OUTLINES OF THE GEOLOGY OF THE PIENINY KLIPPEN BELT OF POLAND

by *Krzysztof Birkenmajer*

The Pieniny Klippen Belt forms part of a geological unit stretching at the boundary of Inner and Outer Carpathians for not less than 550 km (from Vienna to Transcarpathian Ukraine — cf. Andrusov 1938 etc.) and, probably, even for more than 600 km (cf. Świdziński 1962). Though so long, the Klippen Belt is extremely narrow; its width rarely exceeds several kilometres and often is reduced to a few hundred metres.

The geological history of the Pieniny Klippen Belt during the Trias, Jurassic and Lower Cretaceous is clearly related to that of the Inner Carpathians. Starting with the Lower Cretaceous we can see more and more connections with the geosyncline of the Outer Carpathians, which are visible best in the Upper Cretaceous and Palaeogene deposits.

The main structural elements of the Pieniny Klippen Belt of Poland are the Klippen Series and their Upper Cretaceous and Palaeogene Mantle. These terms changed their meaning since they were introduced by M. Neumayr (1871) and V. Uhlig (1890), and still cannot be regarded definite.

The history of investigations of the Belt was presented in numerous papers (Andrusov 1938, 1945, 1959; Birkenmajer 1953 a, 1958 a, 1960 a, b, 1963 a, d; Sokołowski 1954 a; Świdziński 1962; Książkiewicz 1963 etc.). Of the last date are monographs by Birkenmajer (1958 a, 1960 a, 1963 a, b), Małkowski (1958) and Horwitz (1963, posthumous paper). However, the extremely complicated structure of the Belt presents so many difficulties in proper recognizing its structure, that many years will probably elapse before any synthesis will be considered unquestionable.

The main problems discussed at present in the Pieniny Klippen Belt of Poland are: the stratigraphy and palaeogeography of Mesozoic and Palaeogene deposits, the number and character of orogenic phases, and the relation of the Klippen Belt to the border flysch units. These problems were outlined in a paper by Birkenmajer (1963 b) presented to the VIth Congress of the Carpathian-Balkanian Association of Geologists, Poland 1963. One of the major problems discussed is the relation of the Magura Nappe to the Klippen Belt and the pre-Palaeogene stratigraphical column of this nappe.

The Klippen Series were deposited in a basin situated north of the Tatra zone, in the following order (from the N to the S): Czorsztyn Series, Czertezik Series, Niedzica Series, Branisko Series, Pieniny Series and Haligowce Series. The main differences in the composition of the series are stated within the late-Dogger and Malm deposits. The Czorsztyn Series was deposited in the most shallow northern zone, and could be regarded as formed on a shelf (and partly on its slope) which formed margin of a land stretching farther north. To the south this shelf was bordered by a geosynclinal trough, where the rest of the Klippen Series were formed, the Haligowce Series excluded. The Haligowce Series was formed in a more shallow zone bordering this trough to the south.

The stratigraphical succession and lithological columns of the Klippen Series are presented in Text-Fig. 1 and Tab. 1. For more detailed lithological-facial and faunal characteristics of the particular stratigraphic members the reader is referred to the cited paper by Birkenmajer (1963 b). It should be pointed out that according to the working hypothesis presented by the author during the XXXVIth Annual Meeting of the Geological Society of Poland, the Supraflysch Beds, the Liogryphaea Beds, and the major part of the Flysch Aalenian were excluded from the Branisko Series and included to the Magura Series. As refers to the Haligowce Series observations on the relation of the Lias to the Trias deposits and on the relative age of the latter expressed recently by Z. Kotański (1963) were taken into account.

In the present summary attention is paid to the stratigraphic column of the Magura Series and, especially, to its Mesozoic members[1]. The working hypothesis of the present author includes to this series the major part of the Flysch Aalenian, being its oldest member.

The thickness of the Flysch Aalenian is about 200 m. Its lowest part (about 10 m) consists of dark shales with thin intercalations of arenaceous graded crinoidal limestones and of sideritic limestones. The shales yielded the following fauna: *Cornaptychus*, group *A, lythensis* (Qu.) em. Trauth, var. aff. *sigmopleura* Trauth, *Cornaptychus*, group *A*? (determined by Dr. S. M. Gąsiorowski), *Posidonia alpina* (Gras), *Paalzowella* sp., *Citharina colliezi* (Terq.), *Vaginulina clavaeformis* Paalz., *V.* aff. *jurassica* (Gümb.), *Dentalina integra* (Kübl. et

[1] The stratigraphic sequence and lithological-facial and faunal characteristics of the Palaeogene deposits of the Magura Series of the area discussed are presented in the paper cited (Birkenmajer 1963 b).

