Österreichische
Geologische Gesellschaft

c/o Geologische Bundesanstalt Rasumofskygasse 23, A-1031 Wien

Exkursionsführer

6

Guide to the Geological Excursion

Cracow - Zakopane (Polish Carpathians)

Österreichische Geologische Gesellschaft

31. Mai - 3. Juni 1988

G U I D E

to Excursion
of
ÖSTERREICHISCHE
GEOLOGISCHE GESELLSCHAFT

compiled by A.Slaczka and M.A.Gasinski
Jagiellonian University

June 1988
Kraków

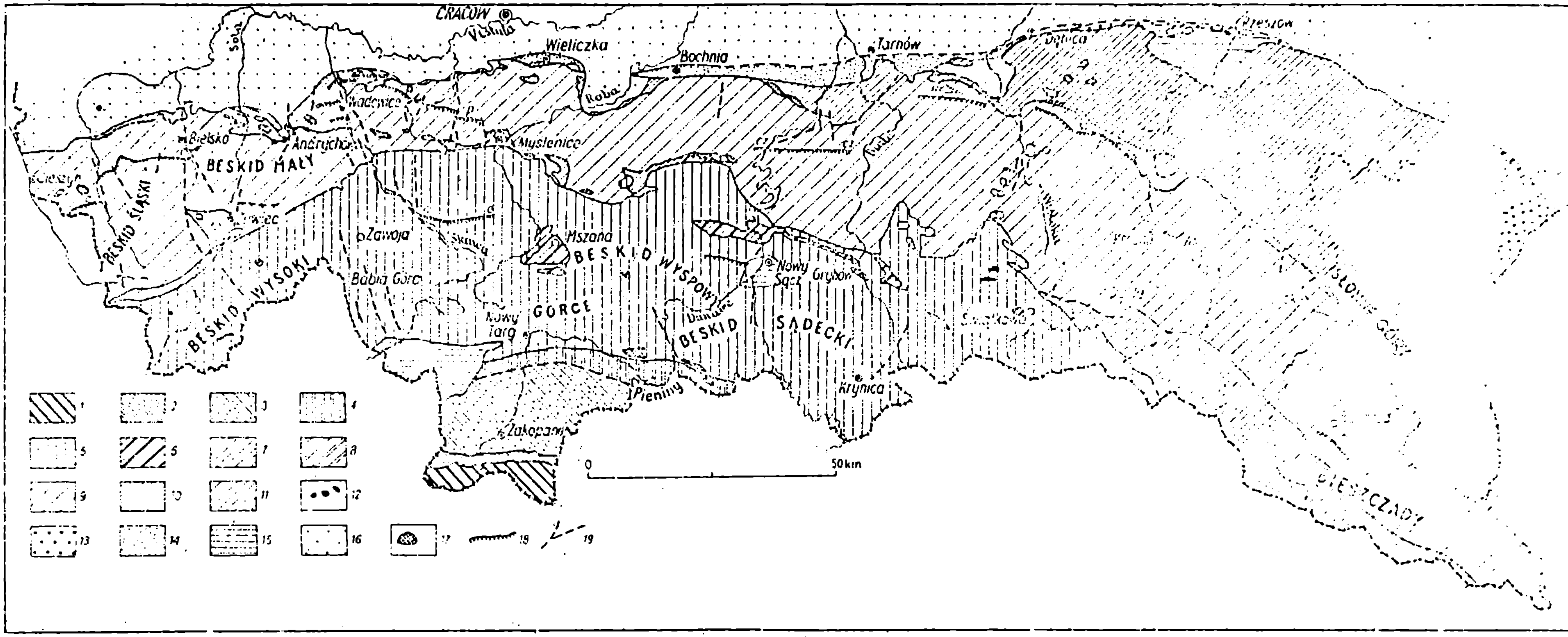

Fig. 237. Tectonic sketch map of the Polish Carpathians

1, 2 — inner, pre-Palaeogene, supposedly pre-Upper Cretaceous units (1 — High Tatra unit, 2 — Sub-Tatra nappes), 3 — post-orogenic cover of the inner units (Podhale Flysch), 4 — Pieniny Klippes Belt, 5 — Magura Nappe, 6 — units that occurs in tectonic windows of the Magura Nappe (Grybów unit = ? Dukla unit), 7 — Dukla folds and imbricated folds, 8 — fore-Magura imbricated fold, 9 — Silesian Nappe, 10 — Sub-Silesian Nappe, 11 — Skole Nappe, 12 — Andrychów Klippe, 13 — Stebnik Nappe, 14 — Wieliczka and Bochnia folds, 15 — Neogene (Tortonian and younger members, weakly disturbed, overlying Flysch and thrust over together with it), 16 — autochthonous Miocene, 17 — andesites and other post-orogenic magmatic rocks, 18 — overthrusts within bigger units: c — c — contact of the Godula Nappe with the Cieszyn Nappe, p — p — contact of the Lower with the Upper Silesian Nappe cz — cz — overthrust of the Czchów Scale, l — overthrust of the Liwocz Scale, o — o — overthrust of the Osielec imbricated fold, b — overthrust of the Bystre Scale, 19 — important faults

Wydawnictwa Geologiczne 1977 r.

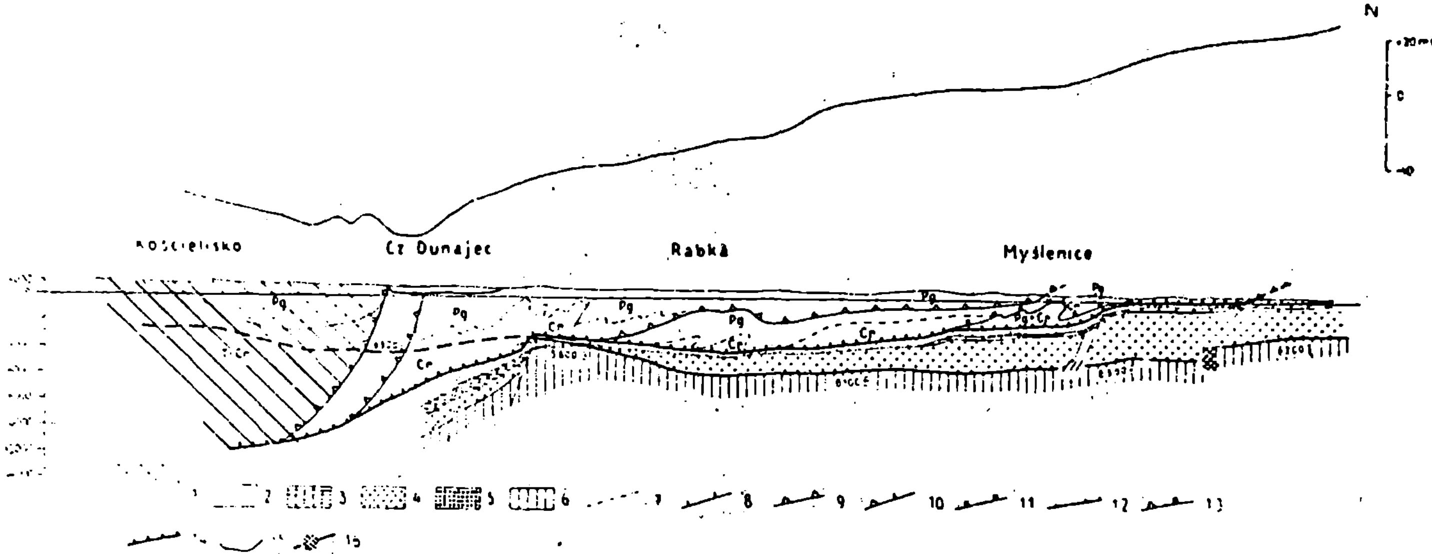

Fig. 2/1

Fig 2 Interpretative cross-sections through the Carpathians and their substratum.

1 — Inner Carpathians. 2 — Miocene deposits. 3 — Mesozoic deposits 4 — Paleozoic deposits. 5 — Metamorphic basement of the Carpathian geosyncline. 6 — Crystalline basement of the Fore-Carpathian Trough (Epivariscan Platform). 7 — Approximative boundary between the Cretaceous and Paleogene deposits. 8 — Overthrust of the folded Miocene together with the burried flysch folds. 9 — Overthrust of the Magura Unit. 10 — Overthrust of the Dukla Unit. 11 — Overthrust of the Silesian Unit. 12 — Overthrust of the Subsilesian Unit. 13 — Pieniny Klippen Belt boundary. 14 — Overthurst of the Carpathians. 15 — Bouger gravity anomaly. 16 — Seismic-refraction profiles according to A. Mikołajczak, A. Wojas, E. Haloń and R. Materzok with the velocity value (m/sec).
/after A.Ślączka 1975/

"Flysch Zone". During the orogenic period several nappes were formed with prevalent northerly direction of thrusting : 1. the Magura nappe bordered from south by the Pieniny Klippen Belt, 2. Pre-Magura-Dukla nappes, 3. the Silesian nappe, 4. the Sub-Silesian nappe, 5. the Skole nappe. Along the outer margin of the Carpathians narrow belt of the folded Miocene deposits was developed. The extent of thrusting of nappes reaches 40 km in the western part of the Carpathians and the whole orogene is thrust onto the North European platform more than 40 km (Fig.3). The platform is built of the Paleozoic and Mezozoic rocks covered by the Miocene molasse of the Carpathian Foredeep.

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Attention! In the Guide there are included parts of printed guides and works of M.Ksiazkiewicz and K.Birkenmajer.

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II. THE WESTERN PART OF THE POLISH CARPATHIANS.

The region west from river Olza is built of the Silesian nappe which is trust onto Sub-Silesian one and both units are overthrusted onto the North European Platform (Fig.4). Several bore - holes passed through both units and penetrated Miocene sediments underlain by the Lower Carboniferous, Devonian and Cambrian rocks. Below them metamorphic basement was struck. In the southermost drilling (Bystra IG 1, SE from Zywiec) below the Carpathians only Miocene sediments and gneissic basement was founded at a depth ......m.

Between rivers Olza and Wisla the Silesian nappe (Fig.4) consist of uppermost Jurassic and Lower Cretaceous beds (Cieszyn fm., Grodziszcze Beds and Vezovice shales) folded disharmonically with respect to the main body of the nappe. They represent the oldest sediments of the Outer Carpathians and started with dark predominantly slumped marls (Lower Cieszyn shales - Late Kimeridgian to Middle Tithonian/ which rappidly pass upwards into calcareous turbidites (Cieszyn Limestones, Late Tithonian - Berriasian) and at last into

