Mahel 1963) may correspond to some varieties of the Murań limestone. Calcareous turbidites similar to those of the sub-tatric succession crop out in the Haligovce Klippe south of the Pieniny Gorge (Birkenmajer 1959). As those sediments were laid down over an Oxfordian radiolarite-bearing sequence (showing reduced vertical symmetry), it is quite probable that a lower part of slope of the Pieniny through was the depocenter of the Haligovce succession.

This conclusion highly contradicts a supposition by Scheibner (*in* Mahel 1968) that the Haligovce succession was deposited over geoanticline. Southward palaeogeographic continuation of this succession is difficult to decifer as it occupies the southernmost position in the Klippen Belt, and merges in this direction under the Podhale Flysch. Książkiewicz (1972) presumed that it may palaeogeographically connect the high-tatric succession of the Tatra Mts somewhere under the Podhale Flysch. Such a conception, however, should require an existence of a transitional (coarse detrital) facial unit inbetween these two which is actually unknown. A palaeogeographic reconstruction under the Podhale Basin inbetween the Tatra Mts and the Haligovce Klippe faces many uncertainties but farther east the Drużbaki horst distanced less then 5 km from the Klippen Belt (9 km from Haligovce Klippe) maybe regarded as a real missing link in this respect. The Drużbaki sequence shows abyssal facies in the Middle and Upper Jurassic, tintinnid-bearing limestones in the Tithonian-Berriasian and probable calcareous turbidites in the Neocomian(?) (Mahel 1963). Such a facial development seems to be intermediate between the Haligovce and the sub-tatric (Hawrań unit) successions, and makes the image of the basin more clear. Distal Urgonian reef-detrital zone, a source area for the calcareous avalanche turbidites of the Murań limestone, does not crop out in the eastern part of the Tatra Mts, nevertheless, it is known to occur at surface in the Osobita area in the Western Tatra Mts. A connection between the high-tatric facies of the Osobita area and the Haligovce Klippe was presumed by Kotański (1963b) who even untimely named the hypothetical, intermediate sequence — the "Podhale" succession (Kotański 1961). The latter one should be represented by the above mentioned sequence at Drużbaki, which in its Lower Cretaceous part exhibits a sort of distal calcareous turbidites. Tracing these sediments back to their presumed source area, we find the proximal turbidites in the Murań limestone complex of the Hawrań unit in the Bielskie Tatra Mts, and the Urgonian reef-detrital facies in the high-tatric zone (*sensu lato*) in the Tatra Mts and/or vicinity. Such a palaeogeographic position of the Hawrań tectonic unit seems to be supported by some recent tectonic observations in the Bielskie Tatra Mts where the orientation of many drag-folds points to tectonic transport of that unit from the NNW. This does not pertain, however, to other sub-tatric units of the Eastern Tatra Mts.

Northern prolongation of the Lower Cretaceous turbidites of the Drużbaki is dim, nevertheless, it seems highly probable that their continuation can be found in the carbonate clastic, possibly turbidite sediments of the Haligovce succession ("Urgonian" limestone of Birkenmajer, 1959), the thickness of which (40 m according to Birkenmajer, *op. cit.*) fits well to the thinning of distal turbidites as compared to that of the proximal ones of the Murań limestone (80—100 m).

In the light of the above palaeogeographic reconstruction for the Barremian times between the Tatra Mts and the southernmost part of the Klippen Belt there is no place for any kind of proximal turbidites other than those ones of the Murań limestone. It must be kept in mind, however, that the above considerations do not pertain to the more westerly situated parts of the Podhale.

Out of this basin reconstruction it comes that:

1. The primary depocenter of the sub-tatric succession of the Hawrań unit must not be far distanced from its present-day position.
2. The Mesozoic substratum of the Podhale Palaeogene shows presumably much more simple relations then it was supposed before.
3. A direct palaeogeographic connection of the Drużbaki sequence with that of the Haligovce Klippe cannot be excluded.

According to the above conception the successions of the Haligovce, Drużbaki and the Hawrań unit of the Tatra Mts should represent the southern basin slope deposition zones of the Klippen Belt Basin.

SOME REMARKS ABOUT THE SO CALLED KRIŻNA UNITS

In many previous palaeogeographic reconstructions the sub-tatric succession (Zone) of the Tatra Mts was regarded as one uniform nappe structure which was thrusted over the high-tatric zone from the south (among others Passendorfer 1961, Andrusov 1959). According to nappe theory the sub-tatric succession was palaeogeographically connected with the so called Križna nappe of Slovakia. In all geologic works in Slovakia the successions characterized by deep marine sediments of Middle-Upper Jurassic age were classified to Križna nappe (Andrusov 1936a, b). Some recent studies, however, have revealed that the so called "sub-tatric nappes" were formed in various, sometimes distant sedimentary basins (Biely & *al.* 1968). The same is probably true about the sub-tatric zone of the Tatra Mts, where some tectonic scales do not fit lithologically one to another as it is the case with the scale at Gładkie Upłaziańskie in the Western Tatra Mts. It is not certain whether the western part of the sub-tatric succession has sedimented in the same trough as the eastern part (Hawrań unit in particular). In fact, there is no tectonic continuity from west to east in the sub-tatric zone. South of Zakopane, in the central part of that zone several apparently independent scales occur (Guzik & Kotański 1963) which probably do not stretch too far toward east and west. The palaeogeographic analysis presented above clearly shows that at least the Hawrań unit (Bielskie Tatra Mts and Polish Eastern Tatra Mts) differs from other sub-tatric scales (*e.g.* the Holica, Gęsia Szyja etc.) and should not be directly connected with them in palaeogeographic sense. Also its direct connection with the more southerly situated "Križna units" in Slovakia seems doubtful. Although any new tectonic reconstruction of the sub-tatric zone would be premature at the moment, it seems highly probable that the numerous sub-tatric scales have been thrusted over the high-tatric zone from various directions and not neccessarily simultaneously. There exist differences in the tectonic style in the western and eastern parts of the sub-tatric zone as well. In the West, it passes gradually into the "Križna unit" of the Choč Mts, whereas in the East the Hawrań unit of the Bielskie Tatra Mts constitutes a tectonically independent monocline separated from adjacent tectonic scales. It continues toward the Drużbaki horst under the Podhale Flysch.

Facial analyses of sedimentary basins in the Inner Carpathians should reveal existence of some "transitional" sequences *sensu* Mahel *(1960)* which might separate palaeogeographically the particular successions actually classified to the Križna nappe. At the present time an affiliation of a sequence to the Križna nappe merely means deep oceanic (basinal) facies, regardless of its proper paleogeographic position. On the other hand, facial analysis of such nondifferentiated sediments as Middle-Upper Jurassic radiolarites gives no clues to exact position in a basin. Analysis of clastic sediments both carbonate and quartz clastic seems to be the only criterion in this respect. Tracing these clastics back to their source areas (if possible) may point to paleogeographic connection inbetween the particular successions.

In the present author's opinion the term "Križna" should be abandoned and the particular successions classified to it should be placed within the correctly analysed sedimentary basins.

Palaeontological part

DESCRIPTION OF AMMONITE FAUNAS

The ammonites here described come from two stratigraphic members. One is an Upper Tithonian fauna which was unknown so far from the Tatra Mts. Another one derives from the Neocomian marlstones and is of the Valanginian-Hauterivian and Barremian age.

The Tithonian ammonites come from the Grześ hill in the Chochołowska Valley (Pl. 3) in the Western Tatra Mts. The fossils occur in fine micritic Biancone-type limestone. Another site from which such ammonite fauna is known is the Lejowa Valley.

The ammonites are preserved as external or internal casts. No suture lines are preserved. Representatives of the genus *Berriasella* prevail over all other genera and constitute in fact, about 95 per cent of all specimens found so far. A complete list of ammonites is given in Table 17.

Table 17

Occurrence of ammonite faunas in the sub-tatric Tithonian and Lower Cretaceous. After Vigilev (1914) and author's own researches

Lower Aptian and Barremian	Silesites aff. seranonis /d'Orb./ Balearites sp. Crioceratites emerici Lév.
Hauterivian	Crioceratites cf. nolani /Kilian/ C. aff. sornayi Sarkar Neolissoceras sp. Distoloceras sp.
Valanginian	Olcostephanus astierianus /d'Orb./ Spiticeras sp. Neocomites neocomiensis /d'Orb./ N. cf. teschenensis Uhlig
Berriasian	
Upper Tithonian	Berriasella callisto /d'Orb./, Corongoceras sp. B. subcallisto [Toucas/Gevrey] B. lorioli /Zittel/, Neocomites beneckei /Jacob/ B. oppeli /Kilian/, Protacanthodiscus chaperi /Pictet/ B. praecox Schneid, Lytoceras sp.

The Lower Cretaceous ammonite fauna comes from three collections namely those of Vigilev, Passendorfer and the author's own. The collections by Vigilev and Passendorfer were neither described nor illustrated. The Vigilev's collection consists of about 80 various fossils, predominantly ammonites. Most of them are very badly preserved. Vigilev's communique (1914) gives only names of 12 ammonites and some other fossils. The collection of Passendorfer comes from the same or similar sites as that of Vigilev. Almost all the fossils derive from the Kościeliska Valley in the Western Tatra Mts.

Vigilev collected his fossils in 6 outcrops there, namely:

1. Pass between Turnia Kończysta and Jaworzyna Miętusia.
2. Mouth of the Miętusi Potok to the Kościeliski Potok at the beginning of a touristic path to the Hala Upłaz.
3. A gully between Kopki and Stara Kopa Kościeliska.
4. Beginning of a path to the Miętusia Valley.
5. Small outcrops on the left (west) bank of the Kościeliski Potok between the gully mentioned at 3. and Brama Kantaka.
6. A gully in the Kopki on the side of the Lejowa Valley.

The complete list of Vigilev's fossils is a follows:

Astieria Astieri d'Orb.
A. scissa Baumberger
A. psilostoma Neumayr & Uhlig
Hoplites amblygonius Neumayr & Uhlig
H. oxygonius Neum. & Uhlig

H. aff.*neocomiensis* d'Orb.
Crioceras Duvali d'Orb.
Cr. Emerici d'Orb.
Cr. Picteti (var. *jurensis*) Nolan
Haploceras sp.
Lytoceras sp.
Hamulina sp.
Belemnites dilatatus Blainville
Rhynchonella sp.
Terebratula Moutoni d'Orb.
Terebratulina sp.
Lima sp.
Cyclolites sp.
Aptychus Didayi Coquand
A. angulicostatus Pictet & Loriol
A. seranonis Coquand
Cycadaceae? and Coniferae?

According to Vigilev (1914) *Phylloceras Tethys* d'Orb. and *Desmoceras* sp. from the Bielskie Tatra Mts were known to Uhlig. Ammonites determined by Vigilev as *Hoplites amblygonius* Neum & Uhlig and *H. oxygonius* Neum & Uhlig belong in fact, to *Neocomites*. The aptychi of Vigilev belong to group *D* of Gąsiorowski (1962, Table 1) and characterize Upper Valanginian and Hauterivian. Passendorfer's specimens come from the Wściekły Żleb (gully), and from the Chochołowska Valley. His collection was never described. The ammonites collected by the author come from the Kościeliska Valley (Wściekły Żleb), Kryta gully in the Chochołowska Valley and from the Szalony Wierch (Bielskie Tatra Mts). All specimens were found in debris not in situ, hence they give no information about exact age of the particular rock complexes. It maybe only inferred that the Neocomian marlstones of the sub-tatric succession cover a time span from the Valanginian up to the Lower Aptian inclusively.

All ammonites are preserved as molds which are strongly flattened due to compaction of the marlstones, and tectonic pressure. In many cases exact measurements could not be done.

Venter is never preserved and the only features observed is ornamentation on sides of whorls. Only best preserved specimens are illustrated on plates.

SYSTEMATIC DESCRIPTIONS

Family **Berriasellidae** Spath, 1922
Subfamily **Berriasellinae** Spath, 1922
Genus *BERRIASELLA* Uhlig, 1905
Berriasella callisto (d'Orbigny, 1847)
(Pl. 8, Fig. 1)

1868. *Ammonites Callisto*; Pictet, Pl. 38, Figs 3—4.
1890. *Hoplites Calisto*; Toucas, p. 600, Pl. 17, Fig. 3.
1907. *Hoplites (Berriasella) Callisto*; Kilian, p. 181 (nomen).

1919. *Berriasella Callisto;* Rodighiero, p. 104, Pl. 11, Fig. 11.
1939. *Berriasella Callisto;* Mazenot, p. 56, Pl. 4, Figs 6—12.
1968. *Berriasella callisto;* Hegarat & Remane, p. 29, Pl. 1, Fig. 7; Pl. 2, Fig. 1.

For description see Mazenot (1939).

Material. — Incomplete external cast with partly preserved outer whorl.
Dimensions[3]: D — 50 mm, U — 16 mm, H — 18.5 mm.
Remarks. — The specimen was determined entirely on the basis of ornamentation which consists of thin, flexuous ribs bifurcating in about half of whorl. Some simple ribs occasionally occur. Ribs are prorsiradiate, slightly falcoid with a tendency to rectiradiate toward body chamber. Venter invisible. The specimen resembles most Figs 7 and 11 of Plate 4 *in* Mazenot (1939).
Occurrence. — Grześ hill, Chochołowska Valley (Western Tatra Mts). Uppermost Tithonian of the sub-tatric succession.

Berriasella subcallisto [Toucas (Gevrey) 1892]
(Pl. 8, Fig. 2)

1890. *Hoplites Calisto* var. *subcalisto;* Toucas, Pl. 17, Figs 4—5.
1939. *Berriasella subcallisto;* Mazenot, p. 59, Pl. 3, Figs 11—14.

For complete synonymy and description see Mazenot (1939).

Material. — One external cast of a half of specimen.
Dimensions: D — 59 mm, U — 23 mm, H — 24 mm.
Remarks. — Specimen determined on the basis of poorly preserved ornamentation. Fine ribs slightly prorsiradiate bifurcate about outer one third of whorl. Ribs are very slightly falcoid, much less then in *B. callisto* (d'Orbigny). Nonbifurcating ribs rare. Venter invisible. Inner whorls strongly damaged. Ornamentation of this specimen makes it close to Mazenot's (1939) Fig. 14*a* on Pl. 3.
Occurrence. — Grześ hill in the Chochołowska Valley (Western Tatra Mts). Uppermost Tithonian of the sub-tatric succession.

Berriasella oppeli (Kilian) 1889
(Pl. 8, Fig. 3)

pars 1890. *Hoplites Calisto* var. *Oppeli;* Toucas, pp. 601 and 599, Pl. 16, Figs 5—6.
1939. *Berriasella Oppeli;* Mazenot, p. 49, Pl. 3, Figs 1—8.

For complete synonymy and description see Mazenot (*op. cit.*).

Material. — One internal mold (cast) of a specimen.
Dimensions: D — 39 mm, U — 16 mm, H — 15 mm.
Remarks. — Due to almost complete flattening of the specimen its sides differ considerably. Ornamentation consists of rectiradiate ribs which bifurcate slightly above half of whorl, and toward the body chamber — in one third (upper) of whorl. On more flattened side the ribs are projected (probably in result of compression).
This specimen resembles most the one figured by Mazenot (1939) on Pl. 3, Figs 5—6.
Occurrence. — Uppermost Tithonian Biancone at Grześ hill, Chochołowska Valley (Western Tatra Mts).

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[3] Abbreviations used for dimensions are: D — shell diameter, U — umbilical diameter, H — whorl height.

Berriasella cf. *lorioli* (Zittel)
(Pl. 8, Fig. 4)

1890. *Perisphinctes Lorioli;* Toucas, p. 598, Pl. 16, Fig. 2.
1939. *Berriasella Lorioli;* Mazenot, Pl. 19, Figs 6—7.
For complete synonymy and description see Mazenot (*op. cit.*).

Material. — One incomplete external cast.

Dimensions: D — 34 mm, U — 12 mm.

Remarks. — Fine, moderately spaced rectiradiate ribs bifurcate at one third (outer) of whorl. Venter invisible. The specimen strongly resembles Fig. 7*b* on Plate 19 of Mazenot (1939). Bad state of preservation does not allow to determine it specifically.

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts).

Berriasella cf. *praecox* Schneid 1914
(Pl. 8, Fig. 5)

1890. *Perisphinctes eudichotomus;* Toucas, p. 599, Pl. 16, Fig. 4.
1915. *Berriasella (Aulacosphinctes?) praecox;* Schneid, p. 64, Pl. 3, Fig. 5—5c.
1939. *Berriasella praecox;* Mazenot, p. 41, Pl. 1, Figs 10—13.
For complete synonymy and description see Mazenot (*op. cit.*).

Material. — Small fragment of external cast.

Dimensions: (estimated) D — about 47 mm, U — *c.* 22 mm, H — 19 mm.

Remarks. — The preserved fragment exhibits rectiradiate ribs which bifurcate about a half of whorl. It is similar to specimens illustrated by Mazenot (1939) on Plate 1, Figs 11—12 and 13*b*.

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts).

Genus *PROTACANTHODISCUS* Spath, 1923
Protacanthodiscus chaperi (Pictet) 1868
(Pl. 9, Fig. 4)

1939. *Berriasella chaperi;* Mazenot, p. 80, Pl. 8, Figs 5—9; Pl. 9, Fig. 1.
1956. *Protacathodiscus chaperi;* Arkell, Pl. 44, Fig. 4.
For complete synonymy and description see Mazenot (1939).

Material. — A half of external cast.

Dimensions: D — *c.* 77 mm, *H* — 37 mm.