STRATIGRAPHIC TABLE OF THE KLIPPEN SERIES, MAGURA SERIES, AND KLIPPEN MA
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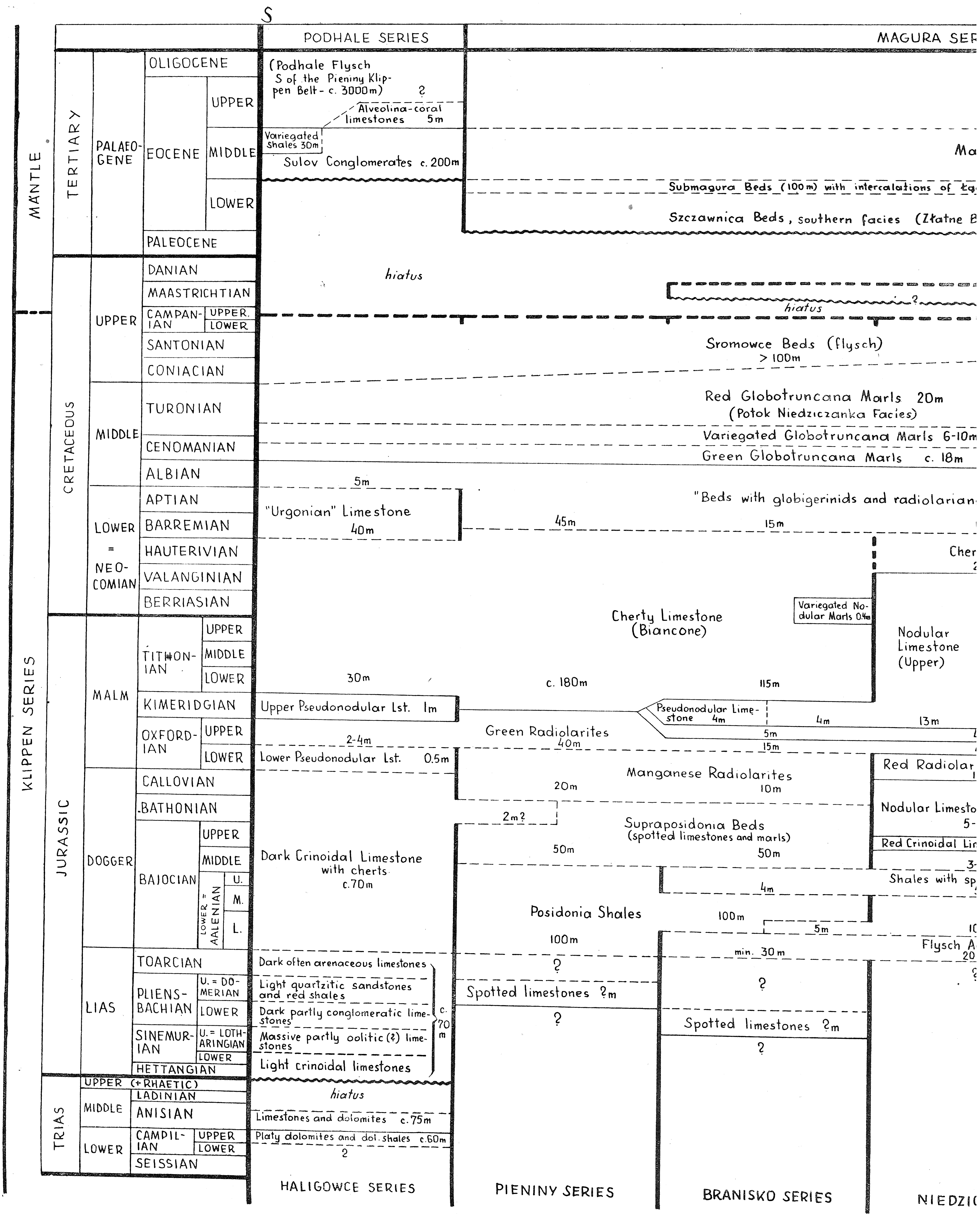
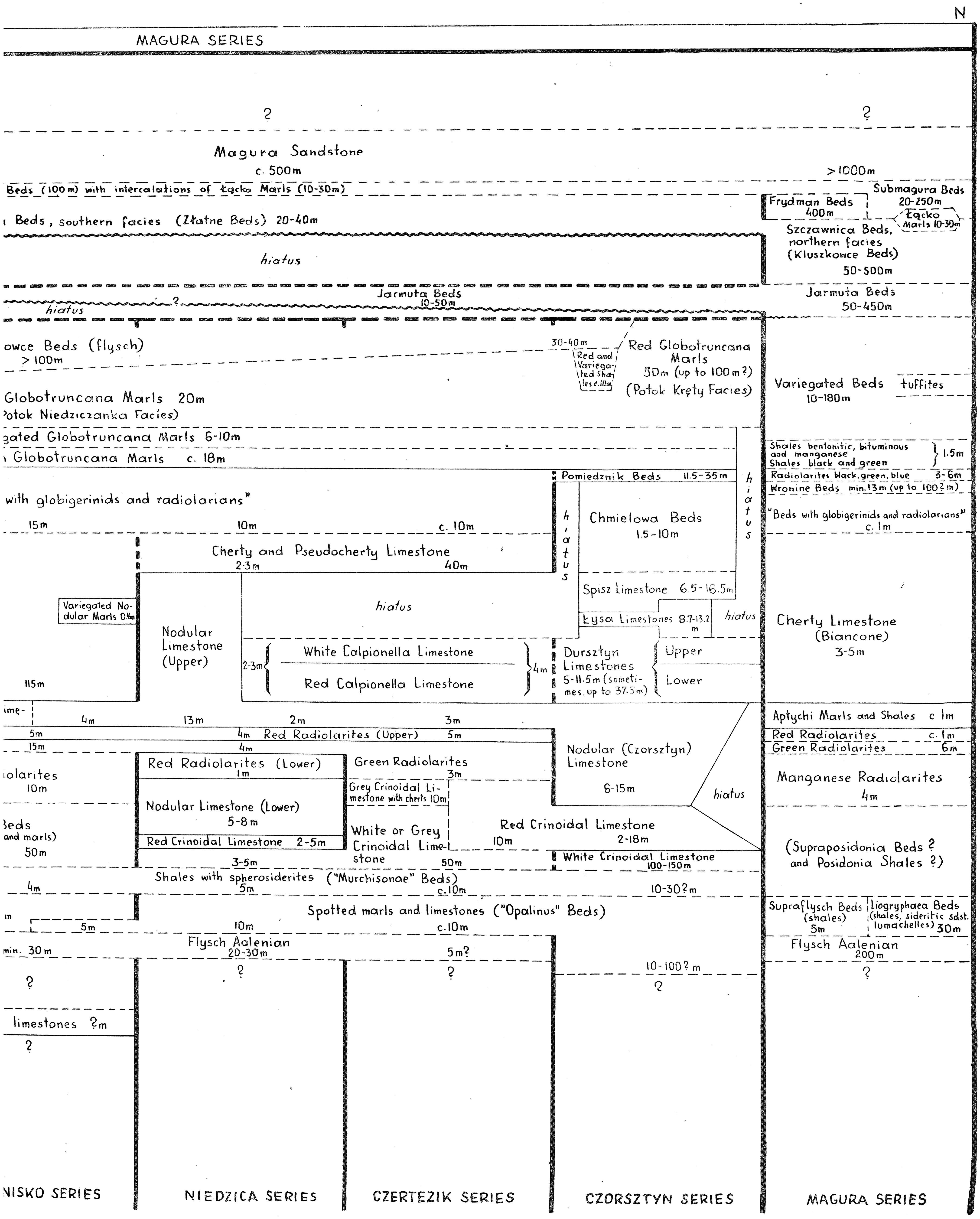