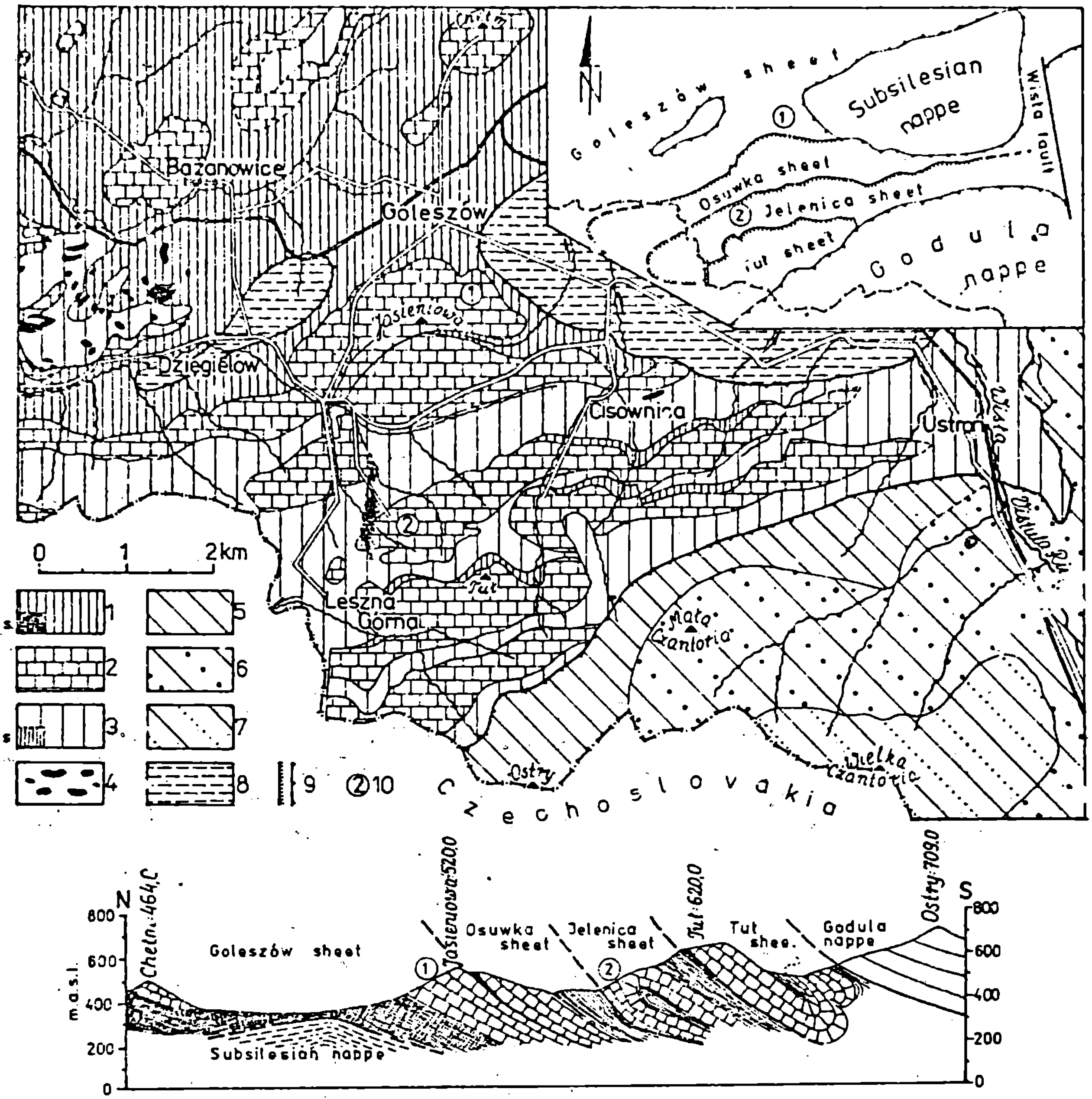


Fig. 2. Geology of the visited area with locality of stops. Cieszyn subnappe: *1* – Lower Cieszyn Shales (Upper Kimmeridgian–Middle Tithonian); *2* – Cieszyn Limestones (Upper Tithonian–Berriasian); *3* – Upper Cieszyn Shales (Valanginian–Hauterivian); *4* – intrusions of teschenite. Godula subnappe: *5* – Wierzowice Shales, Grodzisko Shales and Lgota Beds (Hauterivian–Lower Cenomanian); *6* – Lower Godula Beds (Upper Cenomanian–Turonian); *7* – Middle Godula Beds (Turonian). Subsilesian nappe: *8* – undivided sediments (Upper Cretaceous–Palaeogene). *9* – overthrust fronts; *10* – stops

/after M.Książkiewicz from A.Lalik 1986/

siliciclastic shally flysch (Upper Cieszyn Shales, Valanginian - Hauterivian). The Jurassic and Neocomian beds of the Cieszyn -Bielsko region contain numerous sills of teschenite.

The Inner part of the Silesian nappe is built of flysch sediments of Albian (Lgota f.m), Late Cretaceous (Godula and Istebna fms.) and Paleogene (Ciezkowice Sandstones, Hieroglyphic, Menilitic and Krosno fms.) age. These sediments dip monoclinally southwards, below the Pre-Magura and Magura nappes.

East from Bielsko - Biala, near Andrychów, along the border between the Silesian and Sub - Silesian nappes, several klippen occur. They consist of crystalline, Jurassic, Senonian and Paleogene beds (Fig. 5). The rocks of the klippen differs markedly from the sediments of the both adjacent nappes and they represent remnants of a carbonatic platforms which separated locally Silesian and Subsilesian basins during the Cretaceous and Paleogene times.

Fig. 5

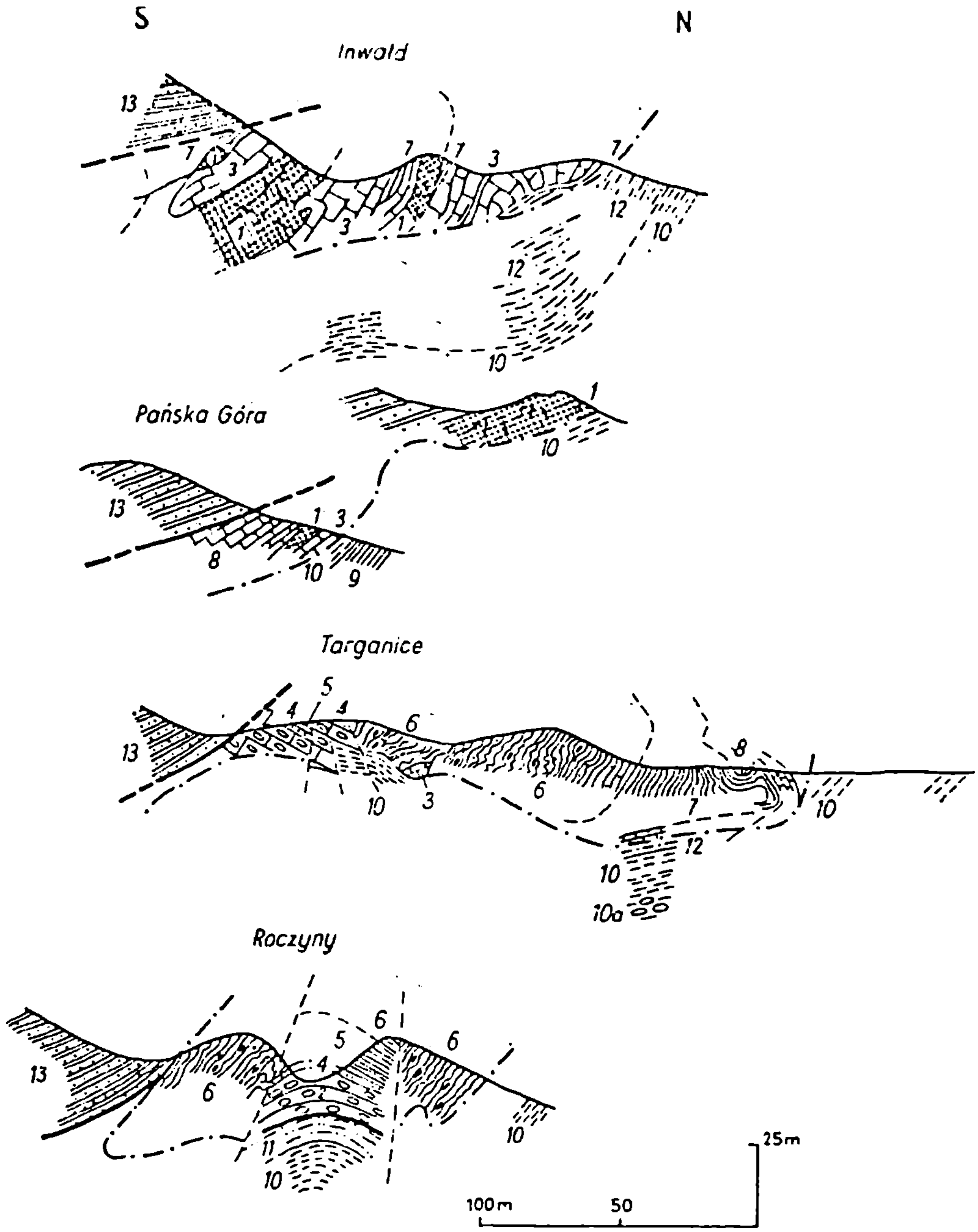
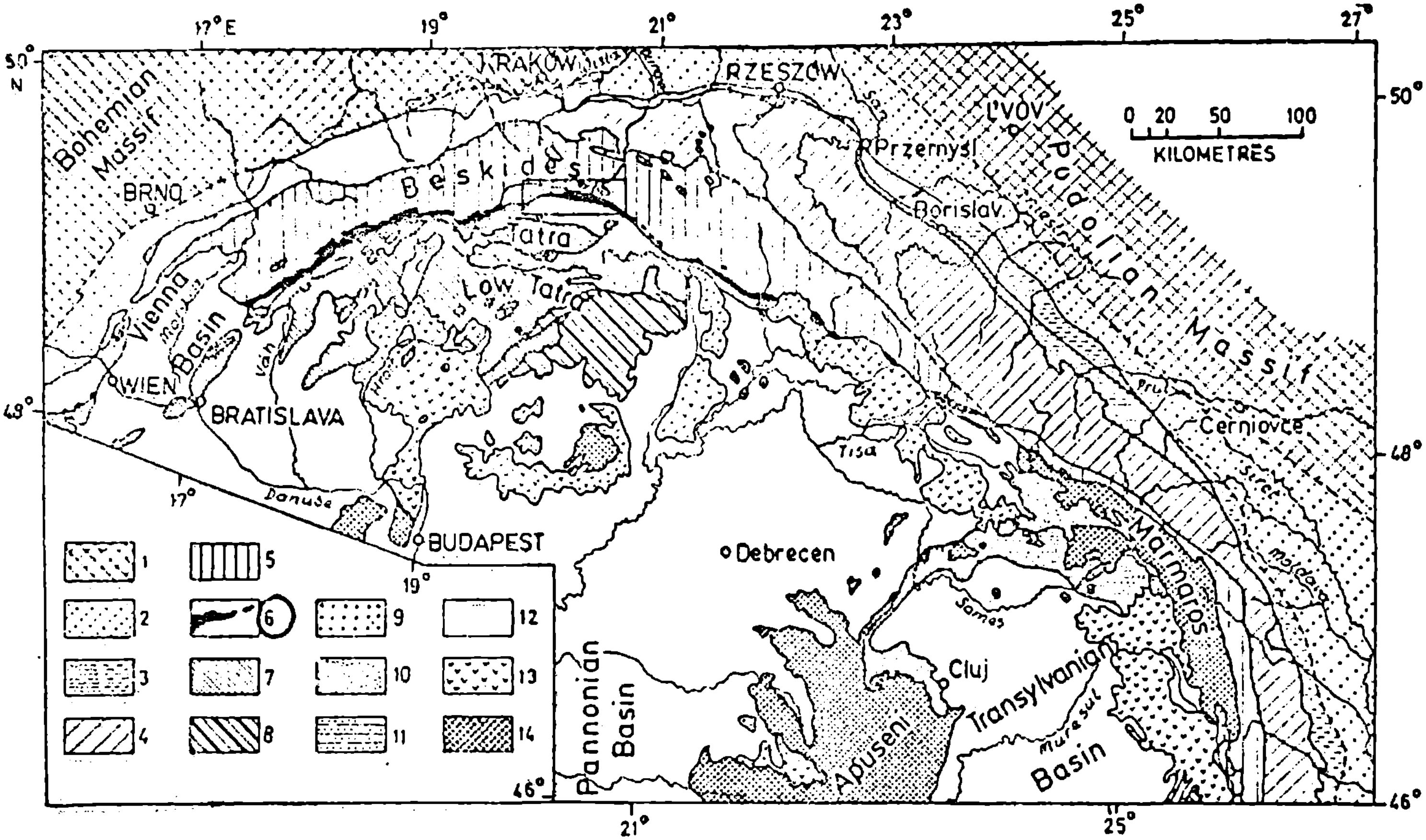


Fig. 255. Cross-section of the Andrychów Klippen, after 11 Książkiewicz

Klippen suite: 1 — granitogneisses, mylonites, 2 — (Upper?) Oxfordian (limestones with cherts), 3 — Tithonian (Stramberk Limestones), 4—7 — Senonian (4 — conglomerates, 5 — shaly marls, 6 — limestones with cherts and marls, 7 — grey marls), 8 — Palaeocene — Lower and Middle Eocene (Bryozoan-Lithothamnian limestones); Sub-Silesian Nappe: 9 — Cenomanian — Turonian (variegated shales), 10 — Senonian (Węglówka Marls), 10a — Senonian intermingled with Lower Cretaceous, 11 — Eocene (green and grey shales), 12 — Oligocene (Krosno Beds); Silesian Nappe: 13 — Albian (Lgota Beds)



Main structural zones of the Carpathian Mountains

/acc.to Książkiewicz 1963 and Birkenmajer 1974/

1. Foreland, mostly pre-Neogene formations, partly with Neogene sedimentary cover; 2. Foredeep filled with Neogene sediments; 3-5. Outer Carpathians /3. outer zone, 4.central zone, 5. inner zone/; 6. Pieniny Klippen Belt; 7-11. Inner Carpathians /7-Tatrid Hronid units, 8. Gemerid units, 9. Senonian molasse, 10. Paleogene in flysch facies, 11. Paleogene in epicontinental facies/; 12. Neogeme molasse of the intramontane and Pannonian basins; 13. Neogene to Quaternary volcanism; 14. Pre-Paleogene rocks of inner zones and the Marmaros zone.