Remarks. — The preserved fragment shows about a half of umbilical part which is Berriasella-like. Character of ornamentation is rather that of *P. chaperi* (*e.g.* Mazenot 1939, Pl. 8, Figs 6*b*—7*a*). It shows some affinities to *aizyensis* form as well (*e.g.* Mazenot, *op. cit., Pl. 10, Fig.* 1*b*). Nods at base of primary ribs are weak.

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts).

Subfamily Neocomitinae Spath, 1924
Genus *NEOCOMITES* Uhlig, 1905
Neocomites beneckei (Jacob), 1904
(Pl. 9, Figs 2—3)

1937. *Neocomites (Berriasella?) Beneckei;* Roman & Mazenot, pp. 182—183.
1939. *Neocomites Beneckei;* Mazenot, p. 206, Pl. 32, Figs 8—14.
pars 1968. *Neocomites(?) beneckei;* Hegarat & Remane, Pl. 5, Fig. 3.

For description see Mazenot (1939).

Material. — One external cast and one imprint.

Dimensions. — Specimen (Fig. 2) imprint: D — 44 mm, U — 13 mm, H — 18 mm. Specimen (Fig. 3): D — 26 mm, U — 7 mm, H — 11 mm.

Remarks. — Figure 2 shows a photograph of latex imprint. This specimen is most similar to those figured by Mazenot (*op. cit.*, Pl. 32, Figs 9—10). Its definitely prorsiradiate, fine ribs in the last whorl make it somewhat similar to *N. allobrogensis* Mazenot (1939, Pl. 33, Fig. 4b). Nevertheless, its thin ribs are no so well arranged in bundles as in *N. allobrogensis* Mazenot. Specimen (Fig. 3) is definitely smaller and shows more spaced fine ribbing slightly projected in outer whorl. It shows affinities to Figs 8 and 11 on Pl. 32 of Mazenot (*op. cit.*). Its ribbing seems to be finer than that of a specimen figured by Hegarat (*in* Hegarat & Remane 1968, Pl. 5, Fig. 3).

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts.)

Neocomites neocomiensis (d'Orbigny, 1840)

non 1881. *Hoplites* cf. *neocomiensis;* Neumayr & Uhlig, p. 167, Pl. 48, Fig. 3a—d.
1901. *Hoplites neocomiensis,* Sarasin & Schöndelmayer; Pl. 9, Figs 2—3.
1901. *Neocomites neocomiensis,* Sayn; p. 29, Pl. 3, Figs 11 and 14.
1902. *Neocomites neocomiensis,* Uhlig; p. 54, Pl. 2, Fig. 9.
1907. *Neocomites*-form, Baumberger & Heim; Pl. 1 Fig. 16.
1919. *Neocomites neocomiensis,* Rodighiero; p. 102, Pl. 11, Figs 3 and 7.
1960. *Neocomites neocomiensis,* Drushtchitz *in* Drushtchitz & Kudryavtzev; p. 282, Pl. 27, Fig. 2a, b.
1961. *Neocomites neocomiensis,* Eristavi; p. 93, Pl. 4, Fig. 1.
1967. *Neocomites neocomiensis neocomiensis,* Dimitrova; p. 112, Pl. 53, Fig. 4.

Material. — A dozen or so imprints and external casts both from Vigilev's and Passendorfer's collections.

Dimensions: (average) D — 64—40 mm, U — 23 mm, H — 24 mm.

Remarks. — Most of specimens are heavily pressed, flattened, so difficult to determine. Nevertheless, better preserved specimens show characters typical for the species, among others — sinuous to falcoid ribs and slight umbilical tubercles. Some specimens may represent some varieties of this genus but the material is too badly preserved to make detailed studies.

Occurrence. — Lower Cretaceous marlstones of the sub-tatric succession, Kościeliska and Chochołowska valleys (Western Tatra Mts). Valanginian marlstones of the sub-tatric succession, Tatra Mts.

Neocomites teschenensis (Uhlig 1902)

1902. *Hoplites teschenensis;* Uhlig, p. 54, Pl. 3, Fig. 4.
1907. *Neocomites teschenensis;* Sayn, p. 32, Pl. 3, Fig. 13; Pl. 6. Fig. 3.
1967. *Neocomites teschenensis;* Dimitrova, p. 113, Pl. 53, Figs 2—3.

Material. — Several imprints and external casts. Specimen here described comes from Vigilev's collection No. A-28/28a.

Dimensions: D — 62—66 mm, U — 18—20 mm, H — 25 mm.

Remarks. — Specimen illustrated by Sayn (1907, Pl. 3, Fig. 13) shows distinct sinuous to falcoid ribs which are also observed in the sub-tatric specimens. Umbilical tubercles in the latter are not always distinct. Being an extreme variety of *N. neocomiensis* (d'Orb.), *N. teschenensis* (Uhlig) is quite similar to the former, which pertains to the tatric forms as well.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — According to Sayn (*op. cit.*) it occurs in the Upper Valanginian (Saynoceras verrucosum Zone).

Neocomites sp.?

Material. — One external cast. Author's own collection. Specimen No. K-37.

Dimensions: D — 37 mm, U — 8 mm, H — 16 mm.

Remarks. — Form involute like *Neocomites* but ribs bifurcate at first third of whorl side, not at umbilical edge. Venter not preserved. Ribs rather fine, arcuate, prorsiradiate in early whorls, straight in later whorls. Slightly similar to *N. neocomiensis* var. *premolica* Sayn as illustrated by Sayn (1907, Pl. 3, Figs 7—8) but showing more straight ribs in outer whorls. Possibly non *Neocomites* but other genus of Neocomitinae.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Genus *DISTOLOCERAS* Hyatt, 1900
Distoloceras sp.
(Pl. 11, Fig. 2)

Material. — One external cast (incomplete).

Dimensions: D — c. 41 mm, U — 12 mm, H — 19 mm.

Remarks. — Ribs typical of the genus but more projected than in type species as illustrated by Arkell (1968, p. L361, Fig. 473). Ribs in inner whorls similar to *Acanthodiscus* (Arkell 1968, p. L360, Fig. 472-3), tend to lose nods toward outer whorls. This form seems to be intermediate between *Distoloceras* and *Acanthodiscus* but characters of the former prevail.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — According to Arkell (*op. cit.*, p. L361) *Distoloceras* occurs in the Valanginian and Hauterivian.

Subfamily **Himalayitinae** Spath, 1925
Genus *CORONGOCERAS* Spath, 1925
Corongoceras sp.

Material. — Small, badly preserved fragment of external cast.

Dimensions: D — c. 14 mm, H — 6 mm.

Remarks. — By its strong, distant ribs with secondaries it is classified to *Corongoceras* but specific determination is impossible.

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts).

Family **Lytoceratidae** Neumayr, 1875
Subfamily **Lytoceratinae** Neumayr, 1875
Genus *LYTOCERAS* Suess, 1865
Lytoceras sp.
(Pl. 9, Fig. 1)

Material. — Less then half of specimen (external cast).

Remarks. — By its fine, rectiradiate ribs, bifurcating at very acute angle resembles *Metalytoceras* (Arkell 1968, Fig. 227-4) but specific determination impossible.

Occurrence. — Uppermost Tithonian at Grześ hill, Chochołowska Valley (Western Tatra Mts).

Family **Olcostephanidae** Haug, 1910
Subfamily **Olcostephaninae** Haug, 1910
Genus *OLCOSTEPHANUS* Neumayr, 1875
Olcostephanus astierianus (d'Orbigny, 1840)
(Pl. 10, Figs 3—4)

1907. *Astieria astieri*; Baumberger, p. 28, Fig. 106.
1907. *Holcostephanus Astierianus*; Kilian, p. 213, Pl. 4, Fig. 1.
1909. *Astieria astieriana*; Wegner, p. 78.
1914. *Asteria astieri*; Vigilev, p. 48 (nomen).
1961. *Olcostephanus* cf. *astieri*; Eristavi, p. 86.
1967. *Olcostephanus (Olcostephanus) astierianus*; Dimitrova, p. 90, Pl. 43, Fig. 5.

Material. — One internal mold of adult specimen and two internal molds of young forms. Vigilev's collection Nos. A-28-9c and A-28-93. Passendorfer's collection No. K-8.

Dimensions. — Specimen A-28-9c: D — 52 mm, U — 11 mm, H — 23 mm.

Remarks. — Thin ribs rather rursiradiate branch from umbilical bullae. Few extra secondaries. Distinct constriction at end of shell (oblique to ribs). Ribs in specimen No. A-28-93 are less prorsiradiate, and constrictions are rather recti- or even rursiradiate. It resembles somewhat *O. filosa* (Baumberger 1907, Pl. 22, Fig. 3a). Two other specimens (K-8 and A-28-93) seem to be young forms of *O. astierianus* (see Baumberger 1907, p. 28, Fig. 106). Ribs in specimen A-28-9c are rather rursiradiate — in earlier chambers evidently prorsiradiate.

Occurrence. — Lower Cretaceous marlstone in the Kościeliska Valley (Vigilev 1914), and at Kopy Sołtysie — Polish Eastern Tatra Mts (Grabowska-Hakenberg 1958).

Age. — Upper Valanginian. Cited also from Lower Hauterivian of Bulgaria (Dimitrova 1967, p. 91). Vigilev (1914) mentions also *O. scissa* and *O. psilostoma* but those specimens are lost.

Subfamily **Spiticeratinae** Spath, 1924
Genus *SPITICERAS* Uhlig, 1903
Spiticeras sp.
(Pl. 11, Fig. 3)

Material. — A fragment of external cast of the last whorl. Specimen from Vigilev's collection No. A-28-137. Also an imprint No. A-28-120a.

Dimensions: (reconstruction) D — about 45 mm, H — 16 mm.

Remarks. — Specimen considerably flattened thus the dimensions inexact. The sub-tatric specimen shows some affinities to that one illustrated by Rodighiero (1919; Pl. 10, Fig. 8) — *Spiticeras gratianopolitense* Kilian. Rather fine ribs branch from umbilical tubercles. Constriction not preserved.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — According to Rodighiero (*op. cit.*) occurs in the Valanginian of Northern Italy (Veneto Occidentale).

Family **Ancyloceratidae** Meek, 1876
Subfamily **Crioceratitinae** Wright, 1952
Genus *CRIOCERATITES* Léveillé, 1837
Crioceratites aff. *sornayi* (Sarkar, 1955)
(Pl. 10, Fig. 1)

pars 1894. *Crioceras angulicostatum* d'Orbigny; Nolan, p. 195, Pl. 10, Fig. 3b.
1955. *Crioceras sornayi;* Sarkar, p. 50, Pl. 1, Figs 4 and 7.

Material. — One incomplete specimen. Vigilev's collection No. A-28-159.

Dimensions: D — *c.* 84 mm, U — 40 mm, H — 22 mm.

Remarks. — The specimen is more compressed than *C. sornayi*. Outer whorls lack spines and their ribs are Hoplites-like. Outer whorls are similar to *C. pseudoangulicostatum* Sarkar var. *gracilis* Sarkar (Pl. 2, Fig. 5 *in* Sarkar 1955). Spines and ribs of outer whorl (but not coiling) are similar to *C. angulicostatum* of Nolan (1894; Pl. 10, Fig. 3b). Some affinities to *C. nowaki* Sarkar (character of ribbing of the last whorls and coiling). It is also similar to *C. krishnaae* var. *tuberculata* Sarkar (Pl. 5, Fig. 9 of Sarkar 1955) mostly in general aspect and size, but its ribs on the last whorl are not flexuous as in the variety of Sarkar.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — According to Sarkar (*op. cit.*) it occurs generally in the Neocomian.

Crioceratites cf. *nolani* (Kilian)

1907. *Crioceras Nolani;* Kilian, Pl. 4, Fig. 3.
1919. *Crioceras nolani;* Rodighiero, p. 112, Pl. 12, Figs 5 and 8; Pl. 13, Fig. 1.
1955. *Crioceras nolani;* Sarkar, p. 44, Pl. 7, Fig. 19.
1964. *Crioceratites (Crioceratites) nolani* var. *elegans* (d'Orbigny); Thomel, p. 17, Pl. 2, Fig. 1.
1967. *Crioceratites pictetí;* Dimitrova, p. 43, Pl. 17, Fig. 5.

Material. — One imprint. Vigilev's collection No. A-28-40a.

Dimensions: (inferred) D — about 90 mm, H — about 22 mm.

Remarks. — Bad state of preservation does not allow specific determination. This form is most similar to *Crioceratites (Crioceratites) nolani* (Kilian) var. *elegans* (d'Orbigny) as illustrated by Thomel (1964; Pl. 2, Fig. 1).

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — In southeastern France *Crioceratites nolani* occurs from the Lower Hauterivian up to the Lower Barremian inclusively (Paquier & Killian — *fide* Sarkar 1955, p. 45). According to Thomel (1964) *C. elegans* variety occurs in the Upper Hauterivian.

Crioceratites emerici Léveillé, 1835
(Pl. 12)

1902. *Crioceras Emerici*, Sarasin & Schöndelmayer; p. 115, Pl. 13, Figs 1—3.
1907. *Crioceras emerici*; Kilian, p. 271, Pl. 6, Fig. 6.
1919. *Crioceras emerici*; Rodighiero, p. 113, Pl. 12, Fig. 9.
1955. *Emericiceras emerici*; Sarkar, p. 75, Pl. 5, Fig. 13 and 21.
1964. *Crioceratites (Emericiceras) emerici* (Lév.) var. *sarkari*; Thomel, p. 31, Pl. 5, Fig. 4.
1967. *Crioceratites emericii emericii*; Dimitrova, p. 45, Pl. 18, Figs 2 and 5.

Material. — Several imprints and small fragments from collections of Vigilev and Passendorfer. Photographed is latex peel of an imprint from Passendorfer's collection No. K-11. No. of Vigilev's collection: A-28-38.

Dimensions: D — 150 mm, H — 46 mm (flattened specimen).

Remarks. — The specimen from Passendorfer's collection (K-11) shows usually 7 ribs inbetween principal ribs, and open coiling. Principal ribs bear lateral and ventro-lateral spines (not umbilical). A specimen figured by Kilian (1907; Pl. 6, Fig. 6) shows only 4—5 ribs inbetween spined ones. The true *C. emerici* illustrated by Rodighiero (1919; Pl. 5, Fig. 10) shows also only 4—5 intermediate ribs. Other specimens illustrated by Rodighiero, according to Sarkar (1955) belong to other species of *Crioceratites* but probably all those forms represent only specific varieties. Dimitrova (1967) mentions 2—5 intermediate ribs in her *C. emericii emericii*. Thomel (1964) illustrated a specimen (Pl. 5, Fig. 4) with 5—6 ribs.

Occurrence. — Lower Cretaceous marlstones. Wściekły Żleb and other localities in the Kościeliska Valley (Western Tatra Mts).

Age. — Thomel (1964) mentions *C. emerici* from the Lower Barremian (Basses Alpes). Dimitrova (1967) also points to Lower Barremian age of her Bulgarian specimens. According to Arkell (1968, p. L208) it should occur in the Hauterivian as well but Sarkar (1955) does not agree to that.

Crioceratites sp.

There are some fragments in Vigilev's and Passendorfer's collections which can be attributed only to the genus. Nos. A-28-39a and K-5.

Genus *BALEARITES* Sarkar, 1955
Balearites sp. (var. nov.?)
(Pl. 10, Fig. 2)

pars 1894. *Crioceras baleare*; Nolan, p. 193, Pl. 10, Fig. 2.
1955. *Balearites* sp. (nov. sp.?); Sarkar, p. 148, Pl. 11, Fig. 10.

Material. — One specimen. Vigilev's collection No. A-28-42.

Dimensions: D — 47 mm, U — 17 mm, H — 14 mm.

Remarks. — Two or three slightly flexuous or straight ribs branch from weak umbilical tubercles. Early whorls show some stronger ribs with usually two lateral spines like in *Crioceratites*. It shows most affinities to Fig. 10 of Plate 11 *in* Sarkar (1955) although close comparison is impossible because Sarkar's illustration is too bad. Two or one intermediate weaker ribs inbetween stronger ones in early whorls. In later whorls periodic stronger ribs hardly marked. In general aspect close to Nolan's (1894) Fig. 2, Pl. 10 — but the latter does not show umbilical tubercles.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — Upper Hauterivian (Arkell 1968, p. L208). According to Sarkar (1955) various species of *Balearites* occur in various horizons of Hauterivian and Barre—ian.

Family **Ptychoceratidae** Meek, 1876
Genus *HAMULINA* d'Orbigny, 1843
Hamulina sp.
(Pl. 11, Fig. 1)

pars 1938. *Hamulina Astieri;* Roman, p. 46, Pl. 5, Fig. 44.
1964. *Hamulina astieri;* Thomel, p. 66, Pl. 12, Fig. 1.

Material. — One internal cast, badly preserved, flattened.

Remarks. — As no ornamentation is preserved the specimen is classified only to the genus. It shows some affinities to Fig. 1, Plate 12 of Thomel (1964) particularly in bending.

Occurrence. — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts), and Bielskie Tatra Mts.

Age. — The genus is characteristic for the Barremian. Thomel *(op. cit.)* cites *Hamulina astieri* (d'Orb.) from the Middle Barremian of the Basses Alpes in France.

Family **Haploceratidae** Zittel, 1884
Genus *NEOLISSOCERAS* Spath, 1923
Neolissoceras cf. *grasianum* (d'Orb).

1960. *Haploceras grasianum;* Drushtzitz *in* Drushtzitz & Kudryavtzev, p. 268, Pl. 18, Figs 6*a*, *b*.
1967. *Neolissoceras grasianum;* Dimitrova, p. 85, Pl. 13, Fig. 2.
1968. *Haploceras (Neolissoceras) grasianum;* Wiedmann *in* Wiedmann & Dieni, p. 107, Pl. 10, Fig. 2.

Material. — One external cast. Vigilev's collection No. A-28-102a.