Table 1

ES, MAGURA SERIES, AND KLIPPEN MANTLE IN POLAND AND IN THE NEAREST VICINITY

(thick wavy lines denote major unconformities)



Zw.), *D. pseudocommunis* Franke, *Spirillina infima* (Strickl.), *Planularia pauperata* J. et P., *Lenticulina* ex gr. *varians* (Born.), *L. varians* f. *recta* Franke, *L.* ex gr. *münsteri* (Roem.) etc. (Birkenmajer, Pazdro 1963 a, b).

The middle part of the Flysch Aalenian (about 140 m thick) consists of grey and black, often strongly micaceous shales, intercalated with strongly micaceous fine grained sandstones and siltstones. The shales are either devoid of microfauna or contain a very poor assemblage of microfossils: *Vaginulina* aff. *jurassica* (Gümb.), *Reinholdella* cf. *media?* (Kapt.) etc. (Birkenmajer, Pazdro 1963 b).

The upper part of the Flysch Aalenian (about 50 m thick) consists mainly of sandstones with subordinate shale intercalations. The latter yielded *Lenticulina* ex gr. *münsteri* (Roem.), *L. toarcense* Payard etc. (*o. c.*). Thin seams of allochthonous coal occur in the middle and, especially, in the upper part of the Flysch Aalenian. They derive from reworked Upper Carboniferous coals, as indicated by the presence of microspores of that age (Birkenmajer, Turnau 1962).

As *Posidonia alpina* (Aalenian-Callovian) occurs already in the lowest part of the Flysch Aalenian, the Toarcian age of the member should rather be excluded; the Lower Aalenian age of the member in question seems to be most probable which is corroborated both by the microfauna and the *Aptychi*.

The Supraflysch Beds (5 m) occur locally immediately above the Flysch Aalenian. They show similarities both to the Flysch Aalenian and the Posidonia Shales and contain abundant *Posidonia alpina* (Gras) and microfossils, e.g. *Lenticulina toarcense* Payard, *Astacolus inaequistriatus* (Terq.), *Dentalina integra* (Kübl. et Zw.), *Vaginulina exarata* (Terq.), *Spirillina infima* (Strickl.) (Birkenmajer, Pazdro 1963 b). The Supraflysch Beds are included to the Middle Aalenian (cf. Birkenmajer 1963 b), as indicated by transitions to the underlying member, and by the general character of microfauna. The latter shows more relations to that of the lower part of the „Opalinus" Beds and the Flysch Aalenian, than to the microfauna of the „Murchisonae" Beds.

The Liogryphaea Beds (30 m thick) occur locally immediately upon the Flysch Aalenian. They consist of shales and sideritic sandstones and lumachelles with abundant *Liogryphaea* sp. The shales yielded but poor microfauna: *Ammobaculites agglutinans* (d'Orb.), *Geinitzina tenera pupoides* Nørvang, *Dentalina pseudocommunis* Franke, *Nodosaria nitidana* Franke, which is generally in agreement with the supposed Middle Aalenian age of the beds in question (cf. Birkenmajer 1963 b; Birkenmajer, Pazdro *o.c.*).

The problem of occurrence of the highest Aalenian, the Middle-Upper Bajocian and the Bathonian in the Magura Series discussed is not yet solved. The next, unquestionable member is represented by the Manganese Radiolarites (probably Callovian-Lower Oxfordian). It is, however, possible that these radiolarites are underlain by Supraposidonia Beds, as indicated by fragments of these beds in the weathering cover. The facial development of the Supraflysch Beds may also suggest the presence of the Posidonia Shales.

The Manganese Radiolarites (4 m thick) consist of black or grey radiolarites alternating with grey shales, with characteristic coating of black manganese oxides. As the member is devoid of determinable fauna, its possible age (?Callovian-Lower Oxfordian?) may only be suggested on analogy with the Branisko-, and the Pieniny Series.

Still higher in the stratigraphical column we may observe the Green Radiolarites (about 6 m thick), consisting of radiolarian cherts and calcareous radiolarites alternating with marly shales, green or greenish brown. On analogy with the Branisko Series the age of the member is tentatively determined as the lower part of the Upper Oxfordian.

The Green Radiolarites pass upwards into the Red Radiolarites (about 1 m thick) which consist of radiolarian cherts alternating with shales, both being either calcareous or devoid of carbonate content. On analogy with the Branisko and the Niedzica Series we may assume a higher Upper Oxfordian age of the member.