I. INTRODUCTION

The Carpathians are a part of the great arc of mountains stretching from about Vienna to the Iron Gate on the Danube. In the West the Carpathians are linked with the Alps and at other end pass into Balkan chain (Fig. 1). The Carpathians are formed by the folding of sediments laid down in a geosyncline which was initiated in the early period of the Mezozoic era. The geosyncline consisted from several longitudinal troughs and ridges with distinctive litostratigraphic successsions. The folding took place in two main phases: the older one towards the end of the Cretaceous which embraced the inner part of the geosyncline, and the younger one in the Late Tertiary. As a result, the Carpathians consist of two ranges: an older one known as the Inner Carpathians (Tatra Mountains p.p.), and a younger one, known as the Outer Carpathians . At the contact of these two ranges the Pieniny Klippen belt is situated. It was affected both by the Upper Cretaceous and Tertiary phases (Fig. 2).

The Tatra Mountains are built up by crystaline core of Paleozoic age and sedimentary rocks of Mezozoic age and consist of several tectonic units: the High-Tatric Zone and the Lower, Middle and Upper Sub-Tatric nappes. The northern margin of the nappes is transgresively covered by Paleogene sediments (Podhale Flysch).

The Pieniny Klippen Belt are built mainly of the calcareous rocks of Jurassic and Cretaceous age and also of the Paleogene rocks. Several tectonic units there were distinguished: Haligowce, Pieniny, Branisko, Niedzica and Czorsztyn ones.

The sedimentary sequences of the Outer Carpathians begins with the Kimeridgian/Tithonian sediments and last till Lowermost Miocene. During the whole period flysch sediments predominated and this range is usually called

Exposure 1. Zywiec - Cieszyn formation and teschenites (Tithonian)

Along the East bank of the Sola river a part of the Cieszyn limestones strongly tectonized is exposed. The limestones are grey-white, thin- to medium-bedded with lamination and/or graded bedding and are alternating with marly shales. Coated skeletal fragments and coated grains and pellets are the main component of detrital limestones. Some of the fine-grained layers contain tintinnides, mainly Calpionella alpina. The Cieszyn limestones exhibit a number of features characteristic for turbidite sediments and they are regarded as beginnig of flysch sedimentation in the Carpathians. Within limestones sequence a sill of teschinite is visible. The principal rock-type consist of plagioclase, augite, biotite, analcite and chlorite. The volcanic activity was connected with Neocimmerian tectonic phase. Although the main bulk of the Cieszyn limestones was derived from the norther border of the geosyncline there is an opinion that source of limestones from Zywiec area were situated along the southern margin (pre-Silesian Cordillera).

In the southern part of examined profile the huge mass of redeposited marls (slump deposits) also with exotic rocks are visible. They represent a pre-flysch deposits (the Lower Cieszyn shales).

Exposure 2. Wisla-Oblaziec (Lower Godula Beds - Turonian)

In the visited quarry thick-bedded, siliciclastic turbidites crop out. They display simple or multiple graded bedding and sole marks with well developed flame structures. The conglomerates contain pebbles of igneous and sedimentary rocks (mainly organogenic Tithonian limestones and Cieszyn Limestones). There is also levels of big slumps with large flat blocks of the Albian thin-bedded sandstones alternating with shales. These blocks were eroded from basement during slump movements. The examined deposits are connected with intensification of sedimentation after quiet period when in the North Carpathian geosyncline radiolarian and red shales were deposited. The material was derived from the Silesian island which was created as en effect of Mid-Cretaceous tectonic movement dividing the south part of the flysch geosyncline in the Magura and Silesian basins.

Exposure 3. Inwald Klippen (Platform deposits).

In abandoned quarry we examine remnants of a carbonatic ridge which during Cretaceous and Paleogene probably divided the Silesian and Sub-Silesian basins. The Klippe is built of the few scales (Fig. 5). Along the entrance to the quarry the Upper Senonian grey marls are visible. They rest unconformable on the massive poorly bedded limestones. They are detrital and consist of organic remnants: algae, echinoderms, foraminifers, bryozoans, corals, gastropodes etc. The thin-bedded intercalations consist of micrite with Saccocoma. The limestones are of a Tithonian age and represent shalow carbonatic platform of Bahamian type. Beneath the limestones mylonites occur. They consist of quartz, feldspar and chlorite and probably represent a granitic rocks. In the southern wall of the quarry, the contact with black shales and quarzitic sandstones (Lgota Beds - Albian) of the Silesian nappes is exposed. It is belived that Andrychów Klippen are thrust sheets thorn away by the Silesian nappe during its advance northward, although there is an opinion that they can represents olistolites at the top of the Oligo - Miocene Krosno fm.

Exposure 4. Kaczyna (Lgota Beds - Albian).

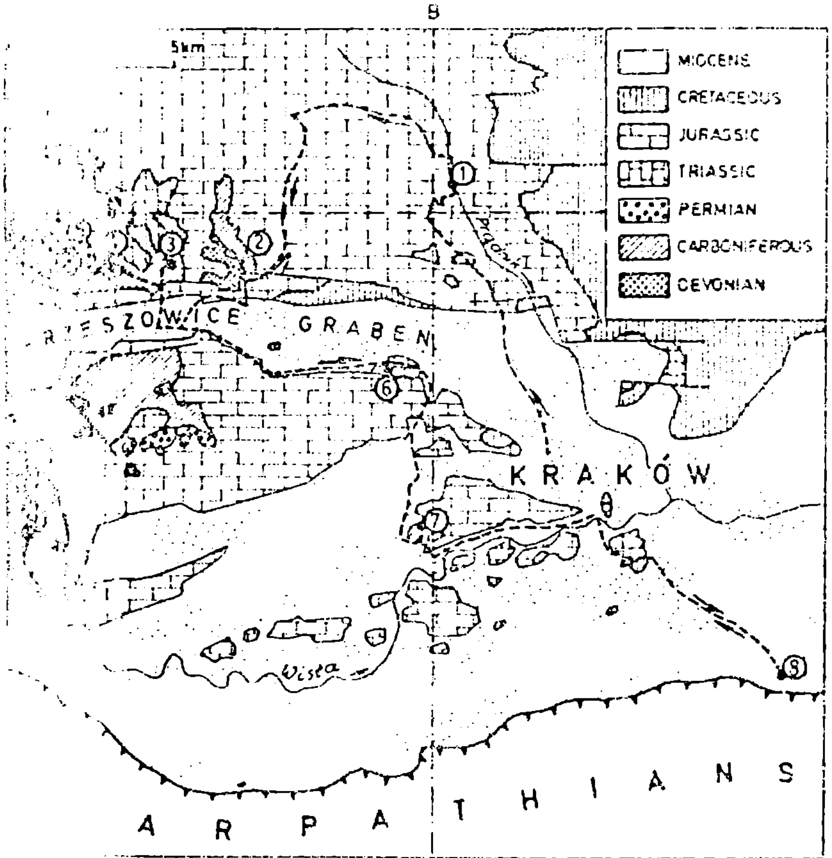
The Albian sediments of the Silesian unit are visible in old quarry. They are composed of alternating thin- and medium - bedded sandstones and black shales. The sandstones are greenish, fine- to coarse-grained distinctly laminated, often graded, with flute marks . The structures in sandstones are typical for turbidite beds, and full sequence of

Bouma division are present. Clastic material was probably derived from a northern margin of the geosyncline. Very thin-bedded sandstones with small-scale cross-laminations are sometimes interpreted as conturites (tractionites). Forams assemblages in shales indicating an upper bathyal depth of the sea floor. In the upper part of sequence the sandstones contain biogenic silica and lenses of spongiolites.

III. GEOLOGY OF THE KRAKÓW AREA.

Kraków is situated on the North European Platform built of strongly deformated Lower Paleozoic formation (Caledonian Krakowidy) flanked from the West by flat laying Lower and Upper Paleozoic rocks with folded Proterozoic basement. Both structures are covered by relatively thin Mezozoic rocks. The platform was dissected by the Miocene faulting into numerous horst and grabens structures expressed in surface relief, e.g. Wawel, Las Wolski, Krzemionki Hills with steep white walls of the Late Jurrasic limestones. Deeper tectonic depresions are filled with the marine Lower and Middle Badenian sediments (Fig. 6).

South from Kraków the Platform is covered by nappes of the Carpathians. In front of them there is a narrow belt of folded Badenian rocks with salt-bearing deposits of Wieliczka (Fig. 7).



Geological map of the Kraków region and location of ... for Excursion 2, 1st Day /by R. Gradziński/ .

IV. CENTRAL PART OF THE POLISH NORTHERN CARPATHIANS.

The central part of the Carpathians is built of several units: Skole, Sub-Silesian, Silesian, Sub-Magura and Magura (comp. Fig 2). The sediments from which these units but Sub-Silesian was formed were laid down in the seperate throughs and are represented mainly by siliciclastic turbidites. The Sub-Silesian sediments were connected with underwater ridge which separated the Silesian and Skole troughs. Probably similar sediments were connected with slopes of the Silesian Cordillera which separated the Silesian and Magura throughs (Fig 8).

Skole unit in the area described disapears completely from the surface and its west prolongation is unknown.

West of the Dunajec river Sub-Silesian unit appear at the surface in two discontinous belts. The northern one runs along the north edge of the Silesian Nappe and built the margin of the Carpathian. The southern one makes it appearance in numerous litlle tectonic windows west from Dunajec (Zegocina, Skrzydlna, Lanckorona windows) within the Silesian Nappe. Characteristic features of the sequence of the Sub-Silesian unit are the Lower Cretaceous deposits similar to the Silesian unit and Senonian - Eocene ones developed mainly as variegated marls (Weglówka Marls). Late Eocene and Oligocene sediments are once more similar to those from the Silesian unit.

The Silesian Nappe forms large synclines, with narrow anticlines built of the Lower Cretaceous deposits. Stratigraphic composition is similar to the Western part of the Nappe near Cieszyn, but here the Cieszyn limestones doesn't exist.

Magura Nappe is sharply delineated from the norther nappes. In Nowy Sacz area three tectonic zones have been distingushed: Siary, Gorlice (Raca), Nowy Sacz (Bystrica) and Krynica zones.