Dimensions: D — 33 mm, U — 4.5 mm, H — 11 mm.

Remarks. — Smooth, flat-sided form with distinct umbilical margin well corresponds to this genus. Lack of suture does not allow specific determination. In its general aspect this form is close to *Neolissoceras grasianum* (d'Orb.).

Specimens probably belonging to this genus were mentioned by Baumberger (1908, p. 40) under the name *Haploceras (Lissoceras) Grasi* d'Orb. from the Hauterivian marls of the Western Swiss Alps.

Occurrence — Lower Cretaceous marlstones in the Kościeliska Valley (Western Tatra Mts).

Age. — According to Arkell (1968, p. L273) *Neolissoceras* occurs from the Upper Tithonian up to the Hauterivian.

Superfamily Desmoceratаceae Zittel, 1895
Family Silesitidae Hyatt, 1900
Genus *SILESITES* Uhlig, 1883
Silesites aff. *seranonis* (d'Orbigny, 1840)

1907. *Silesites seranonis;* Kilian, Pl. 6, Fig. 3.
pars 1919. *Silesites seranonis;* Rodighiero, p. 81, Pl. 9, Fig. 4.
1938. *Silesites seranonis;* Roman, p. 416, Pl. 42, Fig. 403.
1967. *Silesites seranonis;* Dimitrova, p. 162, Pl. 80, Fig. 10.

Material. — A fragment of external cast.

Dimensions: D — about 60 mm, U — about 23 mm, H — 25 mm.

Remarks. — Ornamentation feebly preserved. Constrictions hardly marked. Tubercles on stronger ribs in places where projection starts. Intercalatories thin, arcuate. Venter flattened thus chevrons deformed. Secondaries damaged or nonexisting. In general aspect similar to *S. seranonis* but exact determination impossible.

Occurrence. — Lower Cretaceous marlstones of the Kościeliska Valley (Western Tatra Mts).

Age. — *Silesites* is a Barremian form, but Roman (1938, p. 417) cites *S. seranonis* also from the Hauterivian.

CONCLUSIONS

The Tithonian ammonite fauna here described and illustrated consists predominantly of the representatives of Berriasellinae subfamily. Stratigraphic indications of the described ammonites are as follows:

Berriasella callisto (d'Orb.) according to Kilian (1907) is an index fossil of the Upper Tithonian although Hegarat (*in* Hegarat & Remane 1968, p. 29) claims that this species is most characteristic for the Upper Berriasian in Southeastern France.

Berriasella subcallisto [Toucas (Gevrey)] occurs in the upper part of the Lower Tithonian, in the Upper Tithonian and possibly in the Berriasian according to Mazenot (1939). Such species as *Berriasella praecox* Schneid, *B. lorioli* (Zittel) and *B. oppeli* (Kilian) occur in the Upper Tithonian.

Protacanthodiscus chaperi (Pictet) is an index fossil of the Upper Tithonian (Mazenot, *op. cit.*). Spath (1950) puts it in his emended division of the Tithonian as a chaperi sub-zone of the privasensis Zone (Upper Tithonian). *Neocomites beneckei* (Jacob) occurs both in the upper part of the Lower and in the Upper Tithonian. *Corongoceras* is known to occur in the Tithonian (Arkell 1968). *Berriasella lorioli* (Zittel) and *B oppeli* (Kilian) occur in the Tithonian of Stramberk (Andrusov 1959).

In the light of the above the age of this ammonite fauna is uppermost Tithonian (chaperi sub-zone). The nearest (topographically) Upper Tithonian ammonite fauna occurs at Babierzówka and vicinity (Czorsztyn succession, Pieniny Klippen Belt). It is well known from descriptions by Neumayr, Zittel & Zaręczny (*fide* Birkenmajer 1963). Despite of its proximity (actual distance from the Tatra Mts only 22 km) the assemblage there is completely different, as Berriasellas (*B. richteri*) (Opp.) are extremely rare. A *Berriasella*-bearing ammonite fauna occurs in the sub-

-tatric Tithonian near Lučky in the Choč Mts (Slovakia). The sub-tatric assemblage of the Tatra Mts is similar to that of Central Switzerland (Gerber 1930). Correlation of the tatric assemblage with tintinnids is presented in Table 13.

Contrary to previous views (Vigilev 1914) the Barremian stage is documented in the Lower Cretaceous ammonite fauna by such forms as *Crioceratites nolani* (Kilian) and *C. emerici* Léveillé and *Silesites* aff. *seranonis* (d'Orb.) and *Hamulina* sp. Documentation of the Aptian and higher Cretaceous stages does not exist in the Polish Tatra Mts, nevertheless, a Cenomanian microfauna was found in the sub-tatric marlstones in the Choč Mts of the Orava area in Slovakia (Kantorova & Andrusov 1958). In the Polish part of the Tatra Mts the uppermost portions of the marlstones were destroyed by tectonic movements.

Noteworthy is a comparatively large quantity of forms belonging to Neocomitinae in the sub-tatric Valanginian which makes this fauna similar to that of the Outer Flysch Carpathians (Uhlig 1902).

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REFERENCES

ANDEL T. H. van & KOMAR P. D. 1969. Ponded sediments of the Mid-Atlantic Ridge between 22° and 23° North Latitude. — Bull. Geol. Soc. Amer., vol. 80. Colorado.

ANDRUSOV D. 1931. O stratigrafickém rozdelení spodní křídy spodního subtatranského příkrovu na strednim Slovensku. — Věstn. Státn. Geol. Úst. ČSR, r. 7, č. 2. Praha.

— 1936a. Subdivision des nappes subtatriques sur le versant nord de la Haute Tatra. — Bull. Assoc. Russe Rech. Sci., vol. 4. Praha.

— 1936b. Les nappes subtatriques des Carpathes Occidentales. — Carpatica 1. Praha.

— 1959. Geologia Československych Karpat (Geologie der Tschechoslovakischen Karpaten), Bd. 2. Bratislava.

— 1970. Urgonische Nerineefazies in der Klippenzone der Westkarpaten. — Geol. Sborn., r. 21, č. 2. Bratislava.

ARKELL W. J. 1956. Jurassic Geology of the World. Edinburgh — London.

— 1968. *In:* ARKELL W. J., KUMMEL B. & WRIGHT C. W. — Mesozoic Ammonoidea, Treatise on Invertebrate Palaeontology, Part L *(Mollusca 4)*. Lawrence.

AUBOUIN J. 1959. Granulo-classement vertical (graded bedding) et figures de courants (current marks) dans les calcaires purs: les brèches de flanc des sillons géosynclinaux. — Bull. Soc. Géol. France, vol. 1. Paris.

— 1964. Réflexions sur le faciès "ammonitico rosso". — *Ibidem*, vol. (7) 6.

— 1965. Geosynclines. *Elsevier Publ. Co.* Amsterdam.

— 1967. Quelques problèmes de sédimentation géosynclinale dans les chaînes alpines de la Méditerranée moyenne. — Geol. Rundschau, Bd. 56. Stuttgart.

BAUMBERGER E. 1907. Fauna der unteren Kreide im westschweizerischen Jura.

Vierter Teil — Die Ammonitiden der unteren Kreide im westschweizerischen Jura. — Abh. Schweiz. Paläont. Ges., Bd. 34. Zürich.

— 1908. Die Ammoniten der unteren Kreide im westschweizerischen Jura. — Mém. Soc. Paléont. Suisse, vol. 35. Zürich.

— & HEIM A. 1907. Palaeontologisch-stratigraphische Untersuchung zweier Fossilhorizonte an der Valanginien-Hauterivien-Grenze im Churfirsten-Mattstockgebiet. — Abh. Schweiz. Paläont. Ges., Bd. 34-II. Zürich.

BENEŠOVA E., ELIAŠ M. & MATĚJKA A. 1968. Geology of the Kurovice klippe. — Sborn. Geol. Věd, Geologie, sv. 13. Praha.

BERGER W. A. 1968. Radiolarian skeletons: solution at depth. — Science, vol. 159.

BERGER W. H. 1970. Biogenous deep-sea sediments: fractionation by deep-sea circulation. — Bull. Geol. Soc. Amer., vol. 5, no. 81. Colorado.

BERNER R. A. 1971. Principles of Chemical Sedimentology. New York.

BERNOULLI D. 1960. Die Auflagerung der Radiolaritgruppe in Südtessin. — Ecl. Geol. Helv., vol. 53, no. 2. Bern.

— 1971. Redeposited pelagic sediments in the Jurassic of the Central Mediterranean Area. — Ann. Inst. Geol. Publ. Hung., vol. 54, no. 2. Budapest.

BIELY A., BYSTRICKY J. & FUSAN O. 1968. Zur Problematik der "Subtatrischen Decken" in den Westkarpaten. — Geol. Sborn., r. 19, č. 1. Bratislava.

BIEN G. S., CONTOIS. & THOMAS W. H. 1958. The removal of soluble silica from fresh water entering the sea. — Acta Geochim. et Cosmochim., vol. 14. London.

BIRKENMAJER K. 1957. Nové výskumy stratigrafie pieninského bradlového pásma v Polsku. — Geol. Sborn., r. 8, č. 1. Bratislava.

— 1958a. Przewodnik geologiczny po Pienińskim Pasie Skałkowym. *Wydawn. Geol.* Warszawa.

— 1958b. Submarine erosional breaks and late Jurassic synorogenic movements in the Pieniny Klippen Belt geosyncline. — Bull. Acad. Pol. Sci., Sér. Sci. Chim. Géol. Géogr., vol. 6, no. 8. Varsovie.

— 1959. Znaczenie Skałki Haligowieckiej dla geologii Pienińskiego Pasa Skałkowego (Significance of the Haligowce Klippe for the geology of the Pieniny Klippen Belt — Carpathians). — Ann. Soc. Géol. Pol., vol. 29, no. 1. Kraków.

— 1960. Geology of the Pieniny Klippen Belt of Poland (A review of latest researches). — Jb. Geol. Bundesanstalt Wien, Bd. 103, H. 1. Wien.

— 1963. Stratygrafia i paleogeografia serii czorsztyńskiej Pienińskiego Pasa Skałkowego Polski (Stratigraphy and palaeogeography of the Czorsztyn Series — Pieniny Klippen Belt, Carpathians, in Poland). — Studia Geol. Pol., vol. 9. Warszawa.

— 1965. Zarys budowy geologicznej Pienińskiego Pasa Skałkowego Polski (Outlines of the geology of the Pieniny Klippen Belt of Poland). — Ann. Soc. Géol. Pol., vol. 35, no. 3. Kraków.

— , GĄSIOROWSKI S. M. & WIESER T. 1960. Fragments of exotic rocks in the pelagic deposits of the Bathonian of the Niedzica Series (Pieniny Klippen Belt, Carpathians). — *Ibidem*, vol.: 30, no. 1.

— & GĄSIOROWSKI S. M. 1961. Sedimentary character of Radiolarites in the Pieniny Klippen Belt, Carpathians. — Bull. Acad. Pol. Sci., Sér. Sci. Géol. Géogr., vol. 9, no. 3. Varsovie.

— & ZNOSKO J. 1955. Przyczynek do stratygrafii doggeru i malmu pienińskiego pasa skałkowego (Contribution to the stratigraphy of the Dogger and Malm in the Pieniny Klippen Belt, Central Carpathians). — Ann. Soc. Géol. Pol., vol. 35, no. 2. Kraków.

BISSEL H. J. & CHILINGAR G. V. 1967. Classification of sedimentary rocks. *In:* Developments in Sedimentology — 9A. Amsterdam.

BORZA K. 1957. Poznamky o muranskom vapenci (Bemerkungen über den Muran--kalk). — Geol. Sborn., r. 8, č. 1. Bratislava.

— 1969. Die Mikrofacies und Mikrofossilien des Oberjuras und der Unterkreide der Klippenzone der Westkarpaten. *Slov. Akad. Vied.* Bratislava.

— & HARMAN M. 1970. Lithologisches und elektronenmikroskopisches Studium von Kieselsedimenten der Westkarpaten. — Geol. Sborn., r. 21, č. 2. Bratislava.

BROQUET P. 1970. Observations on gravitational sliding: The concept of olistostrome and olistolite. *In:* Geology and History of Sicily. *P. E. S. L.* Tripoli.

CALVERT S. E. 1968. Silica balance in the ocean and diagenesis. — Nature, vol. 219. St. Albans.

ČEPEK P. 1970. To the facies characterization of the neritic and bathyal sedimentation of the Alpine-Carpathian geosyncline. — Rozpr. Čslov. Akad. Věd, r. 80, sv. 5. Praha.

COLACICCI R. & PIALLI G. 1971. Relationship between some peculiar features of Jurassic sedimentation and paleogeography in the Umbro-Marchigiano Basin (Central Italy). — Ann. Inst. Geol. Publ. Hung., vol. 54, no. 2. Budapest.

COLOM G. 1948. Fossil tintinnids: Loricated infusoria of the order Oligotricha. — J. Paleont., vol. 22. Tulsa.

— 1955. Jurassic-Cretaceous pelagic sediments of the Western Mediterranean zone and the Atlantic area. — Micropaleontology, vol. 1. New York.

— 1967. Sur l'interpretation des sédiments profonds de la zone géosynclinale baléare et subbétique (Espagne). — Palaeogeography, Palaeoclimatol., Palaeoecol., vol. 3. Amsterdam.

CORRENS C. W. 1950. Faktoren der Sedimentbildung, erläutert an kalk- und Kieselsedimenten. — Deutsch. Hydrogr. Z., Bd. 3, H. 1/2.

CRESSMANN E. R. 1962. Nondetrital siliceous sediments. — U. S. Geol. Surv. Prof. Paper 440-T.

DEGENS E. 1965. Geochemistry of Sediments. *Prentice Hall.* New York.

DIMITROVA N. 1967. Fosilite na Bolgaria. IV — Dolna Kreda (Les fossiles de Bulgarie. IV — Crétacé inférieure, Cephalopoda). Sophia.

DRUSHTZITZ V. V. 1960. *In:* DRUSHTZITZ V. V. & KUDRIAVTZEV M. P. — Atlas nizhnemelovoy fauny Kavkaza i Kryma. Moskva.

DŻUŁYŃSKI S., KSIĄŻKIEWICZ M. & KUENEN P. 1959. Turbidites in flysch of the Polish Carpathian Mountains. — Bull. Geol. Soc. Amer., vol. 70. Colorado.

ERICSON D. B., EWING M., WOLLIN G. & HEEZEN B. C. 1961. Atlantic deep-sea sediment cores. — *Ibidem,* vol. 72.

ERISTAVI M. S. 1961. Nekotorye nizhnemelovye golovonogye Centralnykh Karpat. — Geol. Prace, Zpravy 21. Bratislava.

FABIANI R. 1930. Eruzioni sottomarine in Sicilia durante il Giurese. — C. R. XV Intern. Geol. Congress, South Africa, II.

FISCHER A. G. 1969. Geological time-distance rates: The Bubnoff Unit. — Bull. Geol. Soc. Amer., vol. 80. Colorado.

FLÜGEL H. & FENNINGER A. 1966. Die Lithogenese der Oberalmer Schichten und der mikritischen Plassenkalke (Tithonium, Nördliche Kalkalpen). — N. Jb. Geol. Paläont., Abh. Bd. 123, H. 3. Stuttgart.

FRIEDMAN G. M. 1965. Occurrence and stability relationships of aragonite, high--magnesian calcite, and low-magnesian calcite under deep-sea conditions. — Bull. Geol. Soc. Amer., vol. 76. Colorado.

GARRISON R. 1967. Pelagic limestones of the Oberalm Beds (Upper Jurassic — Lower Cretaceous). Austrian Alps. — Bull. Canadian Petrol. Geol., vol. 15. Calgary.

— & FISCHER A. G. 1969. Deep-water limestones and radiolarites of the Alpine

Jurassic. *In:* FRIEDMAN G. M. (*Ed.*) — Depositional environments in carbonate rocks. — Soc. Econ. Paleont. Miner., Special Publ., vol. 14. Tulsa.

GĄSIOROWSKI S. M. 1959. Nowe dane o wieku radiolarytów serii reglowej dolnej w Tatrach (On the age of radiolarites in the sub-tatric series in the Tatra Mts.). — Acta Geol. Pol., vol. 9, no. 2. Warszawa.

— 1962. Aptychi from the Dogger, Malm and Neocomian in the Western Carpathians and their stratigraphical value (Aptychy doggeru, malmu i neokomu Karpat Zachodnich i ich znaczenie stratygraficzne). — Studia Geol. Pol., vol. 10. Warszawa.

GERBER M. 1930. Beiträge zur Stratigraphie der Jura-Kreide-grenze in der Zentralschweiz. — Ecl. Geol. Helv., vol. 23, no. 2. Basel.

GIANNINI E., PIERUCCINI R. & TREVISAN L. 1950. Limestones with nodules of chert and jasper. — Soc. Toscana Sci. Nat. Atti. Mem., vol. 57 A.

GOREK A. 1950. Tektonické okná na západnom ukončeni Vysokých Tatier (Les fenêtres tectoniques de l'extrémité ouest des Hautes Tatras). — Geol. Sborn., r. 1. č. 1. Bratislava.

GRABOWSKA-HAKENBERG H. 1958. Budowa geologiczna zachodniego obszaru Kop Sołtysich w Tatrach (Geology of western part of Kopy Sołtysie — Tatra Mountains). — Kwartalnik Geol., vol. 2, no. 2. Warszawa.

GRUNAU H. 1959. Mikrofazies und Schichtung ausgewählter Jungmesozoischer, Radiolarit-führender sedimentserien der Zentral-Alpen. — Intern. Sedim. Petrogr. Series, vol. 4. Leiden.

— 1965. Radiolarian cherts and associated rocks in space and time. — Ecl. Geol. Helv., vol. 58, no. 1. Basel.