Still higher in the stratigraphic sequence there occur very thin beds represented by red or variegated Aptychi Marls and Shales (about 1 m thick) which yielded the following Kimeridgian fauna (lower part of the Aptychi Subhorizon $VI_{1\alpha}$ *sensu* Gąsiorowski 1962), kindly determined by Dr. S. M. Gąsiorowski: *Lamellaptychus*, group *A*, „sp. *1* ex gr. *a* Trauth", *L.*, group *A*, cf. *beyrichi* (Opp.) em. Trauth, *L.* sp. (forms without lateral depression), *Punctaptychus*, group *A*, cf. *punctatus* (Voltz), *Laevaptychus (Latuslaevaptychus) latus* (Park.), *L. (Hoplisuslaevaptychus) latohoplisus* Trauth. From the member in question derives also a rich fauna of *Aptychi* found in fragments of red or variegated marls occurring as secondary deposit in the Jarmuta Beds (Upper Senonian) at Jarmuta (NE slope): *Laevilamellaptychus* gr. et sp. ind., *Lamellaptychus*, group *C*, *theodosia* (Desh.), *L.*, group *A*, „sp. *1* ex gr. *a* Trauth", *L.*, group *A*, *beyrichi* (Opp.) em. Trauth *f. typ.* Trauth, *L.*, group *A*, *beyrichi* (Opp.) em. Trauth var. *fractocosta* Trauth, *L.*, group *A*, forms with discordant ribs, *Punctaptychus*, group *A*, *punctatus* (Voltz) *f. typ.* Trauth, *Laevaptychus (Latuslaevaptychus) longus* (Mey.), *L. (L.) latus* (Park.), *L. (L.) latissimus* Trauth, *L. (Meneghiniilaevaptychus) meneghinii* (Zigno), *L. (Hoplisuslaevaptychus) latohoplisus* Trauth, *L. (H.) hoplisus* (Spath), *L. (Obliquuslaevaptychus) obliquus* (Qu.), *L. (O.) latobliquus* Trauth (see Gąsiorowski 1962). From this member may also come loose *Aptychi* found as secondary deposit in the Jarmuta Beds (locality as above): *Lamellaptychus*, group *B*, „sp." *1* aff. *kachhensis* Trauth and *L.*, group *B*, „sp." *2* aff. *kachhensis* Trauth (V Aptychi Horizon, lower part of the Kimeridgian — see Gąsiorowski 1962).

The next member is represented by the Cherty Limestone, which is lithologically the same as that of the Branisko and Pieniny Series, but only 3—5 m thick. In the lower part it is light cream yellow and contains numerous (not yet determined) *Aptychi*. At the contact with the Kimeridgian thin plates revealed only the presence of *Stomiosphaera minutissima* (Colom), *Saccocoma* sp., *Globochaete alpina* Lomb., and calcified radiolarians. The tintinnids: *Calpionella alpina* Lor., *C.* „*elliptica*" Cad., *C. intermedia* Dur.-Del. (single specimens) and *Tintinnopsella carpathica* (Murg. et Filip.) — single specimens, appear a little higher in the limestone and are associated with *Stomiosphaera minutissima* (Colom) and *Globochaete alpina* Lomb. Still higher the limestone becomes light grey and contains black or bluish cherts. The thin plates revealed the presence of abundant nannoplanctonic organisms and calcified radiolarians and the lack of tintinnids.

Near Krempachy from the Cherty Limestone in question have been determined: *Lamellaptychus angulocostatus* (P e t.) cf. *f. typ.* T r a u t h, *L. angulocostatus* (P e t.) var. ind. (B i r k e n m a j e r, G ą s i o r o w s k i 1959). To this member may also be related fossils found as secondary deposit in the Jarmuta Beds (the same locality): *Lamellaptychus,* group *D* (d_β), *angulocostatus* (P e t.) var. *atlantica* (H e n n.), *L.*, group *D* (d_γ), *angulocostatus* (P e t.) *f. typ.* T r a u t h, *Pseudobelus bipartitus* B l. (B i r k e n m a j e r, G ą s i o r o w s k i 1959; G ą s i o r o w s k i 1962). The above *Aptychi* indicate the Aptychi Horizon VIII (above the Subhorizon $VIII_{1\alpha}$) i.e. higher Valanginian-Lower Barremian.

In the uppermost part of the Cherty Limestone there appear thin intercalations of black shale, and the member passes upwards into the „B e d s w i t h G l o b i g e r i n i d s a n d R a d i o l a r i a n s" (about 1 m thick). The latter consist of dark grey or nearly black, often spotted limestones and similarly coloured shales. Silification and characteristic orange weathering colouration are frequent. On analogy with the Klippen Series we may assume an Upper Barremian and, eventually, Aptian age of the beds.