As far as composition is concerned the Magura Nappe is very different from the outer units. The Late Cretaceous is

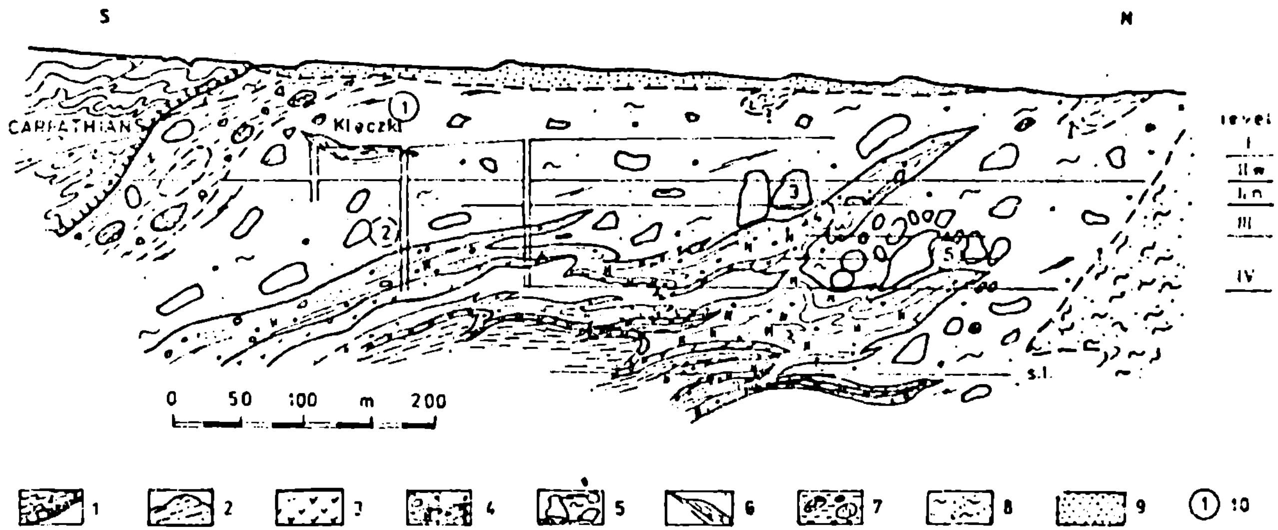


Fig. 4. Transversal cross-section of the Wieliczka Salt Mine. *1* – Carpathians; *2* – marly claystones, Skawina Beds, *3* – lower part of the Stratified Member: green and shaft salt with anhydrites and mudstones; *4* – upper part of the Stratified Member: spiza salt (submarine fan deposit); *5* – Chaotic Member: Żuber (olisthostromes with rock salt blocks); *6* – Chaotic Member: lens of salt conglomerate and sandstone; *7* – Chaotic Member: olisthostromes with Carpathians and Miocene blocks, without salt blocks; *8* – Chodenice Beds; *9* – Quaternary; *10* – stops

/after A.Ślączka and K.Kolasa 1986/

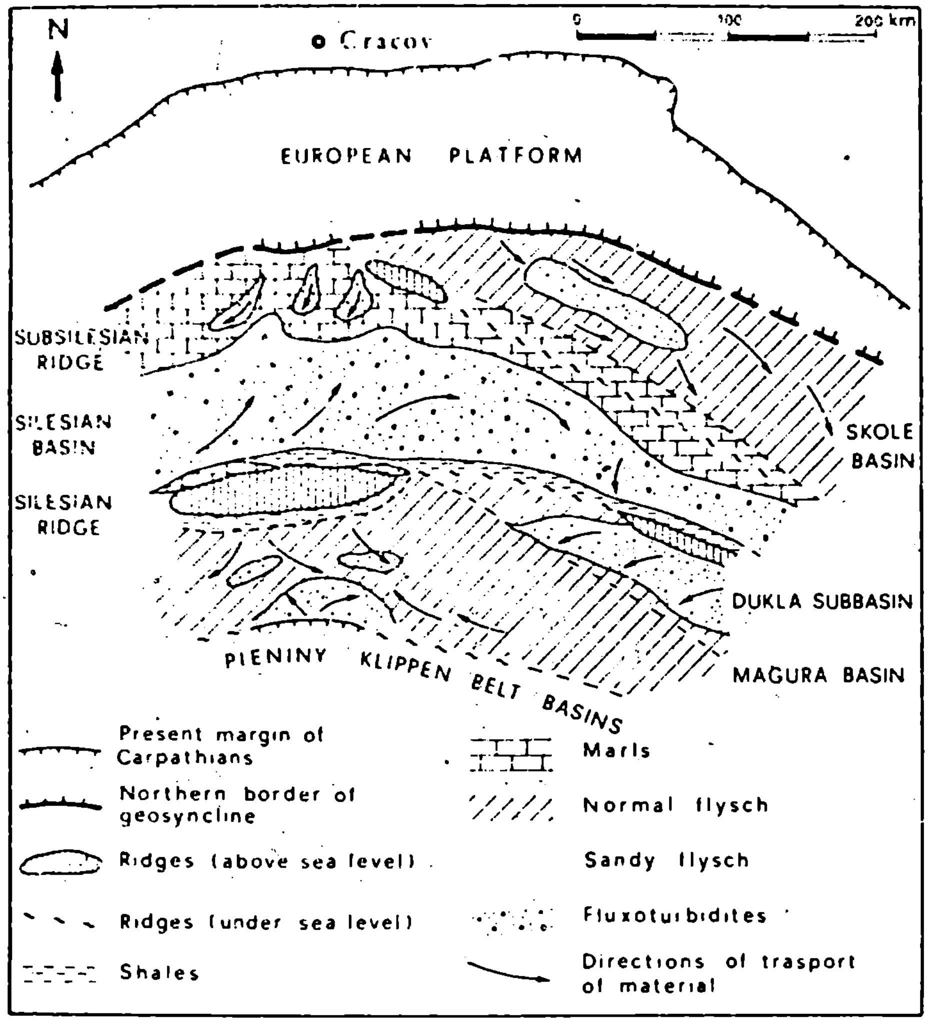


Fig. 4. Northern Carpathians. Source areas and paleocurrent directions in flysch basins.

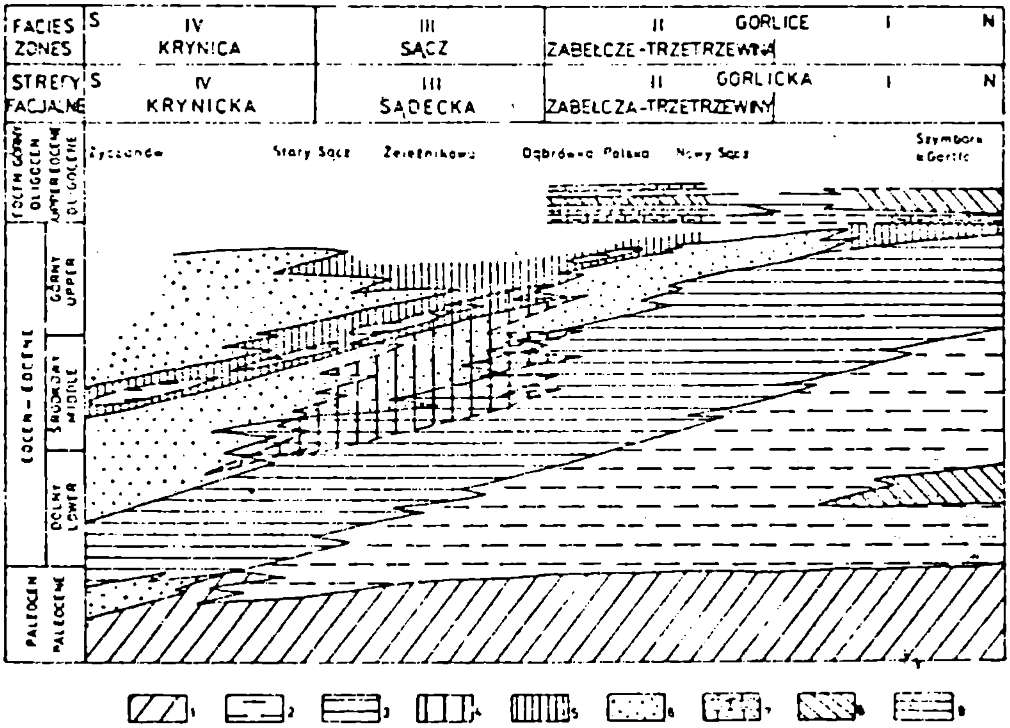


Fig. 6. Schemat rozwoju litofacjalnego serii magurskiej w rejonie Kotliny Sądeckiej (Oszczypko, 1973a, zmodyfikowane i uproszczone) 1 — flisz cienko- i średniolawicowy (warstwy ropianieckie), 2 — łupki pstre, 3 — flisz cienkoławicowy (warstwy z Zarzecza, warstwy beloweskie, warstwy hieroglifowe i warstwy podmagurskie), 4 — margle łąckie, 5 — łupki zielone i flisz cienkoławicowy, 6 — flisz piaszczysty — piaskowce magurskie, 7 — margle globigerynowe, 8 — flisz piaszczysty — piaskowce glaukonitowe, 9 — flisz cienkoławicowy (warstwy malcowskie)

Fig. 6 Lithostratigraphic relation in the Magura series of the Sącz Depression (according to Oszczypko, 1973a; altered and simplified). 1 — fine- and middle-bedded flysch (Ropianka Beds), 2 — Variegated Shales, 3 — fine-bedded flysch (Zarzecze Beds, Beloveza Beds, Hieroglyphic Beds and Sub-Magura Beds), 4 — Łącko Marls, 5 — green shales and fine-bedded flysch, 6 — sandy flysch — Magura Sandstone, 7 — globigerina marls, 8 — sandy flysch — glauconitic sandstones, 9 — fine-bedded flysch (Malcov Beds) developed as Inoceramian Beds. The older strata do not occur except in Fore-Pieniny (Grajcarek) Zone. During the Middle Eocene thick redeposited marls (Lacko Marls) developed and quite characteristic component are the Magura Sandstones. They cross the Magura Nappe diachronicaly (Fig. 9). In the South their sedimentation started in the Early Eocene and in the North at the end of the Eocene only. The distribution of lithofacies during the Eocene show similarity to submarine fan model advanced towards the North.

Within the northern part of the Magura Nappe several tectonics windows (Mszana Dolna, Szczawa, Grybów etc) occur, where lower-Sub-Magura (Dukla-Grybów) unit is visible. Its development is different to the Magura one.

On the Outer Carpathians there are post-orogenic intra-mountainous (piggy-back) basins filled with Early Badenian sediments. The biggest one is the Nowy Sacz Basin.

Exposure 5. Zegocina (Tectonic window of Sub-Silesian unit)

In Zegocina in a core of an anticline of the Silesian Nappe there occur the Sub-Silesian unit and it is folded with the lowest Cretaceous members of the Silesian unit (Fig. 10). The Sub-Silesian unit is mainly represented by the Turonian - Senonian grey Frydek and white Zegocina Marls whereas the red Weglówka marls play a subordinate role here. Frydek Marls display slump structures and often contain exotic rocks. The marls represent probably an slope of basin facies. The southern edge of window is formed by the Magura Nappe. In the quarry we also examine Hauterivian Grodzisko Sandstones which belong to the Silesian Unit. These turbidites carry a profusion of flows structures indicated the eastward direction of transport. Some of the beds contain exotic blocks and were deposited by high-density turbidity currents. The material was probably derived from the north margin of the geosyncline.

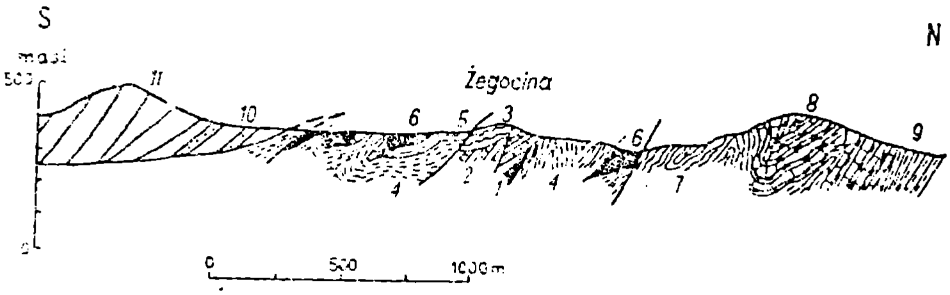


Fig. 254. Cross-section of the Żegocina zone, after K. Skoczylas-Ciszewska

Sub-Silesian Nappe: *1* — Valanginian (Upper Cieszyn Shales), *2* — Hauterivian (Grodziszcze Sandstone), *3* — Albian (Lgota Beds), *4* — Senonian (variegated and grey marls), *5* — Senonian? (Żegocina Marls); Silesian Nappe: *6* — Valanginian (Upper Cieszyn Shales), *7* — Albian (Lgota Beds), *8* — Cenomanian — Turonian (Godula Beds), *9* — Senonian (Lower Istebna Beds); Magura Nappe: *10* — Upper Eocene (Sub-Magura Beds), *11* — Upper Eocene — Oligocene (Magura Sandstone)

Exposure 6. Roznów (Istebna sandstones - Late Senonian).