GUZIK K. 1959. Niektóre zagadnienia stratygrafii liasu-doggeru płaszczowiny reglowej dolnej w Tatrach (Notes on some stratigraphic problems of the Lias-Dogger rocks in the Lower Sub-tatric nappe of the Tatra Mts). — Biul. Inst. Geol. 149. Warszawa.

— & KOTAŃSKI Z. 1963. Tektonika regli zakopiańskich (La tectonique de la zone subtatrique de Zakopane). — Acta Geol. Pol., vol. 13, no. 3/4. Warszawa.

HALLAM A. 1963. Eustatic controll of major cyclic changes in Jurassic sedimentation. — Geol. Mag., vol. 100. London.

— 1967. Sedimentology and palaeogeographic significance of certain red limestones and associated beds in the Lias of the Alpine Region. — Scottish J. Geol., vol. 3. Edinburgh — Glasgow.

— 1971. Evaluation of bathymetric criteria for the Mediterranean Jurassic. — Ann. Inst. Geol. Publ. Hung., vol. 54, no. 2. Budapest.

HAUG E. 1927 Traité de Géologie. II. Paris.

HEATH G. R. 1969. Carbonate sedimentation in the abyssal equatorial Pacific during the past 50 million years. — Bull. Geol. Soc. Amer., vol. 80. Colorado.

HÉGARAT L. G. & REMANE J. 1968. Tithonique supérieur et Berriasien de l'Ardèche et de l'Hérault. Corrélation des Ammonites et des Calpionelles. — Geobios, no. 1. Lyon.

HEIM A. 1958. Oceanic sedimentation and submarine discontinuities. — Ecl. Geol. Helv., vol. 51. Basel.

HOLLMANN R. 1962. Über Subsolution und die "Knollenkalke" des calcare Ammonitico rosso superiore im Monte Baldo (Malm, Norditalien). — N. Jb. Geol. Paläont., Mh. 4. Stuttgart.

— 1964. Subsolutions-Fragmente. — N. Jb. Geol. Paläont. Abh., Bd. 119, H. 1. Stuttgart.

HOWARTH M. K. 1964. The Jurassic period. *In:* HARLAND W. B., SMITH A. G. &

WILCOCK B. (*Eds.*) — The phanerozoic time scale. — Quart. J. Geol. Soc. London, vol. 120. London.

HUDSON J. D. 1967. Speculations on the depth relations of calcium carbonate solution in recent and ancient seas. *In:* HALLAM A. (*Ed.*) — Depth indicators in marine sedimentary environments. — Marine Geol., Special Issue, vol. 5, no. 5/6. Amsterdam.

IRVING E. 1964. Paleomagnetism and its application to geological and geophysical problems. *Wiley and Sons.* New York — London — Sydney.

IWANOW A. 1973. New data on geology of the lower sub-tatric succession in the eastern part of the Tatra Mts. — Bull. Acad. Pol. Sci., Sér. Géogr. Géol., vol. 21, no. 1. Varsovie.

JACOBACCI A. 1965. Frane sottomarine nelle formazioni geologiche. Interpretazione dei fenomeni olistostromi e degli olistolite nell'Appennino e in Sicilia. — Boll. Serv. Geol. Ital., vol. 86. Roma.

KANTOROVA V. & ANDRUSOV D. 1958. Mikrobiostratigrafický výskum strednej a vrchnej kriedy Považia a Oravy. — Geol. Sborn., r. 9. Bratislava.

KAŹMIERCZAK J. 1974. Lower Cretaceous Sclerosponge from the Slovakian Tatra Mts. — Palaeontology, vol. 17, no. 3. London.

KHVOROVA I. V. 1968. Geosynclinal siliceous rocks and some problems of their origin. — Intern. Geol. Congress Repts., Section 8. Prague.

KILIAN W. 1907. Unterkreide. *In:* Lethaea geognostica. II Teil, Bd. 3. Stuttgart.

KONDA J. 1971. Ammonitico rosso and radiolarites in the Transdanubian Central Mts, Jurassic. *In:* Coll. du Jurassique Méditerranéen. — Ann. Inst. Geol. Publ. Hung., vol. 54. Budapest.

KOTAŃSKI Z. 1961. Tektogeneza i rekonstrukcja paleogeografii pasma wierchowego w Tatrach (Tectogénèse et reconstitution de la paléogéographie de la zone haut-tatrique dans les Tatras). — Acta Geol. Pol., vol. 11, no. 2/3. Warszawa.

— 1963a. O triasie Skałki Haligowieckiej i pozycji paleogeograficznej serii haligowieckiej (On the Triassic of the Haligowce Klippen and the palaeogeographic position of the Haligowce series. — *Ibidem*, vol. 13, no. 2.

— 1963b. O charakterze mezozoicznej geosynkliny Karpat Zachodnich i o epimiogeosynklinie podhalańskiej (On the character of the Western Carpathian Mesozoic geosyncline and the Podhale epimiogeosyncline). — *Ibidem*, vol. 13, no. 1.

— 1965. Budowa geologiczna pasma reglowego między Doliną Małej Łąki i Doliną Kościeliską (La structure géologique de la chaîne subtatrique entre la vallée de Mała Łąka et la vallée Kościeliska dans les Tatras Occidentales). — *Ibidem*, vol. 15, no. 3.

KRAJEWSKI R. & MYSZKA J. 1958. Wapienie manganowe w Tatrach między doliną Chochołowską a Lejową (Manganiferous limestones in the Tatra Mts between the Chochołowska and Lejowa valleys). — Biul. Inst. Geol. 126. Warszawa.

KRAUSKOPF K. B. 1956. Dissolution and precipitation of silica at low temperatures. — Acta Geochim. et Cosmochim., vol. 10, London.

KSIĄŻKIEWICZ M. 1951. Kreda Karpat Zewnętrznych (*in Polish*). *In:* Regionalna Geologia Polski. T. I — Karpaty. Z. 1 — Stratygrafia. Kraków.

— 1960. Zarys paleogeografii Polskich Karpat Fliszowych (Outline of the paleogeography of the Polish Flysch Carpathians). — Prace Inst. Geol., vol. 30, no. 2. Warszawa.

— 1971. On the Origin of the Cieszyn Limestone in the Carpathian Flysch. — Bull. Acad. Pol. Sci., Sér. Sci. Géol. Géogr., vol. 19, no. 3. Varsovie.

— 1972. Budowa geologiczna Polski T. IV — Tektonika, Część 3 — Karpaty (*in Polish*). *Wydawn. Geol.* Warszawa.

KUENEN P. 1958. Problems concerning source and transportation of flysch sediments. — Geologie en Mijnbouw., vol. 20. Haag.

KUTEK J. 1969. Kimeryd i najwyższy oksford południowo-zachodniego obrzeżenia mezozoicznego Gór Świętokrzyskich. Część II — Paleogeografia (The Kimmeridgian and Uppermost Oxfordian in the SW margins of the Holy Cross Mts, Central Poland. Part II — Paleogeography). — Acta Geol. Pol., vol. 19, no. 2. Warszawa.

KUŹNIAR C. 1913. Skały osadowe tatrzańskie (Le roches sédimentaires des Hautes Tatras). — Rozpr. Pol. Akad. Um., t. 13, s. 3, dz. A. Kraków.

LEFELD J. 1968. Stratygrafia i paleogeografia dolnej kredy wierchowej Tatr (Stratigraphy and palaeogeography of the High-tatric Lower Cretaceous in the Tatra Mountains). — Studia Geol. Pol., vol. 24. Warszawa.

— 1969. Upper Jurassic carbo-silite sequence in the sub-tatric succession of the Eastern Tatra Mts. — Bull. Acad. Pol. Sci., Sér. Sci. Géol. Géogr., vol. 17, no. 1. Varsovie.

— & RADWAŃSKI A. 1960. Planktoniczne liliowce *Saccocoma* Agassiz w malmie i neokomie wierchowym Tatr Polskich (Les Crinoïdes planctoniques *Saccocoma* Agassiz dans le Malm et le Néocomien haut-tatrique des Tatras Polonaises). — Acta Geol. Pol., vol. 10, no. 4. Warszawa.

LIMANOWSKI M. 1904. Odkrycie płatu dolnotatrzańskiego w pasmie Czerwonych Wierchów na Gładkiem (*in Polish*). — Rozpr. Pol. Akad. Um., t. 4, s. 3, dz. B. Kraków.

LUCAS G. 1955. Caractères pétrographiques du calcaire noduleux à faciès ammonitico rosso de la région méditerranéenne. — C. R. Acad. Sci., vol. 240. Paris.

MAHEL M. 1960. The question of nappes in the Central West Carpathians from the point of view of palaeogeography of the Mesozoicum. — Intern. Geol. Congress. XXI Session, Rpts. 18. Copenhagen.

— 1963. Stratigrafia mezozoika Ružbašského ostrova (Zur Stratigraphie der Mesozoischen Insel von Ružbachy). — Geol. Prace, Zpravy 30. Bratislava.

— 1968. *In:* Regional Geology of Czechoslovakia. Part 2. Praha.

MAPA GEOLOGICZNA TATR POLSKICH scale 1 : 10 000. Sheet B 2. *Wydawn. Geol.* Warszawa.

MAZENOT G. 1939. Les Palaeohoplitidae Tithoniques et Berriasiens du Sud-Est de la France. — Mém. Soc. Géol. France, vol. 41. Paris.

MEISCHNER K. 1964. Allodapische Kalke, Turbidite in riffnahen Sedimentations-becken (Allodapic lmsts). *In:* BOUMA A. H. & BROUWER A. (*Eds.*) — Turbidites-Developments in sedimentology, Part 3. Amsterdam.

MIŠIK M. 1957. Litologický profil Maninskou sériou (Das lithologische profil durch die Maninserie). — Geol. Sborn., r. 8, č. 2. Bratislava.

— 1959. "Lombardiova" mikrofacia — veduci horizont v malmie Zapadnych Karpat (Die "Lombardia"-Mikrofazies ein Leithorizont im Malm der Westkarpaten). — *Ibidem*, s. 10, č. 1.

— 1966. Microfacies of the Mesozoic and Tertiary limestones of the West Carpathians. *Slov. Akad. Vied.* Bratislava.

— 1973. Structures of the chert concretions from the limestones of Tithonian and Neocomian. — Geol. Sborn., r. 24, č. 1. Bratislava.

NAIRN A. E. M. (*Ed.*). 1961. Descriptive Palaeoclimatology — Interscience Publ. New York — London.

NEUMAYR M. & UHLIG V. 1881. Über Ammonitiden aus den Hilsbildungen Norddeutschlands. — Palaeontographica, Bd. 27. Cassel.

NOLAN H. 1894. Note sur le *Crioceras*. — Bull. Soc. Géol. France, vol. 22, no. 3. Paris.

NOWAK W. 1968. Stomiosferidy warstw cieszyńskich (kimeryd-hoteryw) Polskiego Śląska Cieszyńskiego i ich znaczenie stratygraficzne (Stomiosphaerids of the Cieszyn Beds — Kimmeridgian-Hauterivian — in the Polish Cieszyn Silesia and their stratigraphical value). — Ann. Soc. Géol. Pol., vol. 38, no. 2/3. Kraków.

PASSENDORFER E. 1950. Materiały do geologii Tatr. II. O wapieniu murańskim (Matériaux pour la connaissance de la géologie des Tatras. II. Sur le calcaire de Murań). — *Ibidem*, vol. 19, no. 3.

— 1951. Kreda Tatr. *In:* Regionalna geologia Polski. T. I — Karpaty. Z. 1 — Stratygrafia. Kraków.

— 1961. Rozwój paleogeograficzny Tatr (Evolution paléogéographique des Tatras). — Ann. Soc. Géol. Pol., vol. 30, no. 3. Kraków.

PAZDRO Z. 1934. Pasmo Gór Czywczyńskich. *In:* TOKARSKI J. & *al.* — Pasmo Gór Czywczyńskich. Studium petrograficzno-geologiczne (La chaîne de Czywczyn. Étude pétrographique et géologique). — *Ibidem*, vol. 10.

PETTIJOHN F. J. 1957. Sedimentary Rocks. *Harper and Bros.* New York.

PICTET F. J. 1868. Mélanges paléontologiques. Vol. 4. Genève.

PRATURLON A. & RADOIČIĆ R. 1967. Notes on the dasyclad genus *Salpingoporella* Pia. — Geologica Romana, vol. 6. Roma.

PREDA I. 1973. Variatiile de facies si biostratigrafia Jurasicului Superior din Muntii Haghimas (The facies variations and the biostratigraphy of the Upper Jurassic strata from the Haghimas Mts, Roumania). — Studii si Cercetari (Geol.-Geogr.) II. Piatra Neamt.

RABOWSKI F. & GOETEL W. 1925. Budowa Tatr. Pasmo reglowe (Les nappes de recouvrement de la Tatra. La structure de la zone subtatrique). — Spraw. PIG (Bull. Serv. Géol. Pol.), vol. 3, no. 1/2. Warszawa.

REMANE J. 1964. Untersuchungen zur Systematik und Stratigraphie der Calpionellen in den Jura-Kreide-Grenzschichten des Vocontischen Troges. — Palaeontographica (B), Bd. 123, Abt. A. Stuttgart.

— 1970. Die Entstehung der resedimentären Breccien im Obertithon der subalpinen Ketten Frankreichs. — Ecl. Geol. Helv., vol. 63, no. 3. Basel.

RIEDEL W. R. & FUNNEL B. M. 1964. Tertiary sediment cores and microfossils from the Pacific Ocean floor. — Quart. J. Geol. Soc. London, vol. 120. London.

RODIGHIERO A. 1919. Il sistema Crétaceo del Veneto Occidentale compreso fra l'Adige e il Piave, con speciale riguardo al Neocomiano dei Sette Comuni. — Palaeontogr. Italica, Mem. di Paleontologia, vol. 25. Pisa.

ROMAN F. 1938. Les ammonites jurassiques et crétacées. Essai de genera. *Masson.* Paris.

— & MAZENOT G. 1937. Découverte d'une faune pyriteuse d'age tithonique supérieure auy environs de Chomérac (Ardèche). — Bull. Soc. Géol. France, vol. 7, no. 5. Paris.

RUSNAK G. A. & NESTEROFF W. D. 1964. Modern Turbidites: Terrigenous abyssal plain versus bioclastic basin. *In:* MILLER R. L. (*Ed.*) — Papers in marine geology — Shepard commemorative volume. New York.

SAMSONOWICZ J. 1965. *In:* SAMSONOWICZ J., KSIĄŻKIEWICZ M. & RÜHLE E. — Zarys geologii Polski. Warszawa.

SARASIN C. & SCHÖNDELMAYER C. 1901. Étude monographique des Ammonites du Crétacé inférieur de Châtel-Saint-Denis. — Mém. Soc. Paléont. Suisse, vol. 28. Genève.

— 1902. Étude monographique des Ammonites du Crétacé inférieur de Châtel-Saint-Denis. — *Ibidem*, vol. 29.

SARKAR S. S. 1955. Révisiin des Ammonites déroulées du Crétacé inférieur du Sud-Est de la France. — Mém. Soc. Géol. France, vol. 34, no. 72. Paris.

SAYN G. 1901. Les Ammonites pyriteuses des marnes valanginiennes du Sud-Est de la France. — *Ibidem*, vol. 23.

SCHEIBNER E. 1967. Niżna subunit — new stratigraphical sequence of the Klippen Belt (West Carpathians). — Geol. Sborn., r. 18, č. 1. Bratislava.

SCHNEID T. 1915. Die Ammoniten Fauna der Obertithonischen Kalk von Neuburg a-D. — Geol. Paläont. Abh. Jena, Bd. 13. Jena.

SIEVER R. 1962. Silica solubility O—200°C, and the diagenesis of siliceous sediments. — J. Geol., vol. 70. Chicago.

SLAVIN V. I. 1972. Karpatskaya geosynklinalnaya sistema. In: Stratigrafiia SSSR, Jurskaya sistema. Moskva.

SOKOŁOWSKI S. 1925. Spostrzeżenia nad wiekiem i wykształceniem liasu reglowego w Tatrach (Die Beobachtungen über das Alter und Entwicklung des subtatrischen Lias im Tatragebirge). — Ann Soc. Géol. Pol., vol. 2. Kraków.

— 1950. Les Tatry Bielskie. La géologie de leurs versants méridionaux. — Trav. Serv. Géol. Pol., vol. 4. Warszawa.

— 1959. Zarys geologii Tatr (Outlines of geology of the Tatra Mountains). — Biul. Inst. Geol. 149. Warszawa.

SPATH L. F. 1950. A new Tithonian ammonoid fauna from Kurdistan, Northern Iraq. — Bull Brit. Mus. Natur. Hist., Geology, vol. 1, no. 4. London.

STACHE G. 1868. Die Sedimentärschichten der Nordseite der Hohen Tatra. — Verh. Geol. Reichsanst., No. 13. Wien.

STEINMANN G. 1925. Gibt es fossile Tiefseeablagerungen von erdgeschichtlicher Bedeutung? — Geol. Rundschau, Bd. 16. Stuttgart.

STRATIGRAFIA SSSR, Jurajskaya sistema. 1972. *Nedra*. Moskva.

STURANI C. 1969. Intercalazione di vulcaniti medio-giurassiche nel "Rosso Ammonitico" dei Lessini veronesi. — Boll. Soc. Geol. Ital. vol. 88. Roma.

SUJKOWSKI Z. 1932. Radiolaryty Polskich Karpat Wschodnich i ich porównanie z radiolarytami tatrzańskimi (Radiolarites des Karpates Polonaises Orientales et leur comparaison avec les Radiolarites de la Tatra). — Spraw. PIG (Bull. Serv. Géol. Pol.), vol. 7, no. 1. Warszawa.