The beds in question pass upwards into the W r o n i n e B e d s, which in the lower part (about 1.5 m thick) consist of hard, slightly siliceous shales, black, green and, sometimes, variegated, intercalated with limestones coated with manganese oxides. Dr. S. W. A l e x a n d r o w i c z and Dr. S. G e r o c h kindly determined the following microfauna: *Gyroidina infracretacea* (M o r o z.) — R, *Pseudovalvulineria* sp. — F, and *Radiolaria* gen. — C. Higher up the beds are represented by argillaceous or marly shales black, greenish (sometimes variegated), often spotted, with concretions of pyrite, siderite and ferrugineous dolomite. Sometimes they are coated by copper-bearing (malachite) and manganese oxides. They yielded an assemblage of microfossils of little stratigraphical value (often with radiolarians): *Haplostiche* sp., *Plectorecurvoides* sp., *Haplophragmoides latidorsatum* (B o r n.), *Gaudryina richteri* G r a b e r t, *Dorothia* cf. *filiformis* (B e r t h.), *Lenticulina wisselmanni* B e t t., *Planularia complanata* (R e u s s), *Gavelinella* cf. *barremiana* B e t t., *Gyroidina* cf. *infracretacea* (M o r o z.), *Hedbergella trocoidea* (G a n d.), *Rotalipora* sp. etc. (B i r k e n m a j e r, P a z d r o 1963 a).

Most of the above foraminifers may occur within the Barremian-Albian time span, but it seems probable that the Wronine Beds represent mostly the lower part of the Albian. The thickness of the member is minimum 13 m, but it seems probable that, sometimes, it may reach much higher values (up to 100 m ?) [1].

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[1] It should be noted that W. S i k o r a (1962) suggested a Cenomanian (resp. Albian?-Cenomanian — B l a i c h e r *et al.* 1963) age of at least a part of the Flysch Aalenian near Jaworki, renamed by him the „Sztolnia Beds". However, it was not confirmed by new micropalaeontological investigations of the samples taken at the same locality by the present author and Dr. W. S i k o r a in the Autumn, 1963. Doc. Dr. O. P a z d r o found there microfossils which have much in common with the Lower Dogger microfaunas hitherto described from the Pieniny Klippen Belt of Poland. Middle Cretaceous microfossils have been found only when the samples were not cleaned enough before washing, thus indicating possible contamination of the samples taken previously by W. S i k o r a. This problem will be treated in detail separately.

The following member is represented by R a d i o l a r i t e s very similar to the Green Radiolarites of the Oxfordian. Near Szczawnica and Krempachy they are 3—6 m thick and consist of black, greenish brown or bluish radiolarian cherts, alternating with green or dark green argillaceous shales, usually devoid of calcium carbonate. A characteristic feature is the presence of abundant black coating with manganese oxides.

The microfaunal investigations of the radiolarites in question are forthcoming. It seems that the member corresponds to the Upper Albian radiolarites of the Lower Pomiedznik Beds i.e. that it is slightly older than facially analogous radiolarian cherts of the Outer Carpathians (cf. B i e d a *et al.* 1963).

Immediately upon the radiolarites there occurs a very characteristic horizon (up to 1.5 m thick) i.a. with manganese and radiolarian shales recognized by S i k o r a (o.c.) in the Potok Sztolnia creek. At Szczawnica Wyżna have been found alternating B l a c k a n d G r e e n S h a l e s (0.7 m thick). One of the samples taken from these shales revealed the presence of single specimens of *Planomalina buxtorfi* (G a n d.) and *Plectorecurvoides alternans* N o t h, the other one — single specimens of *?Biticinella breggiensis* (G a n d.) and *Haplophragmoides* cf. *chapmani* C r e s p i n (determinations by Dr. S. W. A l e x a n d r o w i c z and Dr. S. G e r o c h). Further investigations are necessary to show whether these shales represent the Upper Albian or the Lower Cenomanian.

In the lower course of the Potok Sztolnia creek the radiolarites are followed by grey greenish, green and grey shales (about 0.5 m thick); the grey shales yielded the following Upper Cenomanian microfauna (determined by Dr. S. W. A l e x a n d r o w i c z and Dr. S. G e r o c h): *Rotalipora cushmani* (M o r r o w), *R.* cf. *apenninica* (R e n z), *Praeglobotruncana stephani* (G a n d.), *P. stephani turbinata* (R e i c h e l) and *Thalmanninella reicheli* (M o r n o d). With the grey shales are associated black shales which contain *Praeglobotruncana stephani* (G a n d.) and *Pseudovalvulineria* cf. *kelleri* (M j a t l j u k).