Along the bank of the artificial lake we examine the sandy facies of the Senonian of the Silesian unit. It is represented by thick-bedded, coarse grained, massive sandstones displaying typical structures of the fluxoturbidites (Fig.11). Graded-bedding is poorly developed and a large part of the beds are structurless with erosional lower surface of individual beds. Slump deposits and erosional channels are visible. These deposits represent a part of submarine fan composed of material derived from the Silesian Cordillera (Fig.12).

Exposure 7. Znamirowice (Globigerina Marls and Menilite fm, a passage between the Eocene and Oligocene).

Along the bank of the artificial lake there are well exposed sediments represented uppermost part of the Eocene: green shales and yellowish bioturbated globigerina marls which pass into brown marls. They are covered by thick bedded sandstone and dark brown shales and cherts which represent already Oligocene. The drastic change of colour, character of fossils (dark shales contain only sporadic diatoms and remnants of fishes), apperance of cherts show important change in character of the Carpathian geosyncline at the border between the Eocene and Oligocene. It was connected probably with Pirenean tectonic phase. Farther to the south thick-bedded and later thin-bedded Krosno sandstones are visible.

Exposure 8. Tylmanowa (Magura Sandstones - Early Eocene).

On the left bank of the Dunajec river there crop out medium- to thick-bedded, medium-grained sandstones with intercalations of complexes of thin- beded ones 9 (Fig 13). The sandstones display different current structures which show NNW-ward directions of currents. They represent turbidites connected with middle-fan distributary chanel- deposi-

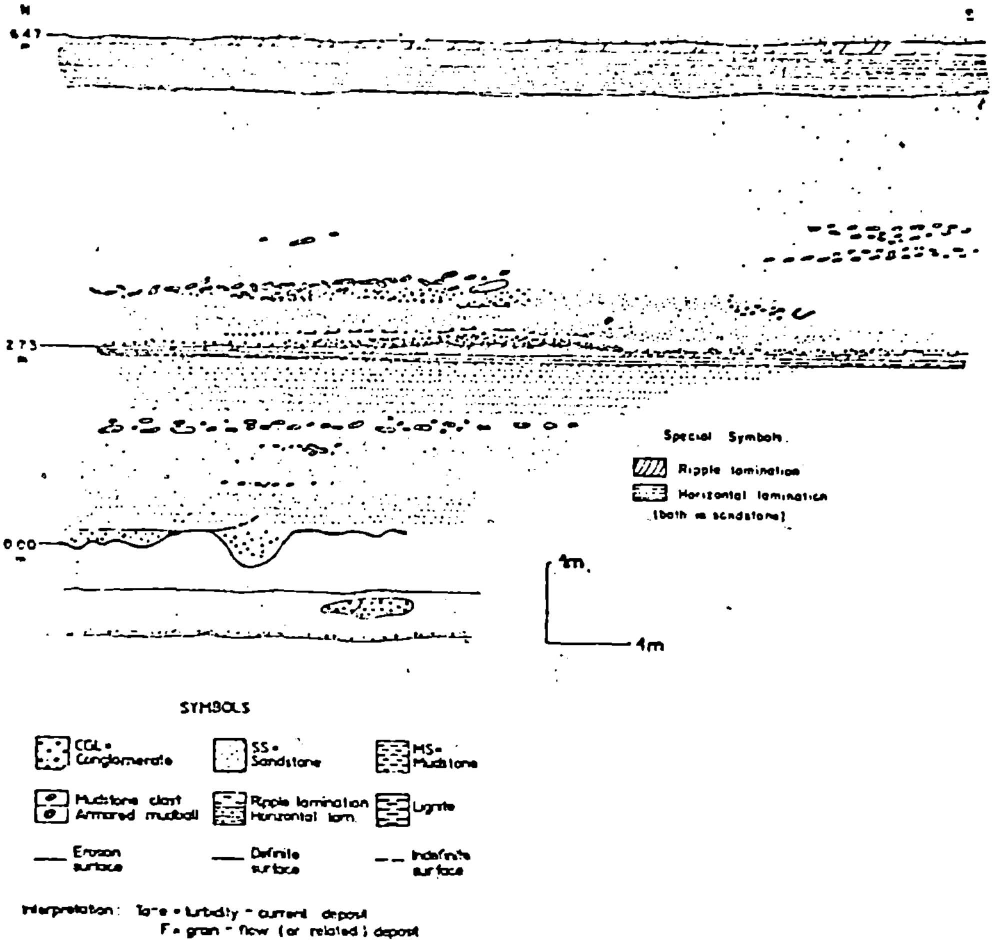


Fig. 6b. Cross section, north-south, of quarry wall at Rożnów. Fig. 6a is located on left side. Principal bedding surfaces occur at 0.00 m, 2.73 m, and 6.47 m. Lateral variability within beds is shown. In lower bed (0.00 to 2.73 m) are lenses and load pockets of gravel in grain-flow deposits. Zones of gravel segregations and mudstone clasts die out laterally. Conglomerate at base of upper bed thickens locally with a convex top indicating a buildup over a slightly higher part of the bottom. Symbols generally are the same as those used in columnar sections; special symbols are indicated

/after A.Ślączka and S.Thompson III,1981/

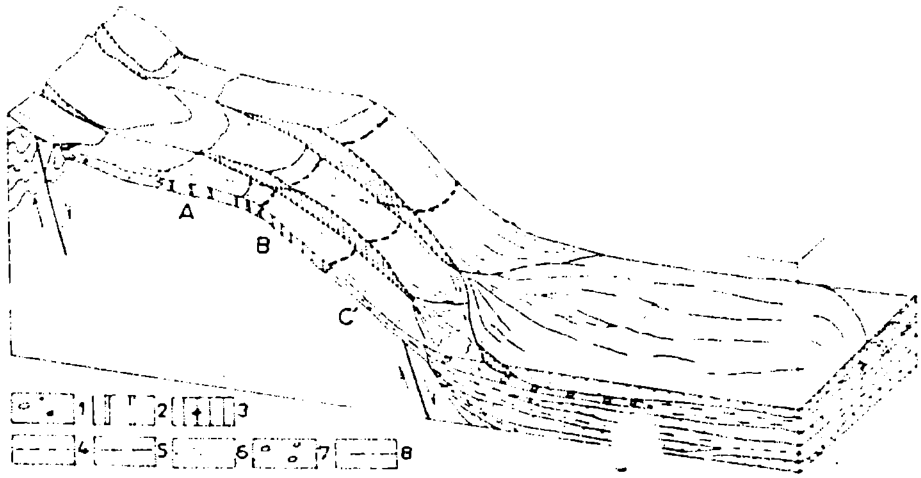


Figure 2. Block diagram (not to scale) showing the distribution of lithofacies in the southern part of the central section of the Silesian Basin (1. near-shore detrital deposits; 2. red marls with "**Association A**" foraminiferids; 3. red marls with "**Association B**" foraminiferids; 4. red shales with "**Association C**" foraminiferids; 5. dark-grey shales with "**Association C**" foraminiferids; 6. fluxoturbidites and turbidites; 7. exotic-bearing pebbly mudstones; 8. thin and medium-bedded, laminated sandstones and grey, green shales).

/after A.Ślączka and M.A.Gasiński 1985/

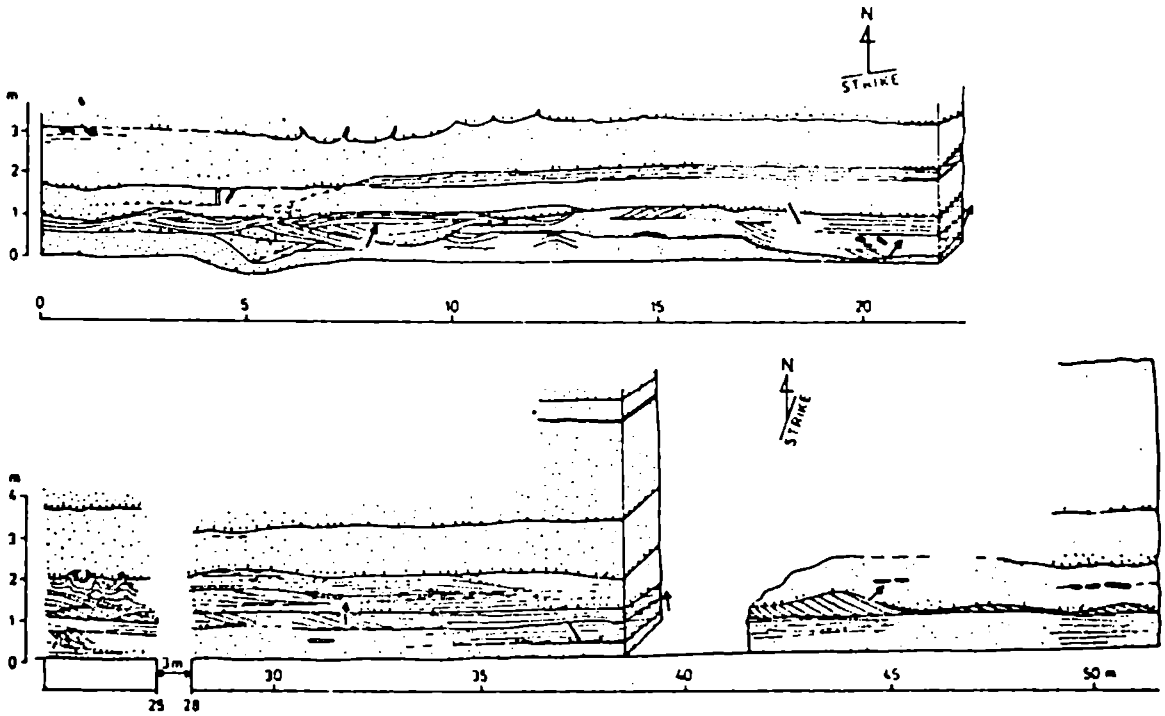


Fig. 90. Details of a sandstone unit with large-scale traction structures. Magura sandstone at Tylmanowa /by N. Oszczypko & S. Porębski/

tional lobe systems. The assemblages of trace fossils are depending on character of sandstones: those associated with thick-beds are different than those associated with thin ones.

PIENINY KLIPPEN BELT

[M.A.Gasinski, mainly based on Birkenmajer 1963 - 1986]

In the late Mesozoic time the depositional basin of the Pieniny Klippen Belt belonged to the Alpine - Carpathian branch of the Tethys. Several longitudinal facies zones, corresponding to througs and ridges of the depositional basin, are diachronous in the cross-section of the Pieniny Klippen Belt, each with its distinctive lithostratigraphic succession. These palaeogeographic zones are as follows (from north to south, Fig. 14): northern synclinal furrow (Magura succession), northern eugeanticlinal ridge (Czorsztyn succession s.l.), synclinal furrow (Branisko-Pieniny succession), southern eugeanticlinal ridge (Andrusov ridge). Several transitional zones of regional extension are distinguished between the above mentioned major ones.

The Pieniny Klippen Belt represents trace of a major axial suture in the Carpathian fold belt, about 600 km long, but only from a few hundred metres to about 20 km wide. It separates two major structural units: the Inner Carpathians to the south and the Outer (Flysch) Carpathians to the north (Fig. 1). In its present form, the Pieniny Klippen Belt is a heterogenous structure consisting of the Klippen succession proper deposited in the Pieniny Klippen Basin, and their sedimentary cover, moreover of the Inner and Outer Carpathians elements incorporated in the Belt during the Late Cretaceous-Early Paleogene, and Early Neogene foldings.