ŚWIDERSKI B. 1938. Die Faunen der Czarny Czeremosz-Szybeny Klippen. — Bull. Intern. Acad. Pol. Sci. Lettres, (B). Kraków.

SZULCZEWSKI M. 1965. Spostrzeżenia nad genezą tatrzańskich wapieni bulastych (Observations sur la genèse des calcaires noduleux des Tatras). — Ann. Soc. Géol. Pol., vol. 35, no. 2. Kraków.

— 1968. Stromatolity jurajskie w Polsce (Jurassic stromatolites of Poland). — Acta Geol. Pol., vol. 18, no. 1. Warszawa.

THOMEL G. 1964. Contribution à la connaissance des Céphalopodes du Sud-Est de la France. Les Ammonites déroulées de Crétacé inférieur vocontien. — Mém. Soc. Géol. France. vol. 43, no. 101. Paris.

TOUCAS A. 1890. Faune de couches tithoniques de l'Ardèche. — Bull. Soc. Géol. France, vol. 18, no. 3. Paris.

TRAUTH F. 1950. Die facielle Ausbildung und Gliederung des Oberjura in den nördlichen Ostalpen. — Verh. Geol. Bundesanst. Wien, 1948. Wien.

TREVISAN L. 1937. Scoperta di formazioni basaltiche e piroclastiche presso Vicari (Palermo) e osservazioni sui fossili baiociani contenuti nei tufi. — Boll. Soc. Geol. Ital., vol. 56. Roma.

TRÜMPY R. 1955. Wechselbeziehungen zwischen Palaeogeographie und Deckenbau. — Vierteljahrschr. Naturf. Ges. Zürich, Bd. 100. Zürich.

— 1960. Paleotectonic evolution of the Central and Western Alps. — Bull. Geol. Soc. Amer., vol. 71. Colorado.
UHLIG V. 1897. Geologie des Tatragebirges. I Th. Einleitung und stratigraphischer Theil. — Anz. Akad. Wiss. Math. Natur. Kl., Bd. 64. Wien.
— 1902. Über die Cephalopodenfauna der Teschener und Grodischter Schichten. — Denkschr. K. Akad. Wiss. Wien, Math. Natur. Kl., Bd. 72. Wien.
UNRUG R. 1963. Warstwy istebniańskie — studium sedymentologiczne (Istebna Beds — a Fluxoturbidity Formation in the Carpathian Flysch). — Ann. Soc. Géol. Pol., vol. 33, no. 1. Kraków.
VIALOV O. S., GLUSHKO V. V., KULTCHITZKI V. I. & SLAVIN V. I. 1960. Stratigrafia Vostochnykh Sovetskikh Karpat. *In:* Materialy Karpato-Balkanskoy Assocyacii Kiev. No. 3. Kiev.
VIGILEV B. 1914. Neokom reglowy w Tatrach (*in Polish*). — Spraw. Komis. Fizjogr. PAU, 48. Kraków.
WALKER R. G. 1967. Turbidite sedimentary structures and their relationship to proximal and distal depositional environments. — J. Sedim. Petrol., vol. 37. Menasha.
WEGNER R. N. 1909. Übersicht der bisher bekannten *Astieria*-formen. — N. Jb. Miner. Geol. Paläont., Bd. 1. Stuttgart.
WIEDMANN J. 1968. Das Problem stratigraphischer Grenzziehung und die Jura/ /Kreide-Grenze. — Ecl. Geol. Helv., vol. 61, no. 2. Basel.
— 1971. Zur Frage der Jura/Kreide-Grenze. — Ann. Inst. Geol. Publ. Hung., vol. 54, no. 2. Budapest.
— & DIENI J. 1968. Die Kreide Sardiniens und Ihre Cephalopoden. — Palaeontogr. Italica, vol. 64. Pisa.
YABE H. & SUGIYAMA T. 1935. Jurassic stromatoporoids from Japan. — Sci. Repts. Tohôku Imp. Univ., ser. 2, vol. 14. Sendai.

J. LEFELD

BIOSTRATYGRAFIA I SEDYMENTOLOGIA ŚRODKOWEJ I GÓRNEJ JURY ORAZ DOLNEJ KREDY SERII PODTATRZAŃSKIEJ TATR

(Streszczenie)

W pracy przedstawione zostały problemy stratygrafii, sedymentologii oraz paleogeografii utworów środkowo- i górnojurajskich oraz dolnokredowych serii podtatrzańskiej [1] (reglowej dolnej — wg dawnej nomenklatury) Tatr. Na podstawie analizy facjalnej stwierdzono istnienie pionowej symetrii w rozkładzie głębokomorskich osadów środkowej i górnej jury, z których te ostatnie zostały zbadane bardziej szczegółowo. Zanotowane zostały dwie fazy maksymalnego przegłębienia morza — jedna w jurze środkowej (bajos-baton), a druga — w oksfordzie. Osady jury osadzały się najprawdopodobniej na stoku rowu geosynklinalnego, o czym świadczy m.in. obecność wapieni bulastych zarówno w spągu jak i w stropie radiolarytów oraz stosunkowo znaczna węglanowość tych ostatnich. Głębokość depozycji wapieni bulastych i radiolarytów została rozpatrzona na podstawie analizy selektywnego roz-

[1] Termin seria reglowa dolna został tu zastąpiony przez „podtatrzańska", który niegdyś stosował M. Limanowski.

puszczania kalcytowych i aragonitowych szczątków organizmów. Większość tych osadów była deponowana pomiędzy poziomami kompensacji kalcytu i aragonitu, a jedynie niektóre zielone radiolaryty — poniżej poziomu kompensacji kalcytu. Wyliczone dane dotyczące tempa sedymentacji radiolarytów górnojurajskich oraz całej sekwencji węglano-krzemionkowej wskazują, że osady te tworzyły się niezmiernie wolno. Radiolaryty jurajskie Tatr można traktować jako rezyduum wynikłe z intensywnego rozpuszczania węglanów. Ponieważ żadne źródło wulkaniczne krzemionki nie istniało w pobliżu serii podtatrzańskiej, źródła krzemionki w radiolarytach można upatrywać w rozpuszczaniu szkieletów radiolarii oraz substancji węglanowej (mułu wapiennego). Tym samym krzemionka ta ma charakter rezydualny.

Istnienie oksfordzkiej fazy przegłębienia morza w serii podtatrzańskiej jest korelowane z maksimum transgresji, jakie miało miejsce w tym czasie na obszarze Polski pozakarpackiej. Charakter facjalny osadów górnej jury, a w szczególności osadów oksfordu, jest ważnym wskaźnikiem położenia danej sekwencji w basenie sedymentacyjnym. Kryterium to sprawdza się niezmiennie, gdyż zawsze ponad geosynklinalnymi osadami jury występują węglanowe turbidity w dolnej kredzie, podczas gdy ponad węglanowymi osadami jurajskimi serii geoantyklinalnych występują rafowe struktury urgońskie lub okruchowe facje towarzyszące urgonowi.

Stratygrafia wapieni krzemionkowych tytono-beriasu typu Biancone oparta została na zespołach Tintinnidae oraz znalezisku fauny amonitowej w górnym tytonie (podpoziom chaperi). Margle neokomu podtatrzańskiego są również częściowo dokumentowane przez Tintinnidae oraz przez amonity.

Analizie facjalnej został poddany kompleks wapieni murańskich Tatr Bielskich i Polskich Tatr Wschodnich w rejonie Kop Sołtysich. Osady te są wynikiem redepozycji ze stref otaczających struktury urgońskie. Są to tak zwane turbidity lawinowe (*avalanche turbidites*) powstałe w wyniku lawinowego zsuwania się klastycznego materiału węglanowego po stoku rowu oraz depozycji i suspensji. Najprawdopodobniej depozycja tych klastycznych osadów węglanowych nie przerwała sedymentacji margli, które pojawiają się znowu ponad wapieniami murańskimi. Wapienie murańskie, w których stropowych partiach występują typowo urgońskie mikroskamieniałości (orbitoliny, miliolidy, glony itd.), są wieku górny hoteryw-barrem, podczas gdy margle je przykrywające reprezentują najprawdopodobniej dolny apt. Margle te zawierają olistolity urgońskie z typowymi urgońskimi skamieniałościami. Istnieje wielkie podobieństwo tych redeponowanych skał urgońskich do takichże z serii wierchowej Tatr.

Na podstawie analizy facjalnej wapieni murańskich sugerowana jest łączność paleogeograficzna jednostki Hawrania z serią Drużbaków na Spiszu oraz, być może, z najbardziej południowymi seriami Pienińskiego Pasa Skałkowego (sukcesja Skałki Haligowieckiej).

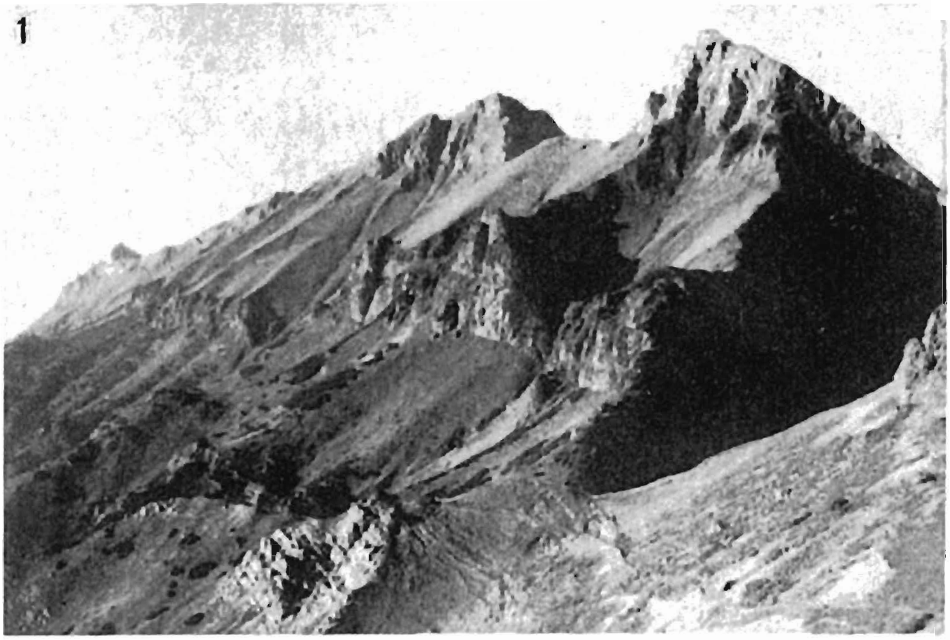
W części paleontologicznej opisano 9 gatunków i rodzajów amonitów tytońskich, a 8 z nich zilustrowano.

Fauna amonitowa dolnej kredy składa się z form walanżyńskich, hoterywskich i barremskich, z których 14 zostało opisanych, a 7 zilustrowanych. Część okazów pochodzi z kolekcji Vigileva i Passendorfera, które dotychczas nie były szczegółowo opisywane.

Pracownia Stratygrafii
Zakładu Nauk Geologicznych PAN
02-089 Warszawa, Al. Żwirki i Wigury 93
Warszawa, w listopadzie 1973 r.

1 — Bielskie Tatra Mts seen from north. White, steep walls — Murań limestones. Murań Mt. on right.
2 — Czerwona Skałka (center) and Holica (right) — both forested hills show profiles of the sub-tatric Middle and Upper Jurassic. Tatra crystalline core behind.

1



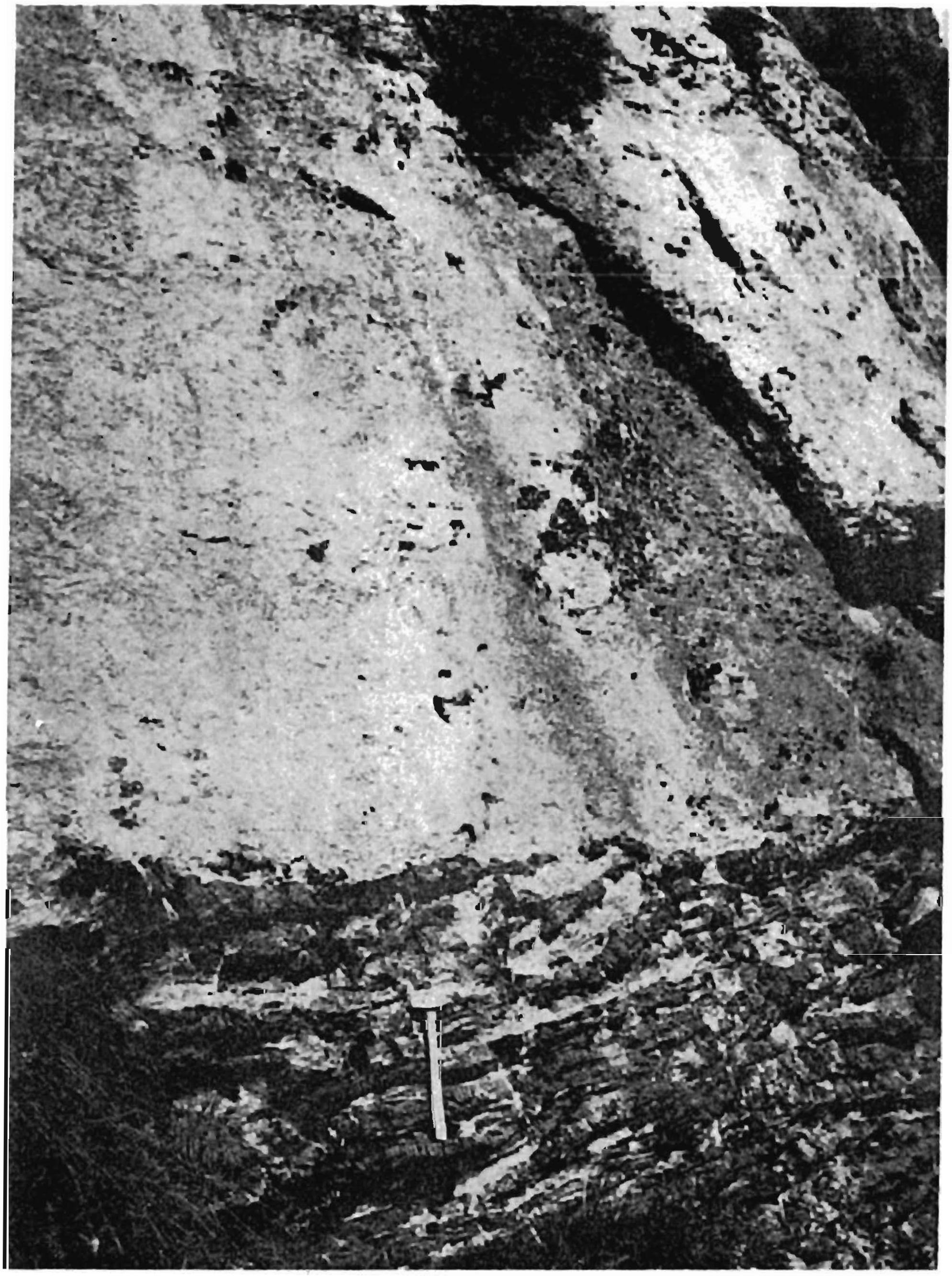
2

The Bielskie Tatra Mts

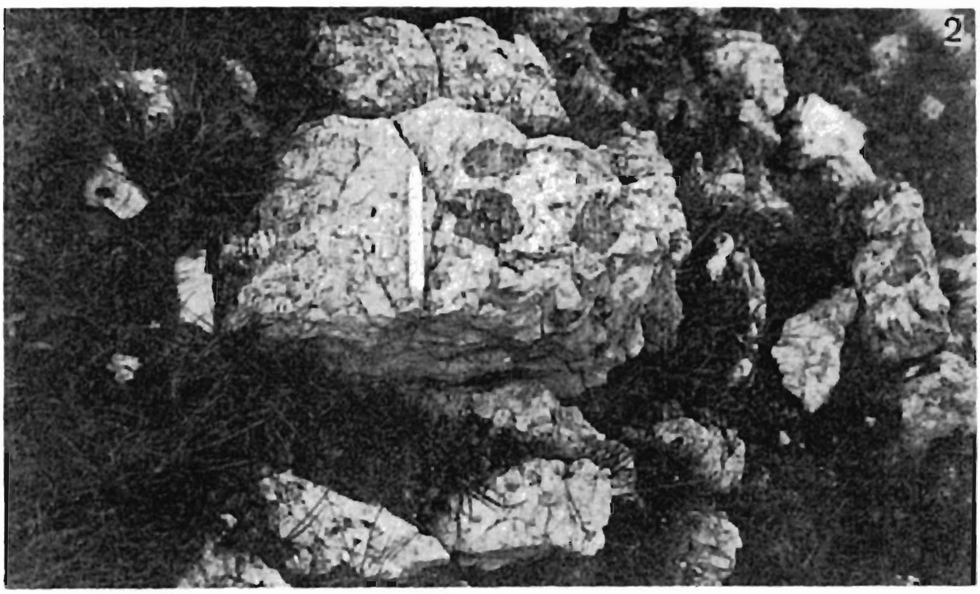
1 — Northwestern part, From right to left: Płaczliwa Skała, Hawrań, Nowy Wierch and Murań. Peaks (except Płaczliwa Skała) build of the Murań lmst. Jurassic rocks crop out in upper part of slope.

2 — Eastern part. Eastward view. Peaks of Jatki — Murań lmst. Jurassic sequence on slope.