In the Kręty Potok stream near Krempachy immediately above the radiolarites and below the green shales with radiolarians there occurs a band 10 cm thick with asphaltite and silicified wood. It seems that radiolarian shales described by W. S i k o r a (o.c.) from the upper course of the Potok Sztolnia creek (with *Plectorecurvoides alternans* N o t h, *Nodellum velascoense* C u s h., *Uvigerinammina jankói* M a j z., *Haplophragmoides* sp. and radiolarians) are slightly younger. Still higher there occur shales resembling menilite shales, with yellow jarosite coatings, as well as benthonitic and bituminous shales, described by S i k o r a (o.c.)[1] from the Potok Sztolnia creek. At Szczawnica (Mt. Hulina, S slope) these beds are 0.5 m thick and contain characteristic laminated paper shales (black and green laminae alternating) with the following microfauna indicating the lower part of the Upper Cenomanian (determinations by Dr. S. W. A l e x a n d r o w i c z and Dr. S. G e r o c h): *Rotalipora apenninica* (R e n z) — S, *R. cushmani* (M o r r o w) — A, *Praeglobotruncana stephani* (G a n d.) — F, *P. stephani turbinata* (R e i c h e l) — R, *Thalmanninella reicheli* (M o r n o d) — F, *Planomalina buxtorfi* (G a n d.) — F and *Gyroidina infracretacea* (M o r o z.) — R.

At the base of the V a r i e g a t e d B e d s there occur green shales and marls (about 20 cm thick), often resembling Globotruncana Marls

[1] He reported also the presence of thin pyritiferous sandstone intercalations.

of the Klippen Series proper. At Szczawnica (Mt. Hulina, S slope) they contain a characteristic assemblage of microfossils (Cenomanian-Lower Turonian) rich in arenaceous benthonic foraminifers (determinations by Dr. S. W. A l e x a n d r o w i c z and Dr. S. G e r o c h): *Gyroidina* sp. aff. *infracretacea* (M o r o z.) — R, *Gavelinopsis* ex gr. *eriksdalensis* (B r o t z.) — R, *Clavulinoides gaultinus* (M o r o z.) — F, *Marssonella oxycona* (R e u s s) — F, *Gyroidinoides nitidus* (R e u s s) — R and *Plectorecurvoides alternans* N o t h — S.

The lithological and microfaunal characteristics of the Variegated Beds (10 m thick in the southern zone and up to 180 m thick in the northern zone) have been presented in a previous paper (B i r k e n m a j e r 1963 b). The Variegated Beds represent the time span from Cenomanian to Campanian inclusively.

There is either transition (in the northern zone) or lack of transition (in the southern zone) between the Variegated Beds and the Jarmuta Beds (Upper Senonian). The Jarmuta Beds (sandstones and conglomerates, subordinately shales) are up to 450 m thick in the northern zone and 50—10 m thick in the southern zone. In the southern zone they contain a considerable amount of sedimentary breccias built up mostly of fragments of Jurassic and Cretaceous rocks. The latter are fragments of the Czorsztyn Series (partly also the Branisko Series proper), and mostly of the Jurassic-Neocomian members of the Magura Series according to the working hypothesis outlined here. The present author assumes that at the time of formation of the Jarmuta Beds, the Klippen Series had been subjected to uplift, folding and denudation. In the zone adjacent to the Klippen Series horst thus formed, the Magura Series was also involved in the tectonic movements. This was the cause of the unconformity between the Jarmuta Beds and the Variegated Beds, as well as of the presence of fragments of the Jurassic-Neocomian rocks of the Magura Series as secondary deposit in the Jarmuta Beds.

Afterwards, the sea expanded farther south and the Jarmuta Beds were deposited unconformably upon folded Klippen Series. Outside the zone of transgression (farther to the south) Upper Senonian supralittoral conglomerates were formed. The orogenic movements continued during the formation of the Jarmuta Beds, the latter being partly folded already before the Palaeogene.

For the faunal characteristics of the Jarmuta Beds the reader is referred to the cited paper by the present author (1963 b). In this paper are also given the lists of fauna and facial-sedimentological characteristics of the Palaeogene sequence of the Pieniny Klippen Belt of Poland and its nearest vicinity. It should be mentioned that after the Laramide folding the Pieniny Klippen Belt of Poland was totally incorporated in the Magura Series sedimentary basin.

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