The Klippen succession include marine sediments laid down in a separate basins, following fragmentation by extensional Early Cimmerian faulting (at the Triassic-Jurassic boundary) of the Triassic carbonate platform. The pre--Triassic basement is known only from fragments contained as

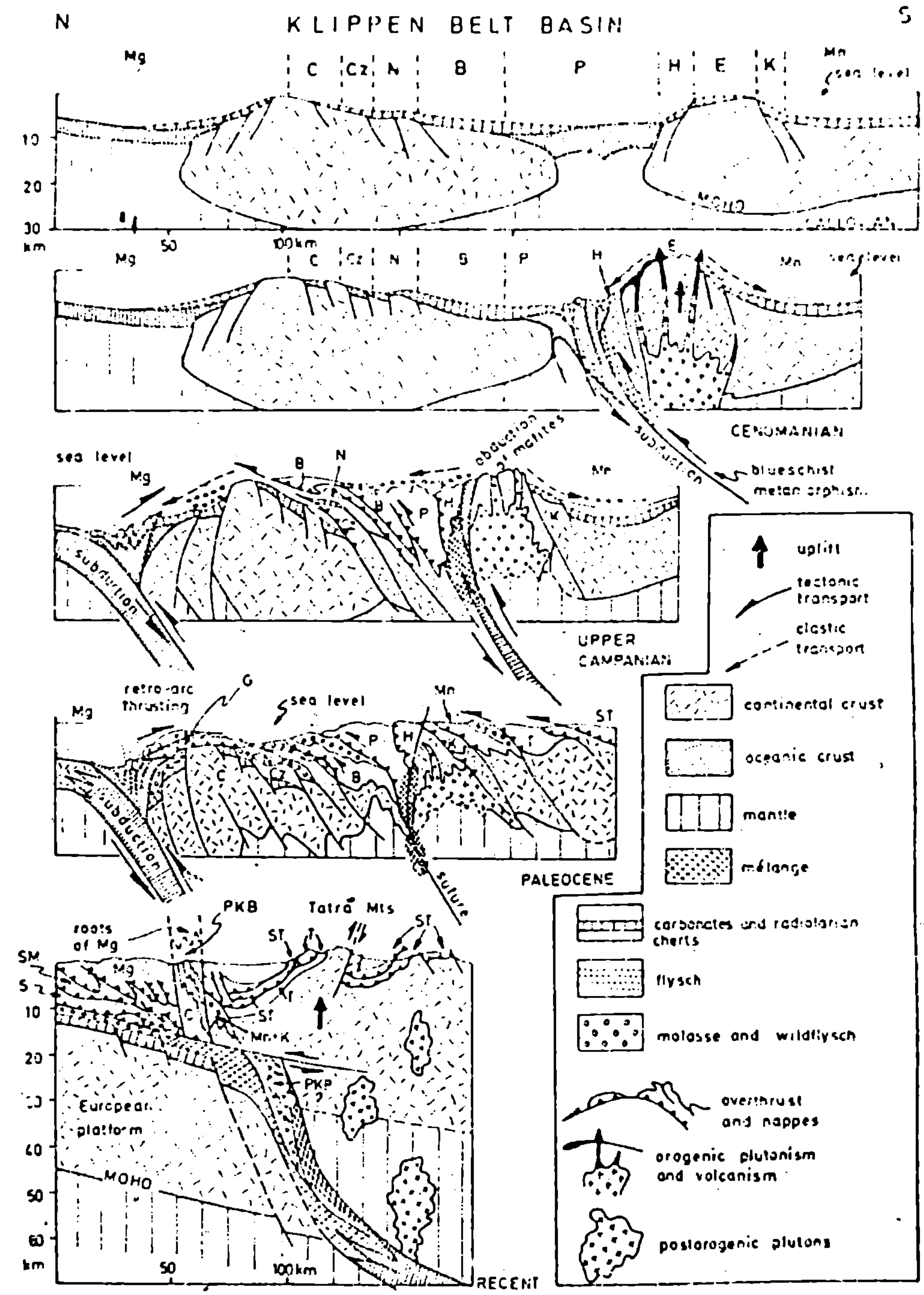


Fig. 5

Model of structural evolution of the Pieniny Klippen Belt, central sector. (after Birkenmajer, 1985b)

Stratigraphic successions and tectonic units: *Mg* — Magura; *G* — Grajcarek; *C* — Czorsztyn; *Cz* — Czertezik; *N* — Niedzica; *B* — Branisko; *P* — Pieniny; *H* — Haligovce; *E* — Exotic (Andrusov Ridge); *K* — Klape; *Ma* — Manin; *T* — Hightatric; *ST* — Subtatric; *PKB* — Pieniny Klippen Belt secondary deposits in the Mid-Jurassic sediments. The estimated width of the Pieniny Klippen Basin was of the order of a minimum 100-150 km during the Callovian expansion stage. Much more width would be added if we accepted an oceanic-type crust under the central part of the furrow.

The Pieniny Klippen Belt is bounded in the south and north along most of its length by strike-slip faults of Early Miocene age. The Belt was a mega-shear zone of translation during Early Neogene clockwise rotation of Inner Carpathians respective to Outer ones. The strike-slipe translation caused megabrecciation and megabudinage so characteristic of the Klippen Belt structure.

Four epoch of structural deformation have contributed to the present structure of the Pieniny Klippen Belt: 1 - Early Cretaceous subduction (in the south considerably reduced width of the basin); 2 - Late Cretaceous-Early Palaeogene subduction (late Subhercynian and two Laramian phases); 3 - The Early Miocene (Savian) deformation (continent-continent type colision: between the European Plate and the Central Carpathian-Pannonian Microplate); 4 - Mid-Miocene (late Savian and Styrian phases: megabrecciation and megabudinage (Fig.14).

Exposure 9. Czorsztyn Castle and Halka (stratotype of the Czorsztyn succession; Late Liassic-Turonian).

The Czorsztyn castle section (Fig.15) is a classic locality of this succession, described and illustrated in innumerable papers since 19th century i.e. Staszic, Pusch, Zejszner, Suess, Neumayer, Alth, Zittel, Uhlig et al. Almost complete Middle Jurassic - Late Createceous succession, from spotted limestones of Late Liassic age to variagated marls of Turonian age, is exposed. A good exposure of the Czorsztyn succession represented by a klippe (Halka) will be examined at the left bank of the Dunajec river (Fig. 16). It shows red crinoid limestones (Bathonian) and red nodular limestone (Oxfordian-Cimmeridgian, Rosso Ammonitico type).

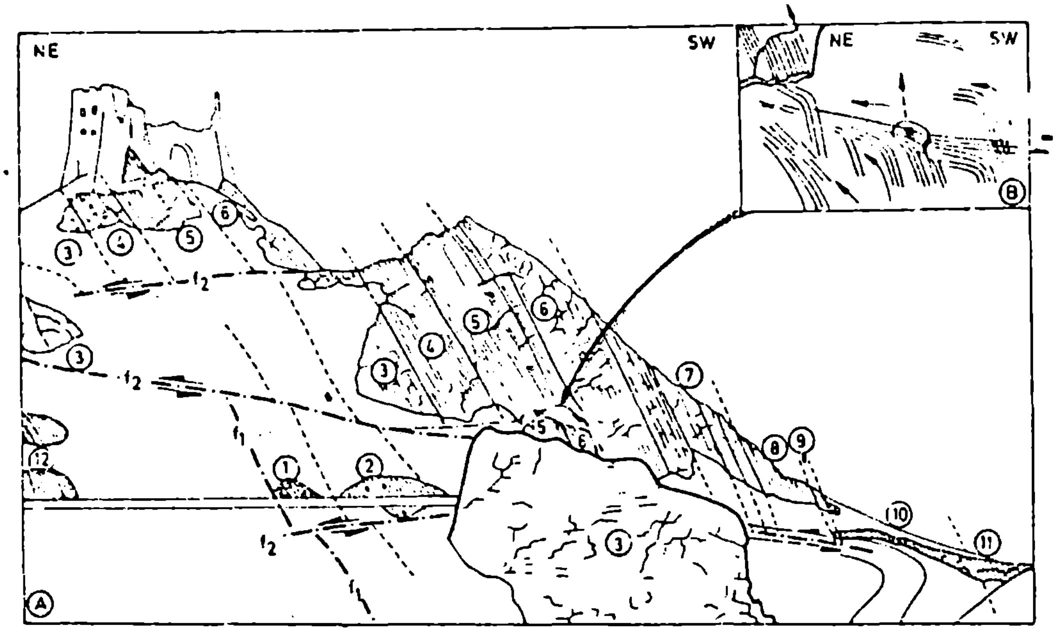


Fig. 51. Perspective geological picture of the Czorsztyn Castle klippes group with location of strike-slip and oblique-slip striae on transversal fault surfaces /after Birkenmajer, 1958, 1963, 1983/

Czorsztyn Unit: 1 - Krempachy Marl Fm.; 2 - Skrzypny Shale Fm.; 3 - Smolegowa Limestone Fm.; 4 - Krupianka Limestone Fm.; 5 - Czorsztyn Limestone Fm.; 6 - Dursztyn Limestone Fm.; 7 - Łysa Limestone Fm.; 8 - Spisz Limestone Fm.; 9 - Chmielowa Fm.; 10 - Pomiedznik Fm.; 11 - Jaworki Marl Fm. Grajcarek Unit: 12 - Szlachtowa Fm. Tectonic elements: f_1 - longitudinal strike-slip fault; f_2 - transversal strike-slip and oblique-slip faults

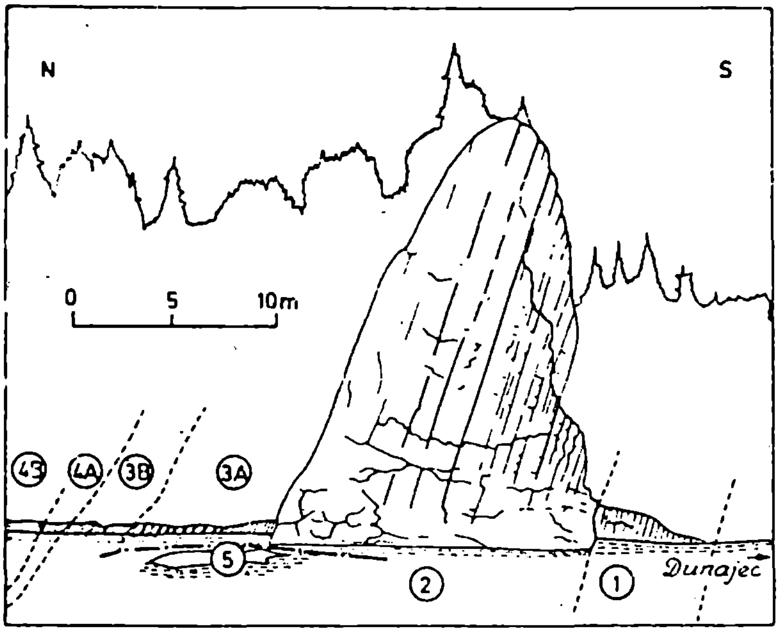


Fig. 53. Geological structure of Halka klippe at Czorsztyn /after Birkenmajer, 1958, 1963, 1979/

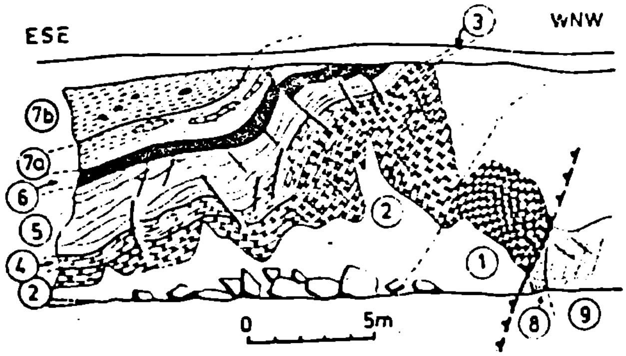
Czorsztyn Unit: 1 - Krupianka Limestone Fm.; 2,5 - Czorsztyn Limestone Fm.; 3 - Pomiedznik Fm. /A - lower; B - upper/; 4 - Jaworki Marl Fm. /A - Brynczkowa Marl Mbr; B - Skalski Marl Mbr/

Local biostratigraphical zonation of the Late Cretaceous have been established here on the basis of planktonic foraminiferes.

Along the road, on the north side, there is visible Mt. Wzar andesite. This is a site of numerous Miocene andesite dykes cutting through the Mt. Wzar anticline built of Paleogene rocks of the Magura nappe. There are two generations of andesite intrusions. The older, the first phase andesites are, according to preliminary dating, probably of an Early Badenian age. It seems to be a succession of intrusive ivents: from infrequent basic plagioclase - amphibole - andesite and magnetite - andesite dykes, to more acid normal amphibole - augite - andesite dykes, which are the most common. The younger dykes, represented by the most acid amphibole - augite andesites, follow lines of transverse faults marked by crush-breccia, thus post-dating the Savian deformation. Basing on palaeomagnetic dating, the younger andesite dykes have been dated as the Badenian - Sarmatian boundary.