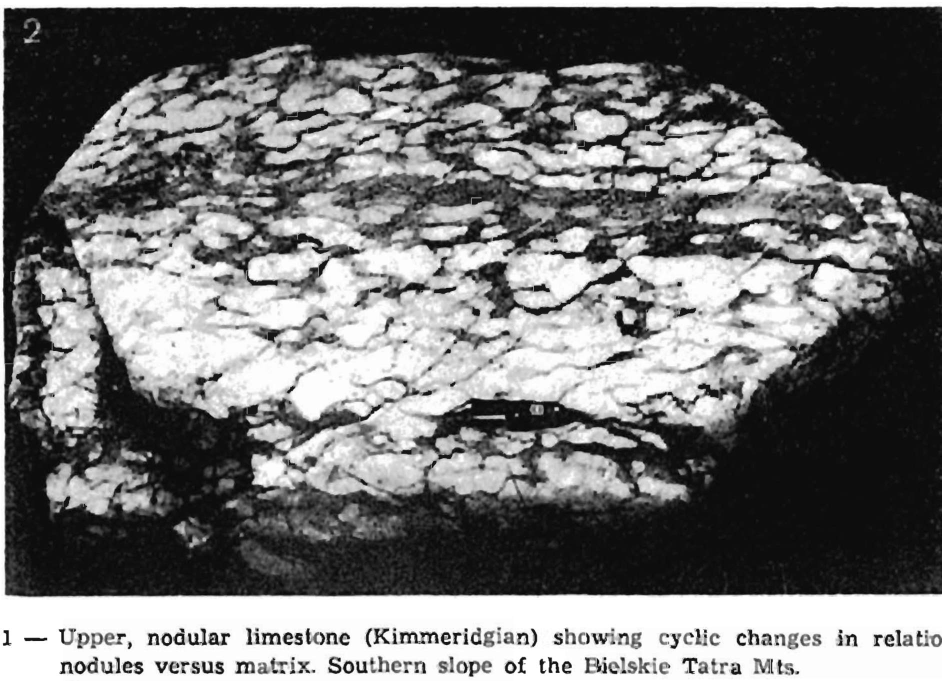
The Grześ hill (center) in the eastern side of the Chochołowska Valley, Western Tatra Mts. Site of Upper Tithonian ammonite fauna



Contact of the Upper Oxfordian red radiolarites (chert bands) with the upper nodular limestone (Kimmeridgian) above. Nowy Wierch in the Bielskie Tatra Mts



1 — Upper green radiolarites (Upper Oxfordian) at Grześ hill.
2 — Lower green radiolarites with dusky-red cherts (Bajocian-Bathonian). Gładkie Upłaziańskie, Western Tatra Mts.

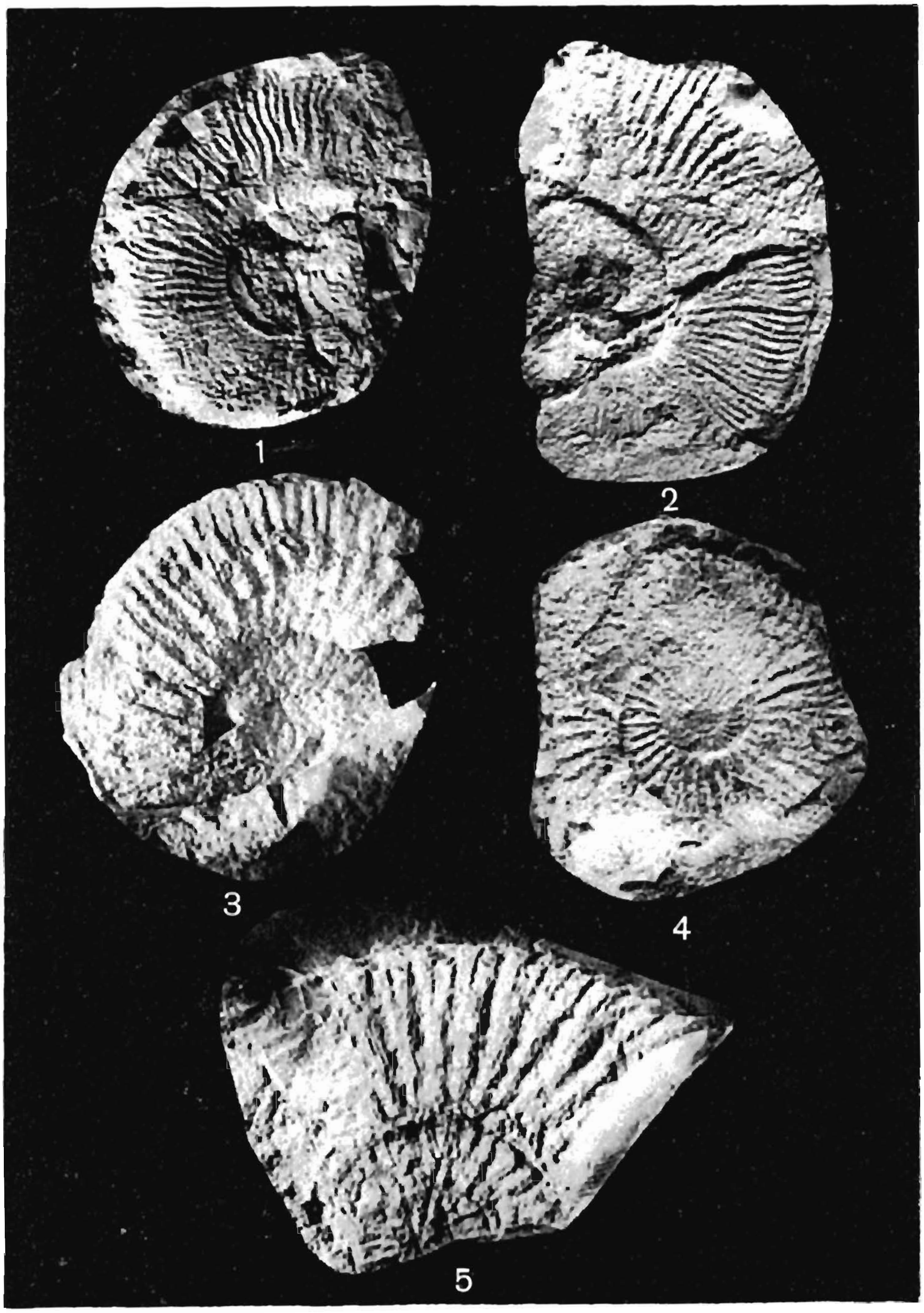


1 — Upper, nodular limestone (Kimmeridgian) showing cyclic changes in relation nodules versus matrix. Southern slope of the Bielskie Tatra Mts.

2 — Upper, nodular limestone (Kimmeridgian). Southern slope of the Murań Mt., Bielskie Tatra Mts.

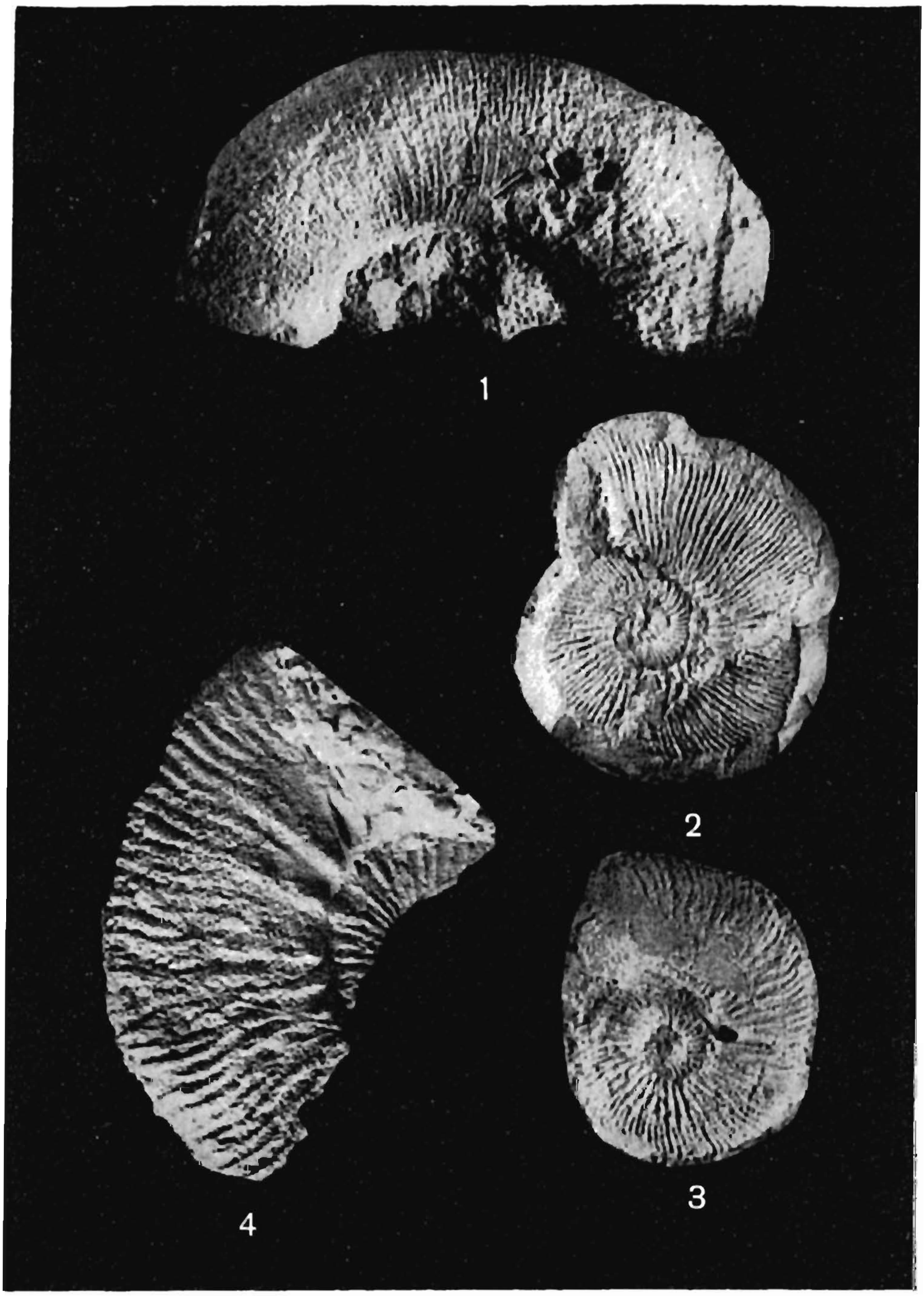
1 — Chert nodules in carbonate, clastic turbidites (Lower Cretaceous), Chochołowska Valley.

2 — Cherts in the Murań limestone. Jatki peak. Bielskie Tatra Mts.



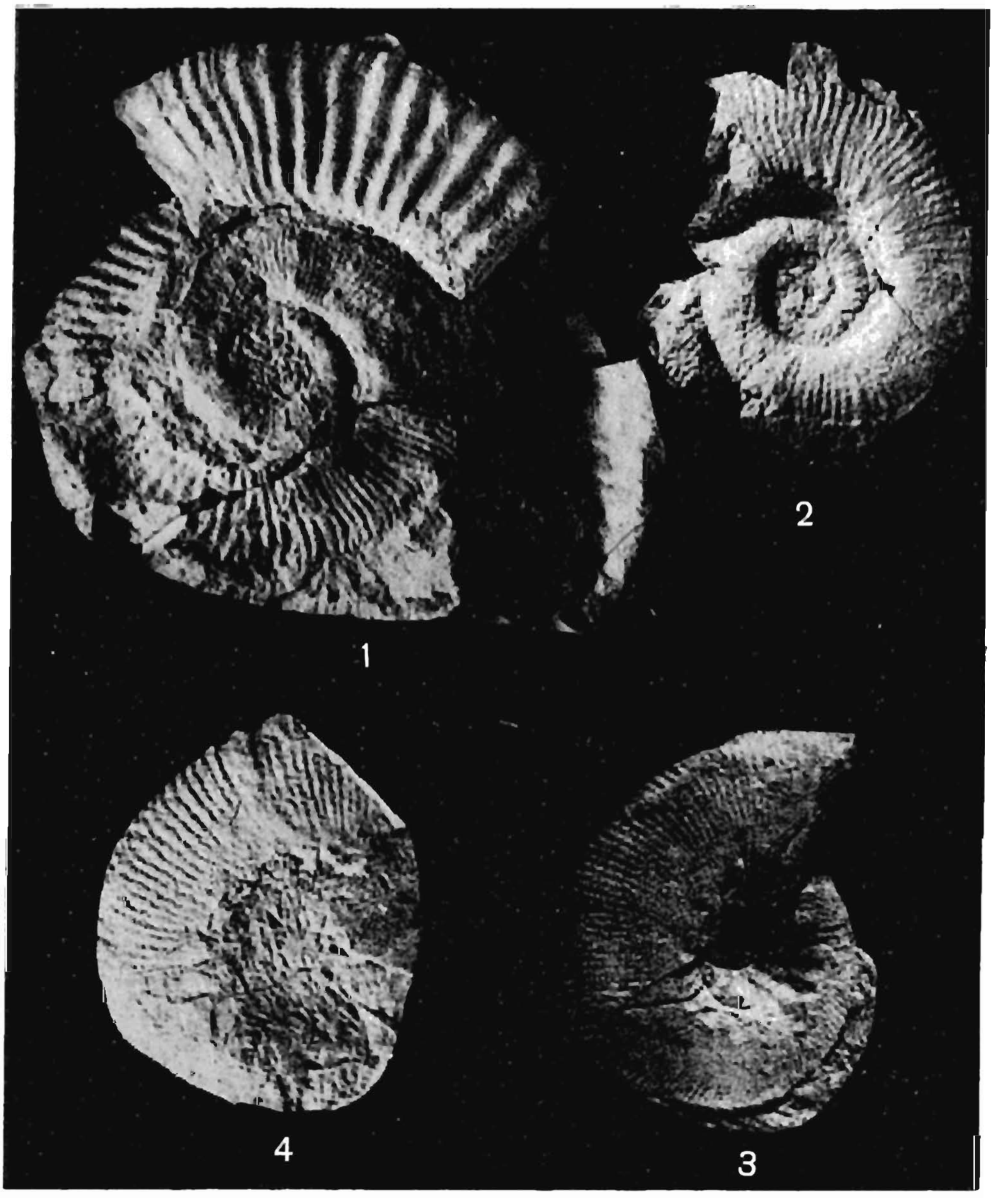
Upper Tithonian ammonite fauna at Grześ

1 — *Berriasella callisto* (d'Orb.); 2 — *Berriasella subcallisto* [Toucas (Gevrey)]; 3 — *Berriasella oppeli* (Kilian), × 1.5; 4 — *Berriasella* cf. *lorioli* (Zittel) × 1.5; 5 — *Berriasella* cf. *praecox* Schneid, × 1.5



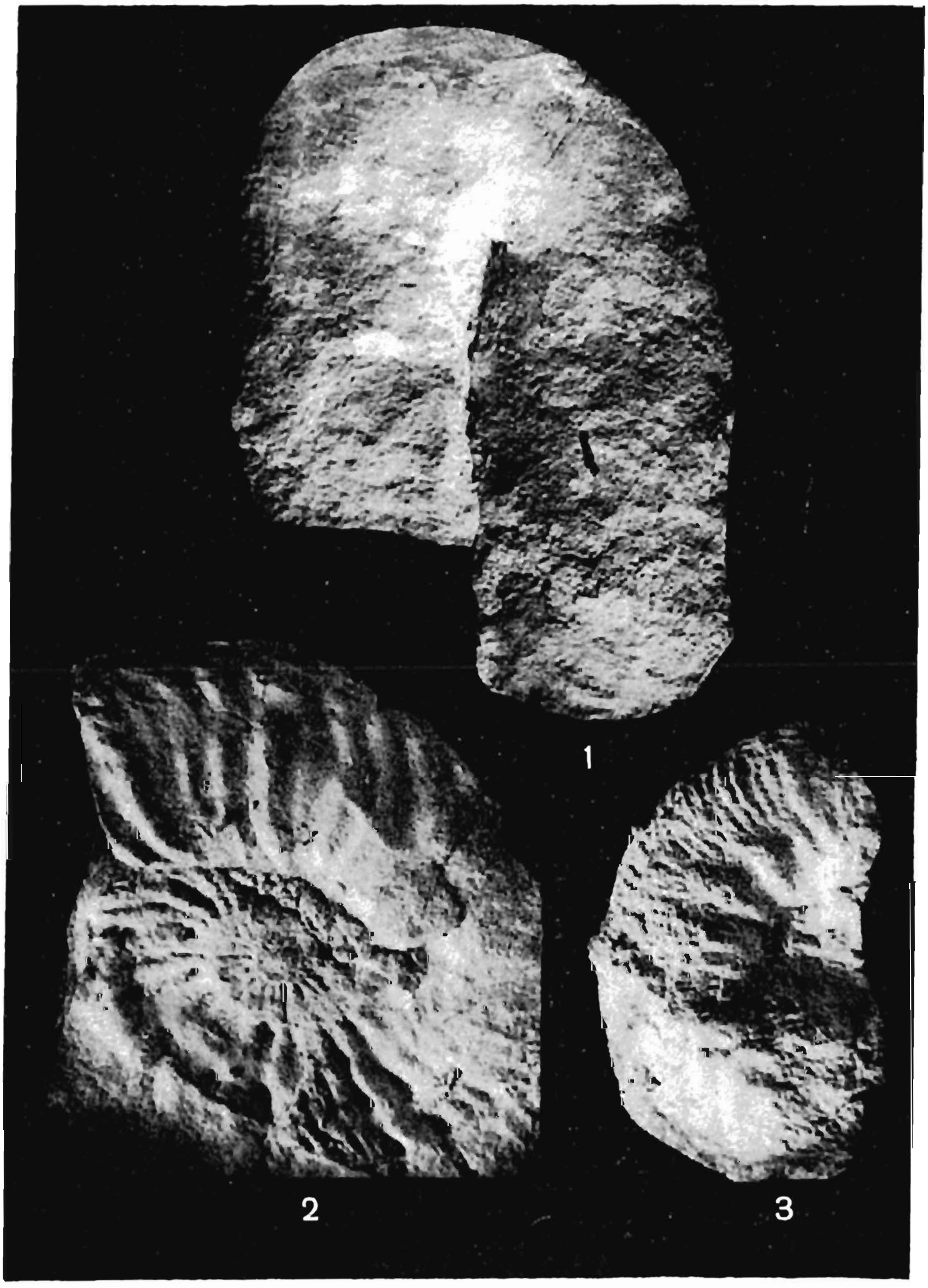
Upper Tithonian ammonite fauna at Grześ

1 — *Lytoceras* sp., nat. size; 2 — *Neocomites beneckei* (Jacob), nat. size; 3 — idem, × 1.5; 4 — *Protacanthodiscus chaperi* (Pictet), nat. size



Lower Cretaceous ammonite fauna

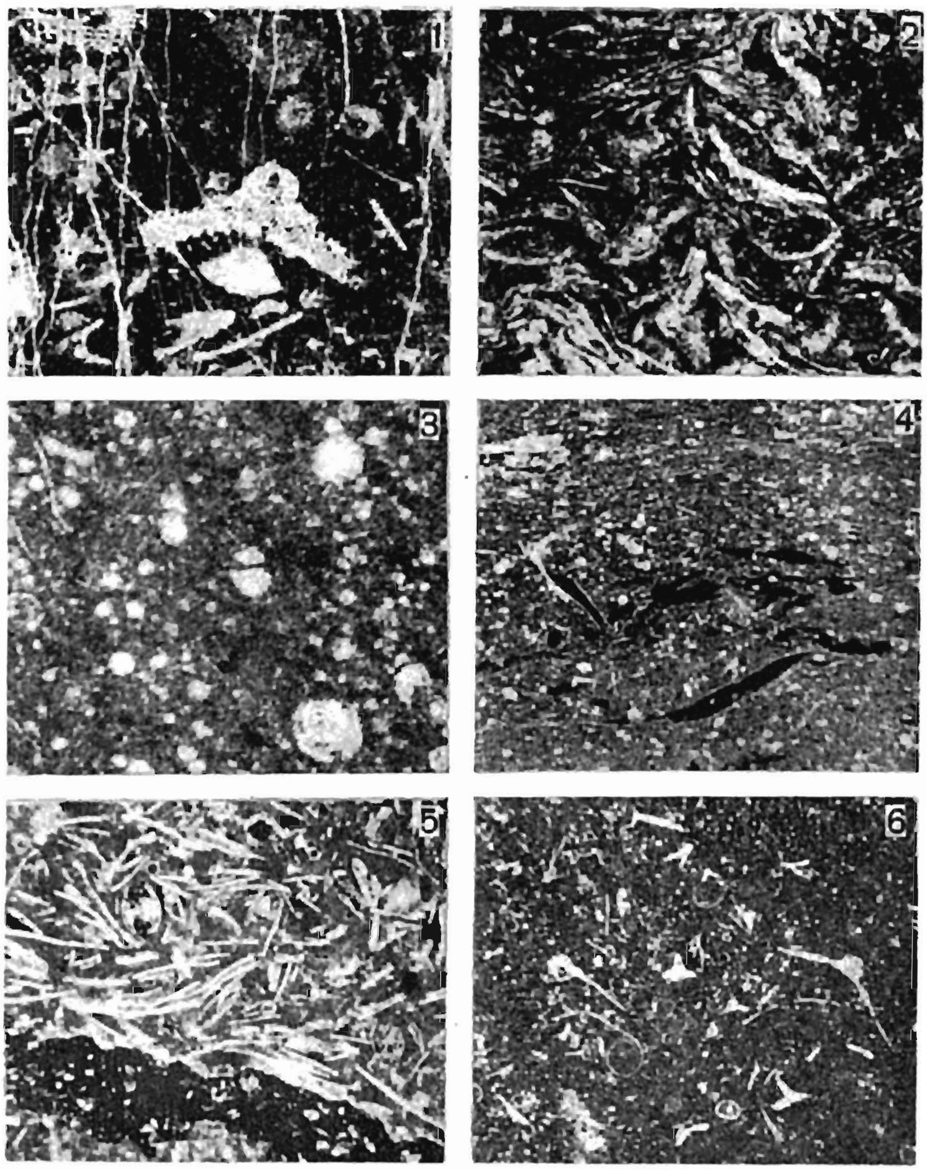
1 — *Crioceratites* aff. *sornayi* (Sarkar), nat. size; 2 — *Balearites* sp., nat. size; 3 — *Olcostephanus astierianus* (d'Orb.), nat. size; 4 — idem, juvenile form, × 1.5. All specimens come from Kościeliska Valley



Lower Cretaceous ammonite fauna

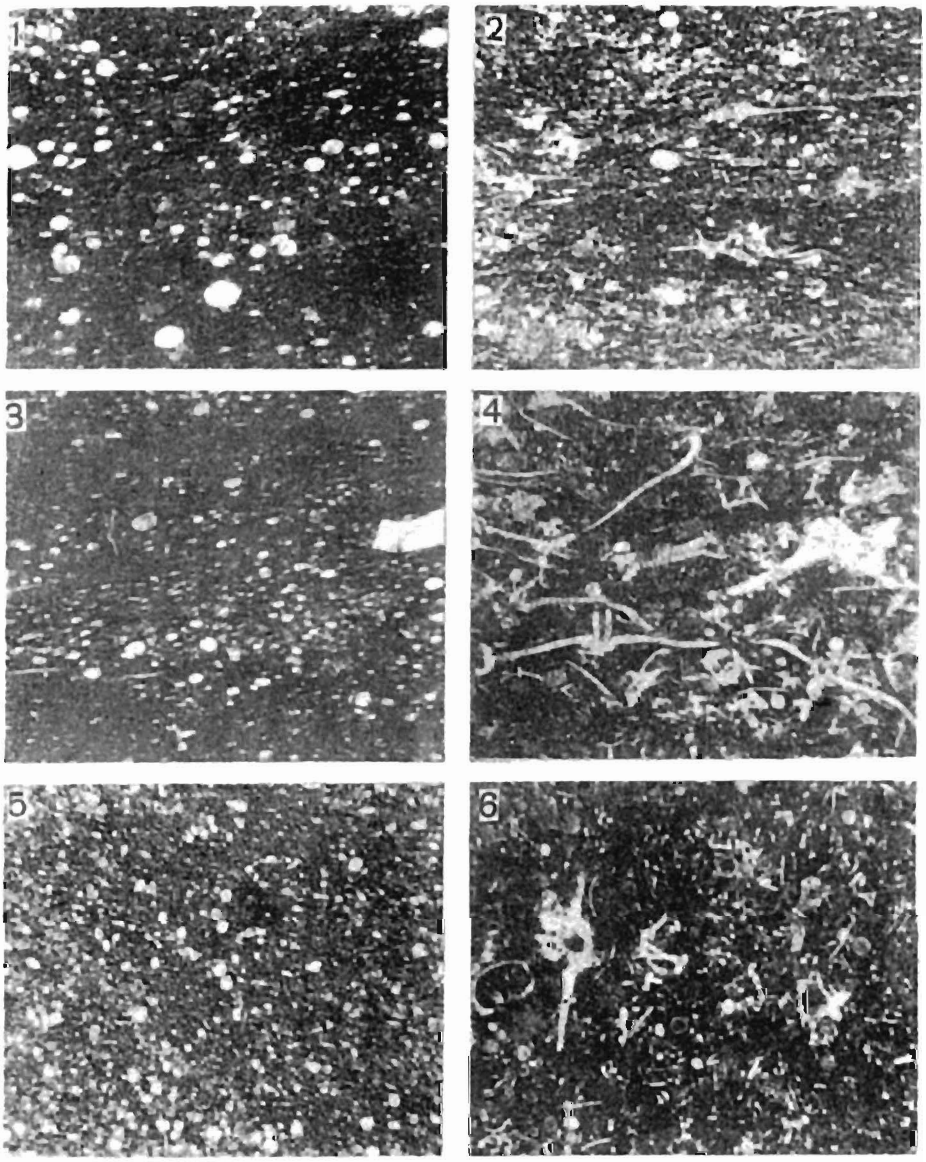
1 — *Ramulina* sp., nat. size; 2 — *Distoloceras* sp., × 1.5; 3 — *Spiticeras* sp., × 1.9. All specimens come from the Kościeliska Valley

Crioceratites emerici Lév. nat. size. Kościeliska Valley
All photographs of ammonites by M. Wąsak



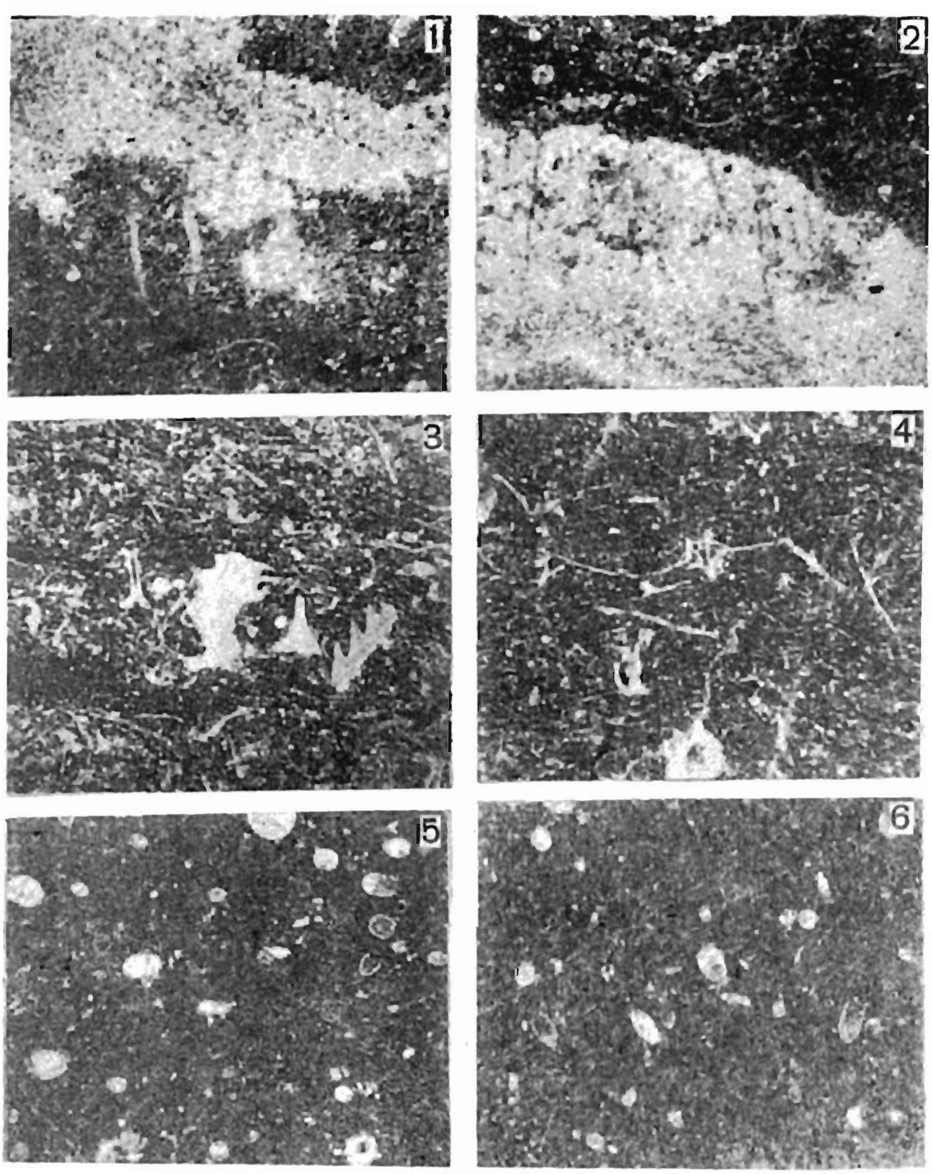
Sub-tatric Middle Jurassic microfacies

1 — crinoidal ossicles in micrite, Lower nodular limestone Toarcian at Holica, × 45; 2 — Bositra microfacies, Bajocian-Bathonian at Hawrań, × 20; 3 — lower, green radiolarite, Grześ, × 35; 4 — pyrite infillings in siliceous micrite, Filipka Valley, Bajocian-Bathonian; 5 — Bositra micrite with a section of an ostracod (upper, left), contact of nodule (micrite) with matrix (black) is visible, Toarcian, Holica, × 22; 6 — skeletal micrite with predominant *Saccocoma* ossicles, Middle nodular limestone, Callovian, Filipka Valley, × 18

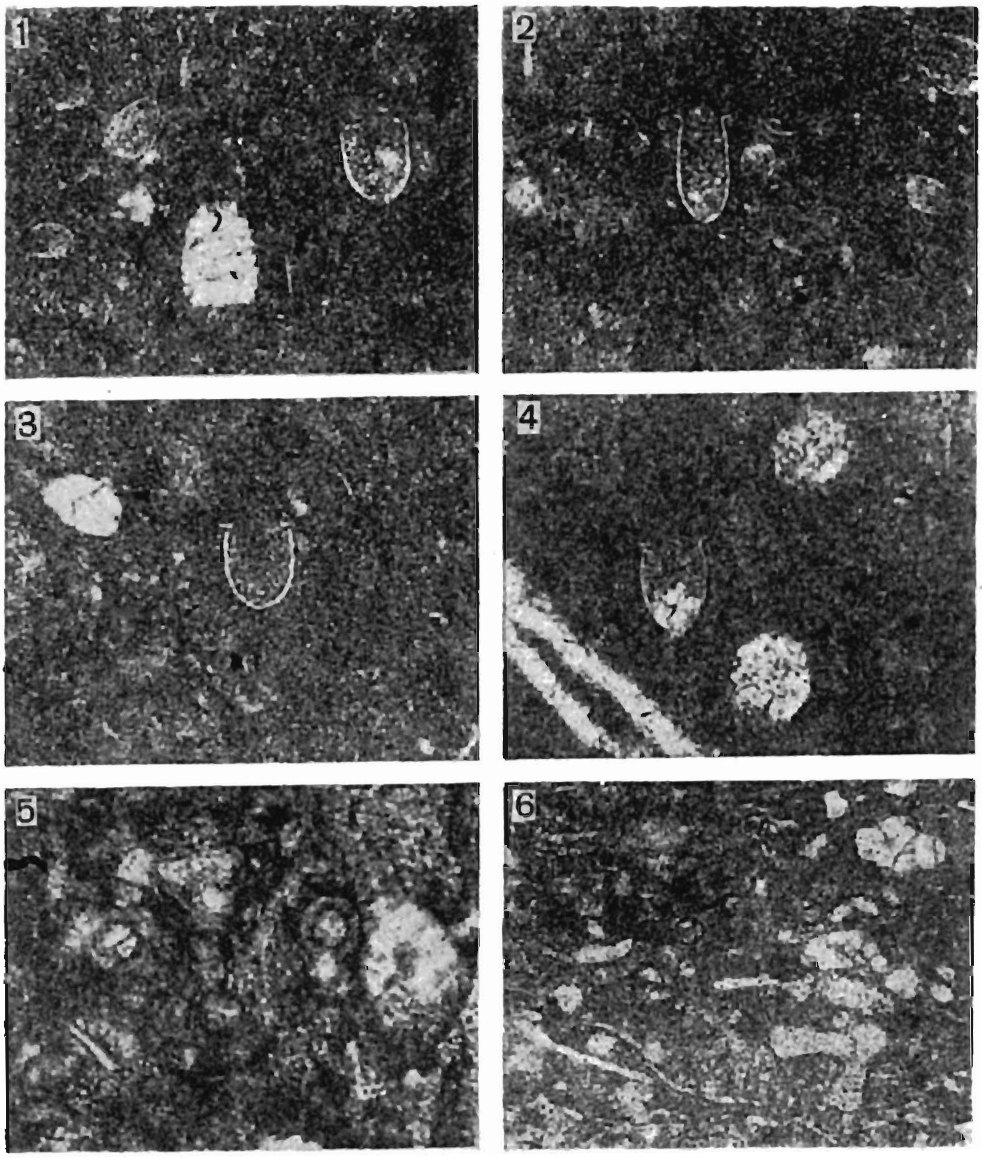


Oxfordian radiolarites and nodular limestones

1 — micrite with radiolarian molds infilled with calcite, lower red radiolarite, Lower Oxfordian, Gładkie Upłaziańskie, × 20; 2 — skeletal siliceous micrite, radiolarian molds and *Saccocoma* ossicles with other skeletal debris, lower red radiolarite, Lower Oxfordian, Lejowa Valley, × 20; 3 — radiolarian micrite, upper green radiolarite, lower part of the Upper Oxfordian, Grześ hill, × 20; 4 — Saccocoma biomicrite, upper green radiolarite, lower part of the Upper Oxfordian, Lejowa Valley, × 27.5; 5 — siliceous micrite with radiolarian molds infilled with calcite and (rarely) with chalcedone, upper red radiolarite, Upper Oxfordian, Murań Mt., × 17; 6 — Saccocoma micrite, nodular limestone, Oxfordian, Manin, Western Slovakia, × 20