Exposure 10. Szczawnica-Rzeznia (Stratigraphy of the Grajca
rek unit: M.Jurassic - L.Cretacous).

Sokolica Radiolarite Fm. (Bajocian-L.Oxfordian): Czajakowa Radiolarite Fm. (L.Oxfordian); condensed Pieniny Limestones Fm. ((Tithonian- ?Aptian); Kapusnica Fm. (lower part Brodno Member, Aptian-Albian); Wronine Fm. (Albian); Malinowa Shale Fm. (Cenomanian-Campanian); Jarmuta Fm. (Maastrichtian) are exposed here. They represent lower part of the Magura succession (Fig.17).



Grajcarek unit. Szczawnica, rzeźnia.
/after K.Birkenmajer 1979/

1-3 - Radiolarite fm. 4- Czorsztyn limestones Fm.
5 - Pieniny limestones Fm. 6 - Kapuśnica Fm.
7 - Wronine Fm. 8 - Jarmuta Fm.

Exposure 11. Homole Gorge (tectonics and stratigraphy of the Czorsztyn and Niedzica successions).

This an unique area, where relicts of late Creataceous Nappes almost undeformed by Tertiary diastrophism are preserved in their original position and form. They are thrust over the Czorsztyn autochthone (Fig. 18). In its present form, the Homole Block is rimmed by strongly refolded Cretaceous nappes and their post-nappe (Paleogene) cover. The Block is being disturbed by gravity faulting since Late Miocene - Pliocene upwarping of the block along a transversal (meridional) axis due to diapirism of Aalenian shales released by downcutting of streams through the Malm - Dogger limestones rocks. In the down-thrown block, at Czajakowa Skala, we see well preserved remnant of the Late Cretaceous Niedzica Nappe forming one larger fold recumbent progressively to the north and several minor folds and scales. The stratigraphic composition of the Niedzica Nappe showing condensed sedimentatation of Middle Jurassic - Late Cretaceous strata.

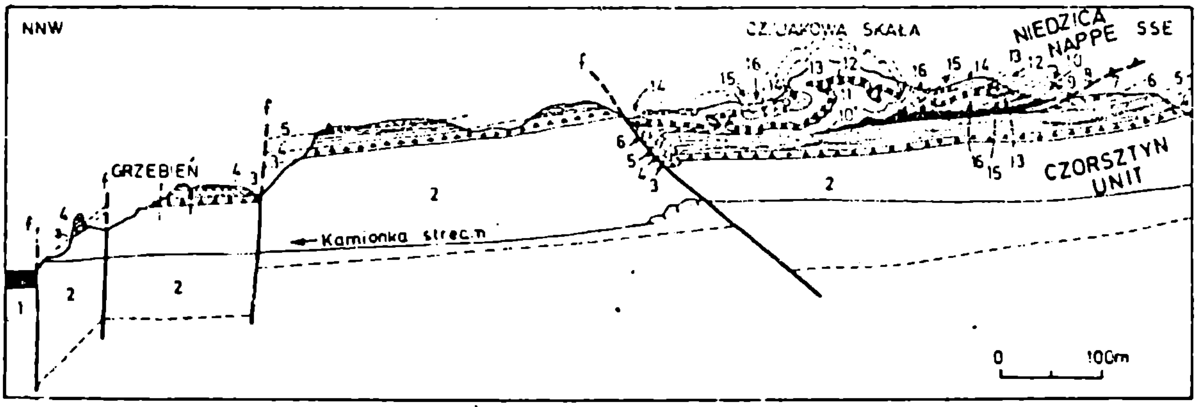


Fig. 72. Geological cross-section of the Homole Gorge /after Birkenmajer, 1958, 1979/
Czorsztyn Unit: 1 - Skrzypny Shale Fm.; 2 - Smolegowa Limestone Fm.; 3 - Krupianka Limestone Fm.; 4 - Czorsztyn Limestone Fm.; 5 - Dursztyn Limestone Fm.; 6 - Pomiedznik Fm.; 7 - Jaworki Marl Fm. Niedzica Nappe: 8 - Krempachy Marl Fm.; 9 - Skrzypny Shale Fm.; 10 - Krupianka Limestone Fm.; 11 - Niedzica Limestone Fm.; 12 - Czajakowa Radiolarite Fm.; 13 - Czorsztyn Limestone Fm.; 14 - Dursztyn Limestone Fm.; 15 - Pieniny Limestone Fm.; 16 - Kapuśnica Fm.; heavy lines denote faults /f/; barbed overthrusts

VI. TATRA MTS.

The Tatra Mts. are a northern fragment of the Central Carpathians. It consists of several rootless surficial nappes (Sub-Tatric nappes) built of the Mezozoic rocks and para -autochthonous High Tatric Zone where pre-Triassic cristalline basement is visible (Fig.19). This core is built of granitoids (granodiorites, tonalits, alaskites) and various metamorphic rocks (gneisses, migmatites, amphibolites) partly originated during the Variscan cycle. The Mezozoic rocks of the Sub-Tatric nappes exhibit generally furrow, and High Tatric well expressed geanticlinal features. The oldest rocks in the Polish part of the Tatra are red sandstones of the Early Triassic age which in the High-Tatra Zone are lying transgresively on the crystalline core. The sediments which belong to higher tectonic units originated in more southerly situated realms and were transported to their present day position (Fig.20, 21) during Upper Cretaceous tectonic movements. Development of the Tatra deposits are partly similar to the Alps ones with Hauptdolomit and Koessen beds in Triassic of Middle Sub-Tatric Nappe, Ramsau dolo-mites, Reifling Limestones, Wetterstein Dolomites of the Upper Sub-Tatric Nappe, Gresten facies, Fleckenmergel and Biancone limestones of the Lower Sub-Tatric Nappe among others. The typical sediment for the Tatra is variegated Carpathian Keuper. The Lower or Middle Cretaceous rocks terminate the sedimentation of the whole Tatra sequences. The Tatra units are prolongations of the tectonic units distingushed in the Calcareous Alps. The High Tatric Zone is correlated with the Lower Austroalpine nappes and the Lower Sub-Tatric Nappe (Krizna unit), Middle Sub-Tatric Nappe (Choc unit) and Upper Sub-Tatric (Strazov) Nappe with the Middle Austroalpine nappes.

After the Mediterranean orogenic phase Tatra was subjected to erosion and in the Late Lutetian came a new marine transgresion covering the whole Tatra massif. The sedimentation started with conglomerates and nummulitic

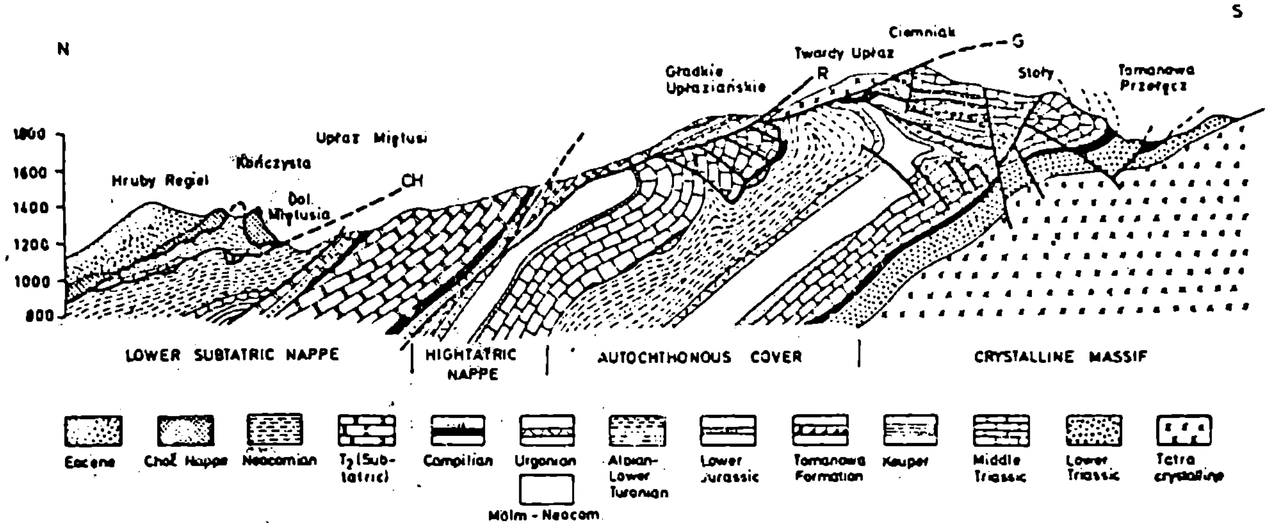


Fig. 27. Geological cross-section of the eastern slopes of the Kościeliska Valley /after F. Rabowski, S. Sokołowski, Z. Kotański, and others/

CH - overthrust of the Choč Nappe; R - overthrust of the Križna Nappe; G - overthrust of the Hightatric Giewont Unit /thrust-fold/

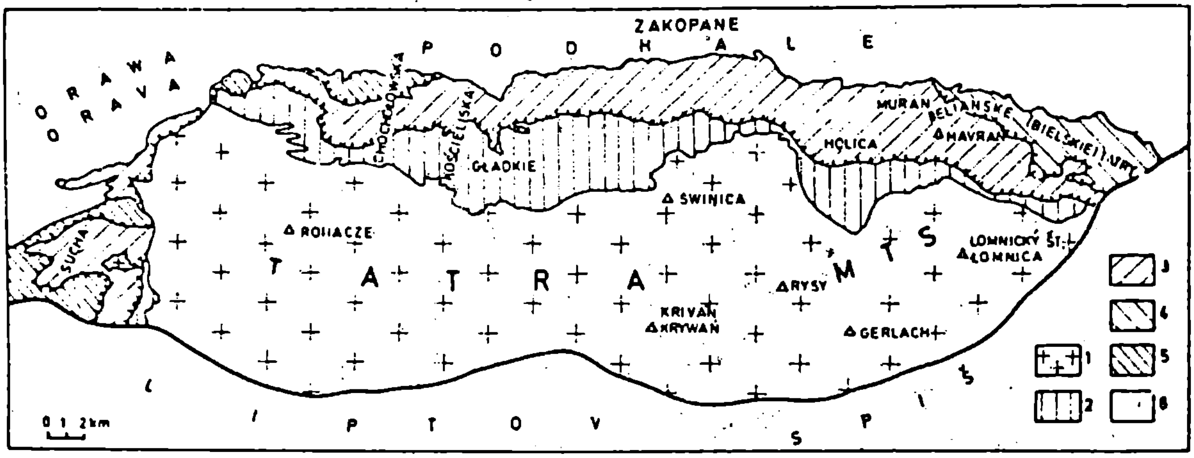
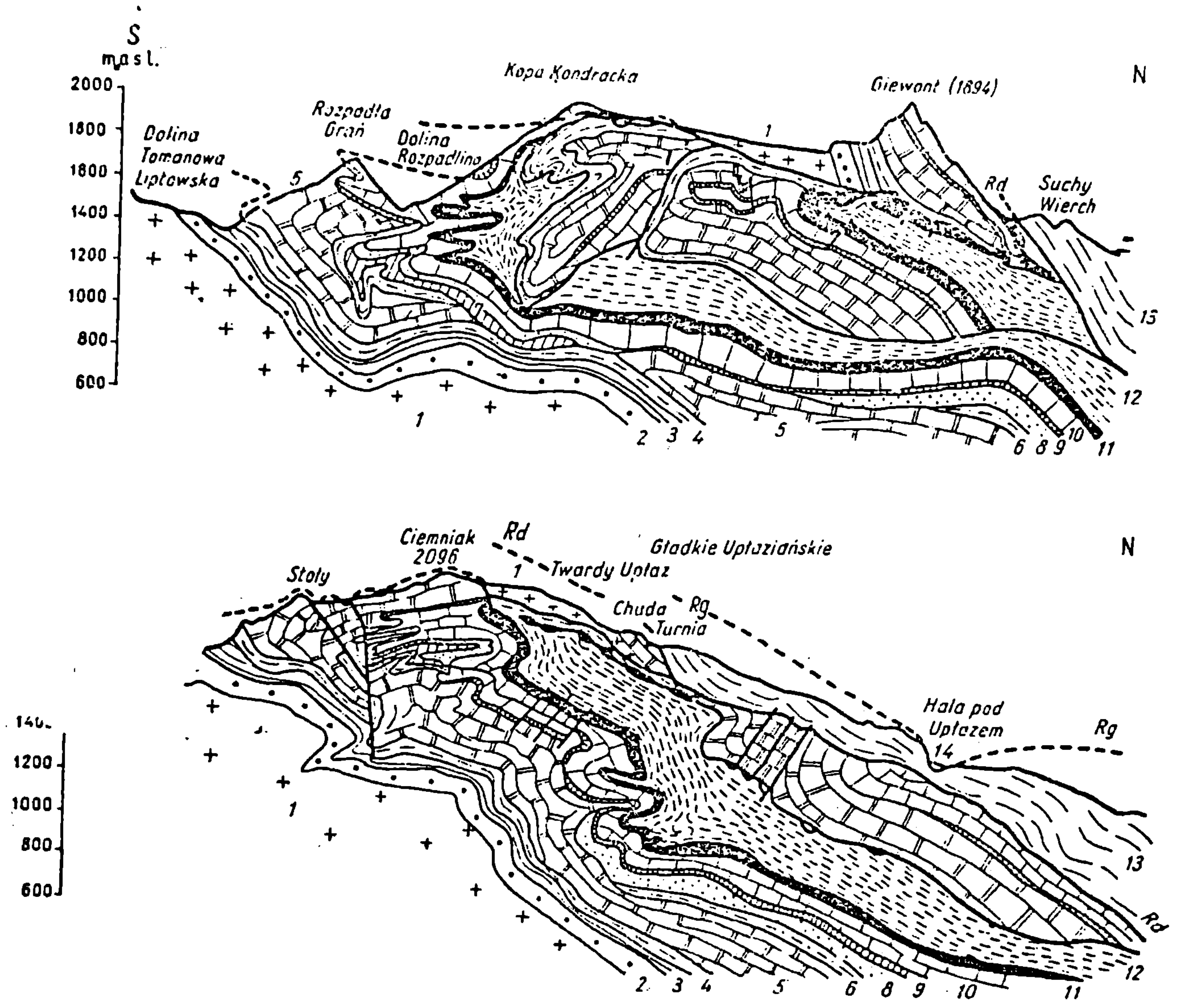


Fig. 25. General geological sketch-map of the Tatra Mountains /compiled from various sources by J. Lefeld/

1 - crystalline core of the Hightatric unit; 2 - Hightatric zone: sediments and overthrust crystalline rocks; 3 - lower Subtatric zone; 4 - Bujači partial nappe; 5 - middle Subtatric zone; 6 - Palaeogene flysch and basal nummulitic limestone and conglomerate. Barbs toward upper tectonic unit



Cross-section of the High Tatra unit in the Mt.Czerwone Wierchy massif, after Z.Kotański

1-crystalline rocks, 2-Lower Seisian, 3-Upper Seisian, 4-Campilian, 5-Middle Trias, 6-Keuper, 7-Rhetian, 8-Lias, 9-Dogger, 10 -Malm and Neocomian, 11-Urgonian, 12-Albian; 13-lower Sub-Tatra Nappe, 14-upper Sub-Tatra Nappe, Rd - overthrust of the lower Sub-Tatra Nappe, Rg - overthrust of the upper Sub-Tatra Nappe.

limestones which pass upwards into black shales and marls (Zakopane Beds) of Oligocenian in age. The shally facies pass upwards gradually into flysch sequence about 3000 m thick (Podhale Flysch, Central Carpathian Paleogene). The transport of material was from the west. Occasionaly there occur slump deposits and intercalations of tuffites. The Paleogene deposits built slightly folded syncline of the tectonic contact with the Pieniny Belt.

Exposure 12. Zakopane - Capki quarry (Nummulitic limestones Late Lutetian).

In the quarry we examine the oldest part of the Central Paleogene Succession (Fig. 22). On the uneven surface of the Ladinian dolomites rest blocks of dolomites and the Liassic sandstones in sandy matrix. They represent probably cliff facies. These deposits pass upwards into dolomitic sandstones and organic limestones abundant in Nummulites and Discocyclines. Here thick complexes of conglomerates known from other parts of Tatra (Fig. 23) do not exist. Locally nummulitic facies disappear and farther to the West near ski jump the sequence start with black shales with few conglomeratic layers (up to 5 cm. thick) only.

Exposure 13. Zakopane - Bialy creek (Zakopane shales - Oli gocenian-pre flysch complex).

In valley of the creek, a bed of conglomerate built of the Tatric material rest unconformably on the Ladinian dolomites (Fig. 21). The conglomerate is passing upward into nummulitic limestones less than two metres thick. The limestones are covered by thick complex of black shales with ankeritic layers and in the lower part of sequence with thin (several cm thick) intercalations of conglomerates with nummulites and discocyclines. Material of conglomerates represent a local, Tatric rocks. In the higher part of the sequence there are appearing intercalations of turbidites, and black shales pass succesively upwards into shaly and

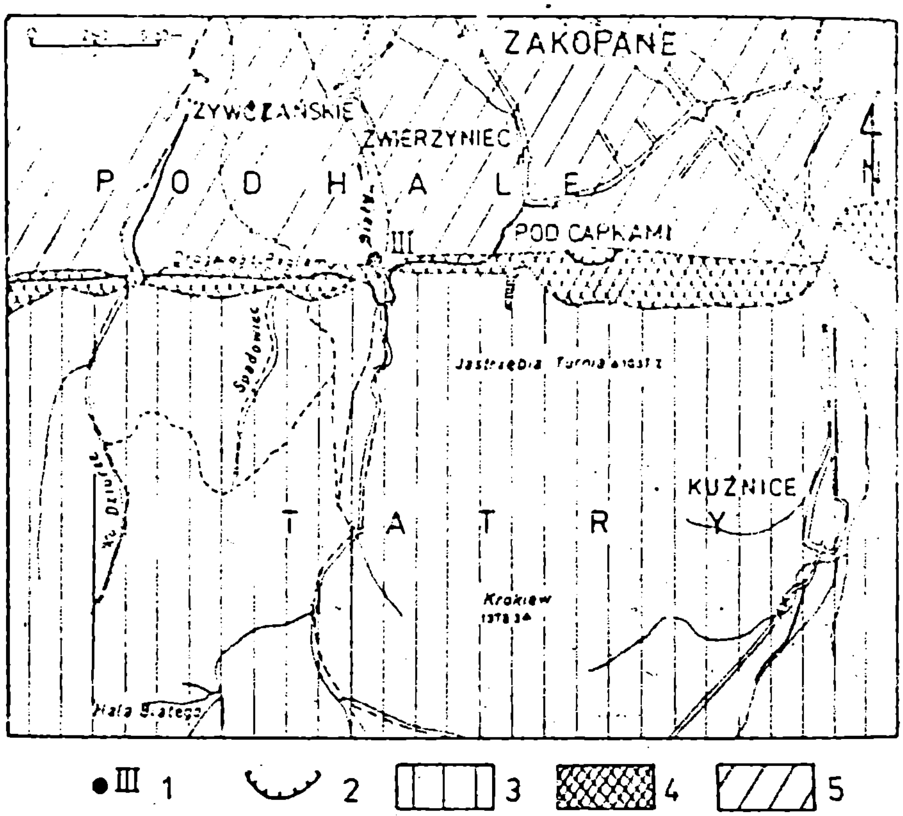


Fig. 23. Sketch-map showing the localization of exotic rocks exposure in Biały creek /III/ and Pod Capkami quarry

1 - exotic rocks exposure, 2 - quarry, 3 - Tatra sedimentary series, 4 - Carbonatic Eocene, 5 - Zakopane Beds

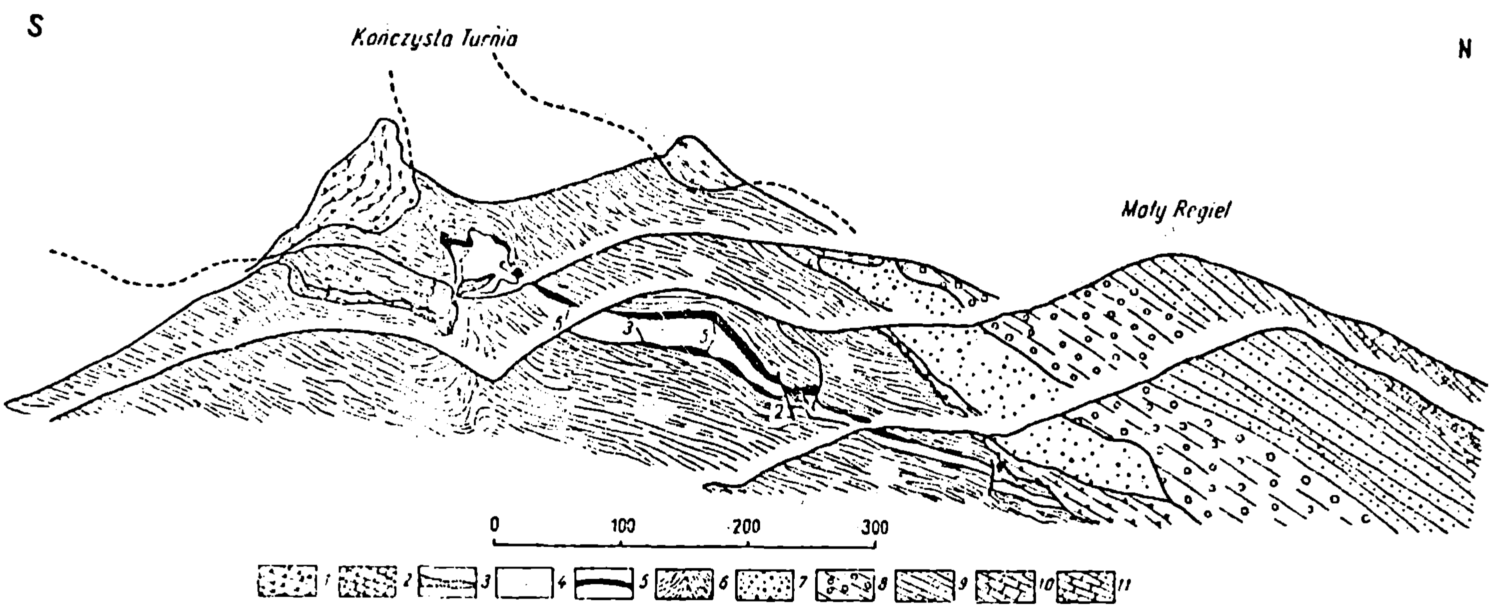


Fig. 216. Cross-section of the eastern slope of the Dolina Kościeliska Valley, down the Dolina Miętusia Valley, after S. Sokolowski

Upper Sub-Tatra Nappe: 1 — Lias (crinoidal and crystalline limestones); Lower Sub-Tatra Nappe: 2 — Middle Trias (dolomites), 3 — Upper Trias (sandstones), 4 — Tithonian — Neocomian (white limestones), 5 — Tithonian — Neocomian? (red limestones), 6 — Neocomian (marls and limestones); transgressive Eocene: 7 — red conglomerates, 8 — grey conglomerates, 9 — detrital dolomites, 10 — dolomitic limestones, 11 — Nummulite limestones higher in sandy flysch (Chocholów Beds). Examined part of the Zakopane shales is folded and faulted.

Exposure 14. Kasprowy Wierch - Liliowe pass (High-Tatric Zone - crystalline and its sedimentary cover).

On the path from Kasprowy Wierch towards the East we observe biotite gneisses, migmatic granitoides, amphibolites and on Beskid Mts. pegmatitic granites. Beneath them, strongly tectonized Lower and Middle Triassic limestones and dolomites are visible. These rocks belong to overturned Giewont Klippe. Liliowe Pass is built of the Albian marls and farther on we cross white Urgonian limestones and small exposures of the Neocomian and Malmian limestones. Yellow Kampilian dolomites are preserved only locally. These rocks are in contact with red quarzitic sandstones and shales of the Lower Triassic, which are the oldest sediments of the Polish part of the Tatra Mts. and they rest on strongly eroded and weathered granitoides. These granitoides built the whole ridge.