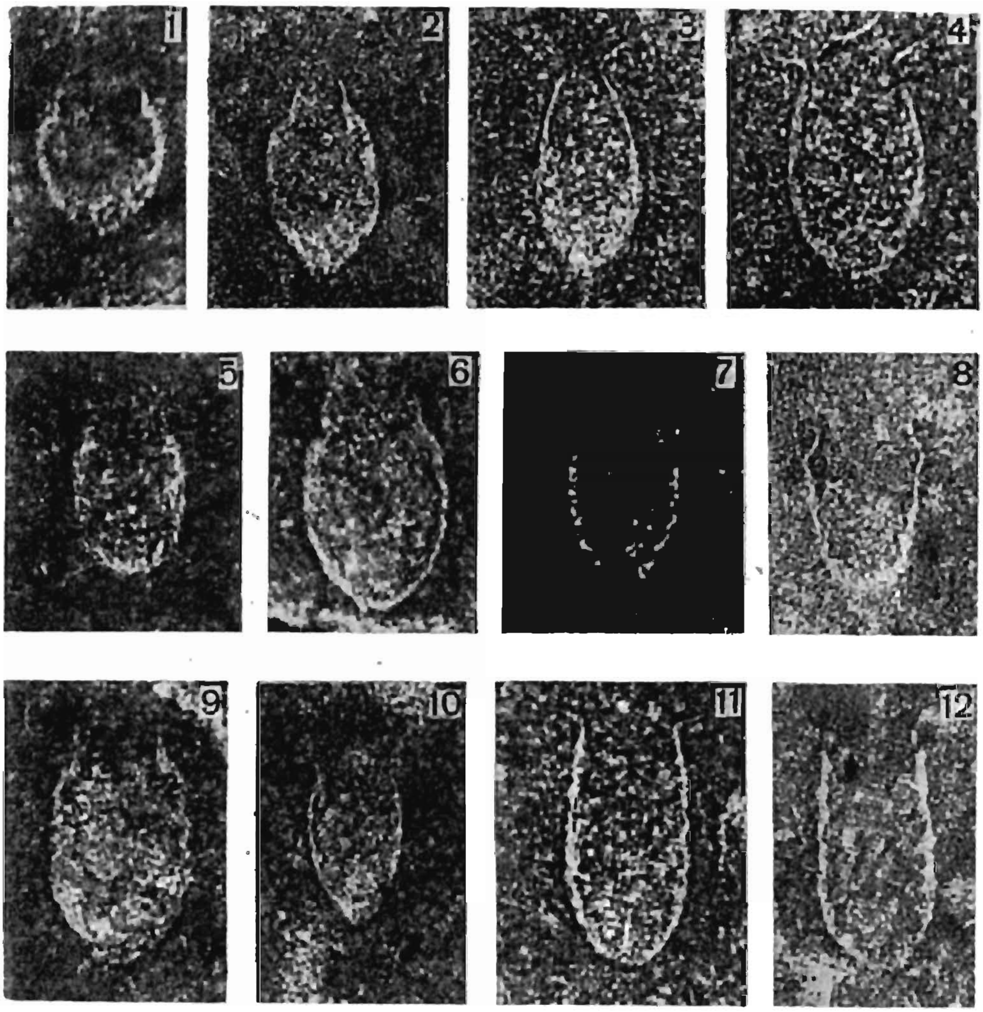


1 — opaline silica (chert) in micrite, upper red radiolarite, Lejowa Valley, Upper Oxfordian, × 20; 2 — contact of a siliceous nodule (chert) with micrite, ibidem, × 20; 3 — skeletal micrite with predominant *Saccocoma*, upper nodular limestone, Kimmeridgian, Grześ hill, × 20; 4 — *Saccocoma* ossicles in micrite, upper nodular limestone, Kimmeridgian, Sucha Valley, × 18; 5 — sub-tatric Biancone, Berriasian, Gęsia Szyja, × 53; 6 — sub-tatric Biancone, Tintinnidae and radiolarian molds, Berriasian, Chochołowska Valley, Huciska Alp, × 53



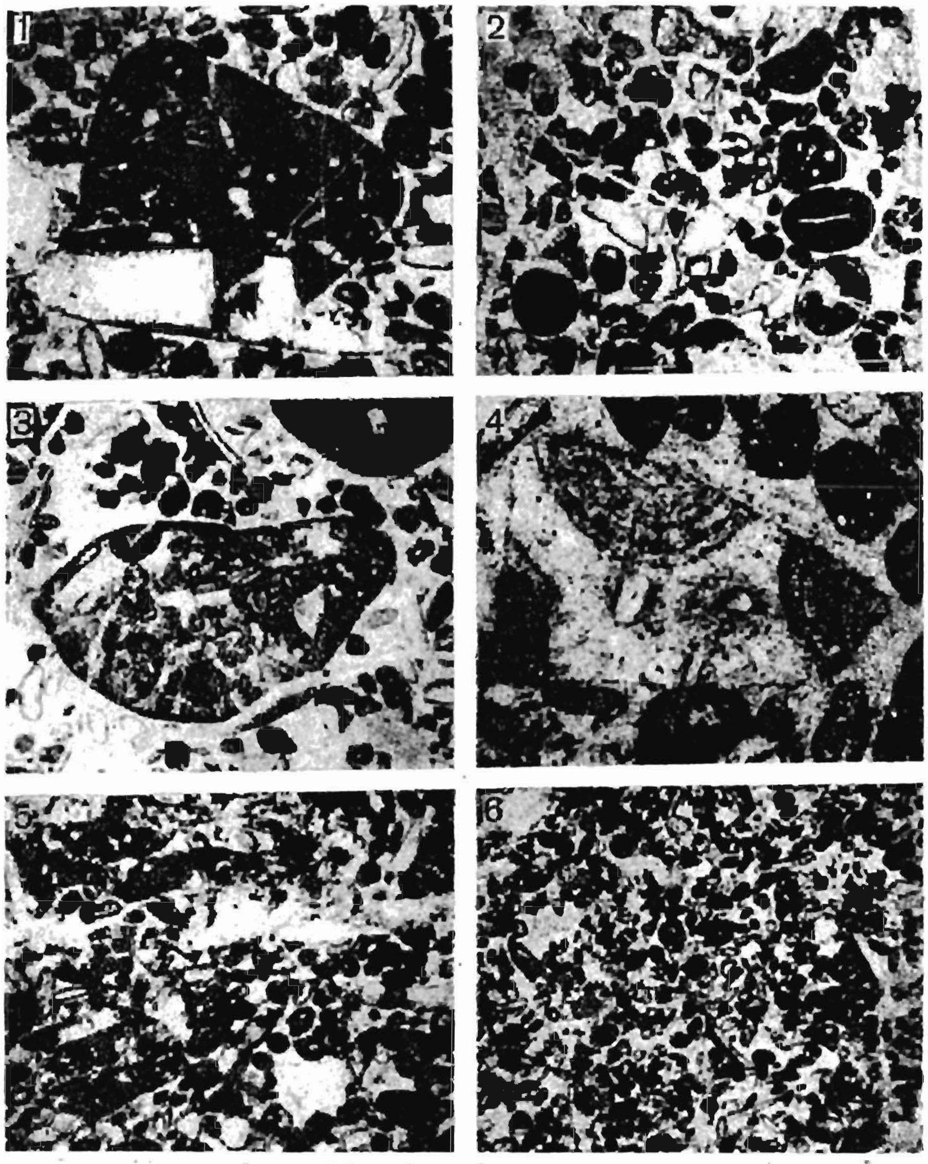
Tithonian-Berriasian microfossils

1 — *Calpionellites darderi* (Colom), Berriasian, Huciska in the Chochołowska Valley, × 14; 2 — *Tintinnopsella longa* (Colom), ibidem, × 143; 3 — *Remaniella cadischiana* (Colom), Upper Berriasian, Chochłowska Valley, × 143; 4 — *Lorenziella* sp., Upper Tithonian at Grześ hill, Chochołowska Valley, × 143; 5 — *Parastomiosphaera malmica* (Borza), Lower-Middle Tithonian, Czerwona Skałka, × 200; 6 — *Colomisphaera pulla* (Borza) and *Saccocoma* ossicles, Middle Tithonian, Czerwona Skałka, × 153



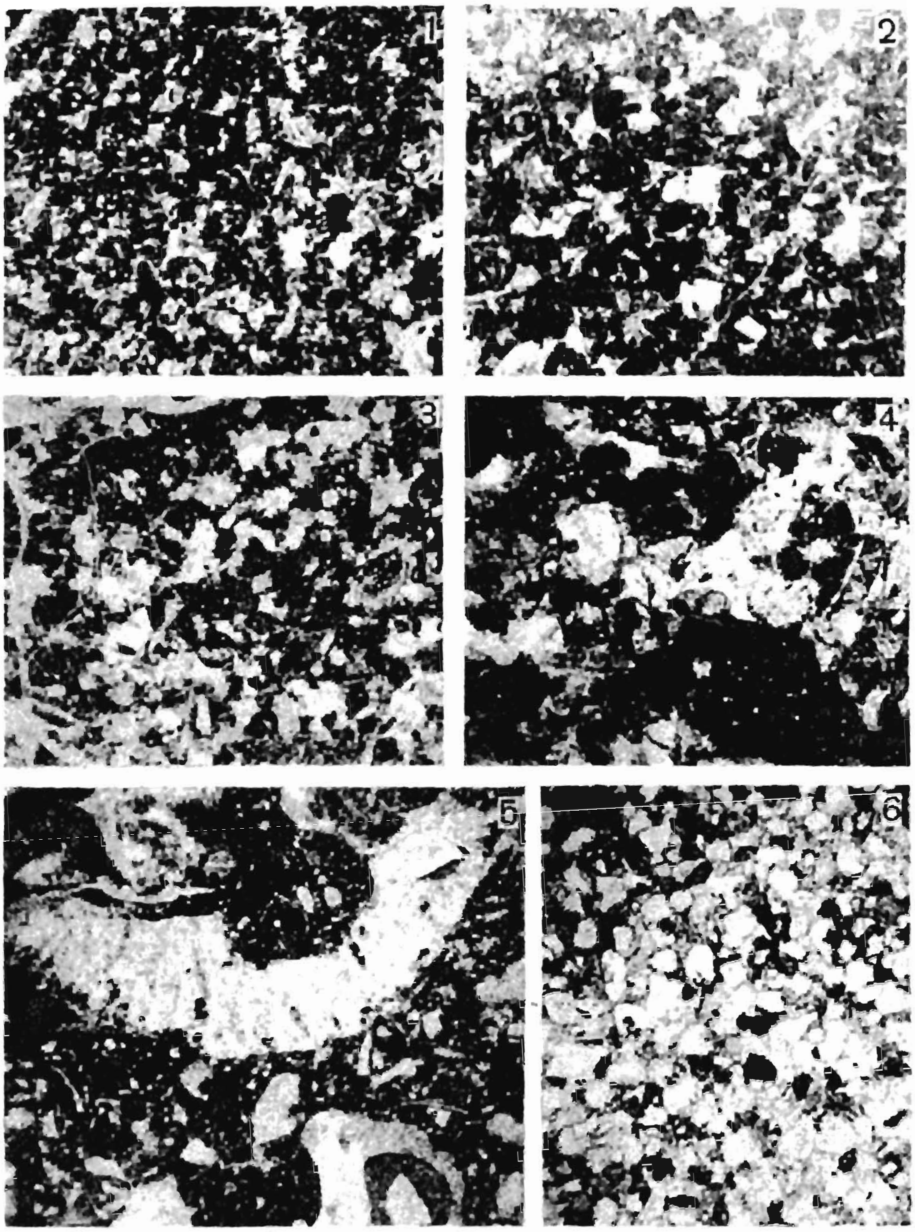
Sub-tatric Tintinnidae

1 — *Calpionella alpina* Lorenz, Upper Tithonian (chaperi-subzone), Grześ, × 380; 2 — *Calpionella elliptica* Cadisch, ibidem, × 330; 3 — *Tintinnopsella* sp., ibidem, × 325; 4 — *Tintinnopsella carpathica* Murg. & Filip, ibidem, × 330; 5–6 — *Calpionella elliptica* Cadisch, Upper Tithonian, Grześ, slightly below the horizon of Figs 1–4, Fig. 5 — × 280, Fig. 6 — × 340; 7 — *Calpionella elliptica* Cadisch, Middle Berriasian, Gęsia Szyja, × 294; 8 — *Crassicollaria massutiniana* (Colom), Upper Tithonian, Jatki Przednie, × 330; 9 — *Calpionella elliptica* Cadisch, Upper Berriasian, Hucīska in the Chochołowska Valley, × 356; 10 — *Crassicollaria parvula* Remane, ibidem, × 294; 11 — *Tintinnopsella longa* (Colom), Upper Berriasian, Hucīska in the Chochołowska Valley, × 340; 12 — *Calpionellopsis oblonga* (Cadisch), Upper Berriasian, ibidem, × 385



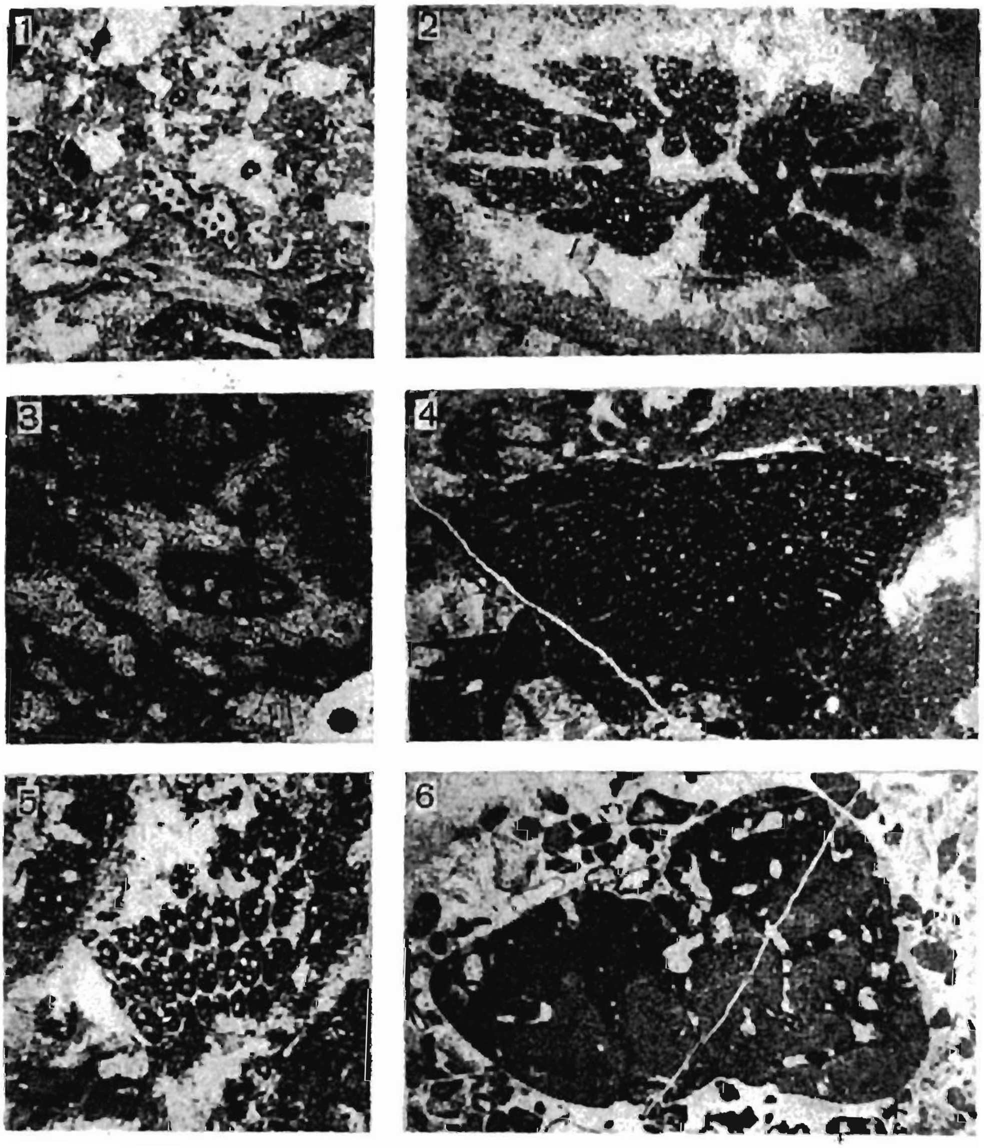
Types of Murań limestones and other turbidites

1 — extraclast in lithobiocalcisiltite, Jatki Zadnie, × 23; 2 — oolites and other extraclasts in sparry calcite, Murań Mt., × 19; 3 — aggregate with oolites, ibidem, × 19; 4 — extraclast of oolitic limestone, Jatki Zadnie, × 17; 5 — typical lithobiocalcisiltite, Fajksowa, × 19; 6 — lithobiocalcisiltite, Fačkov, Mala Fatra Mts, Western Slovakia, Lower Cretaceous, × 20



Calcareous turbidites of the Tatra Mts and Klippen Belt

1 — lithobiocalcisiltite, Lower Cretaceous, Huciska in the Chocholowska Valley, about × 37; 2 — Murań limestone at Łężny Potok, Polish Eastern Tatra Mts, × 21; 3 — Calcareous turbidite, Lower Cretaceous, Haligovce Klippe, Pieniny Klippen Belt, × 20; 4 — lithobiocalcarenite with fragments of orbitolinas, Lower Cretaceous, Niżna, Orava, Klippen Belt, × 20; 5 — a fragment of sclerosponge? in lithobiocalcisiltite, Murań Mt. in the Bielskie Tatra Mts, × 22; 6 — turbidite sandstone, Lower Cretaceous, Kryta, a tributary to the Chocholowska Valley, × 25



Urgonian-derived fossils in the Murań limestone

1 — a section of Dasyclad alga, top marlstones at Murań Mt., × 20; 2 — *Stylosmilia* sp., in olistolith at Murań Mt., × 18; 3 — oblique section of *Pianella* sp., olistolith in marlstone at Murań Mt., × 20; 4 — *Orbitolina lenticularis* (Blumenbach), Murań Mt., Lower Aptian, × 22; 5 — a section of bryozoan? with nestling algae, Murań Mt., × 19; 6 — extraclast with algae (Solenoporaceae?), Murań Mt., × 19