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NEW DATA ON STRUCTURE OF THE FLYSCH CARPATHIANS

UKD 551.243.4:551.763.3/.78:551.263.23]:001.12(438 – 924.51) = 20

The VIth Congress of the Carpatho-Balkan Geological Association (CBGA), organized in this country in 1963, mainly presented developments in the field of stratigraphy of the Flysch strata, a wide range of problems connected with sedimentation of these strata and reconstructions of paleogeographic and bathymetric conditions in the Flysch basin in Poland. Most important of these developments have been presented in two highly informative publications prepared for the Congress: an excellent monograph "Stratigraphie des Karpates externes polonaises", which is a collective work of five authors (F. Bieda et al., 1963), and "Geological Atlas of Poland, Stratigraphic-facies Questions, Part 13, Cretaceous and Lower Tertiary in the Polish Outer Carpathians", prepared by a team of fourteen authors and edited by Marian Książkiewicz.

The above works have been preceded by extensive mapping programmes. The results of works carried out after W.W.II made it possible to compile "Geological map of the Polish Carpathians", 1 : 200,000, Geological Institute, 1958, the eastern part of which was prepared by H. Świdziński (34), and the western by S. Sokołowski (32). An increase in intensity of the mapping works has been accompanied by wider introduction of micropaleontological works, carried out in four laboratories in Cracow. This markedly contributed to the accuracy of delineation of stratigraphic boundaries of the individual Flysch members.

On the basis of the above map, the first attempt was made to carry out a detailed tectonic regionalization of the Flysch zone, presented in the form of insets on the margins of both sheets. The "Karpaty" volume of the Regional Geology of Poland (1953) may be regarded as an explanation to the regionalization. In that volume M. Książkiewicz characterized tectonics of the western part of the Flysch Carpathians, and H. Świdziński – of the eastern part (between the Dunajec and San Rivers). In 1963, S. Wdowiarz presented an outline of stratigraphy and tectonic of the Flysch zone in the northern and eastern Carpathians, differentiating five tectonic elements in the area of Poland. The names of these units became accepted and used by M. Książkiewicz (21), with minor modifications. At the international forum of CBGA, the questions of tectonics of the Polish part of the Carpathians were presented as a part of explanations to the Tectonic Map of the Carpathians and Balkans, prepared by L. Koszarski, W. Sikora, and S. Wdowiarz (14). The ultimately accepted names of tectonic elements are as follows: 1) Magura nappe, 2) Fore-Magura unit, 3) Dukla unit, 4) Silesian nappe, 5) sub-Silesian unit, 6) Skole nappe, 7) Outer Flysch, and 8) Stebnik unit.

The above mentioned work presents the state of knowledge of individual zones and their basement for the year 1972. The following years brought further achievements, especially due to an increase in depth range of drillings made by the oil industry in search for oil and gas, and by the Geological Institute (Cracow Branch) in surveys on deep structure of the Flysch. We assume that it is justified to present to participants of the XIIIth CBGA Congress further advances in the knowledge of this region, including abundant material of borehole data concerning the basement in both the outer part of the Flysch zone and the Carpathian Foredeep. A. Ślączka discusses the Dukla unit, S. Wdowiarz – the eastern parts of the Silesian and sub-Silesian units, Skole nappe and Stebnik unit, and M. Cieszkowski – the Magura nappe, western parts of the Silesian and sub-Silesian units, and units of the Fore-Magura zone. In the accompanying paper S. Jucha discusses the basement of the Carpathians and Carpathian Foredeep (sensu lato).

In the above mentioned paper of 1974, S. Wdowiarz also presented structural outline of the Carpathian Foredeep. The range of the works may be best illustrated by the amount of borehole material analysed by this author for his paper of 1976: over 160 borehole columns from marginal Flysch zone about 25 km wide. The number of the analysed borehole columns will increase to almost 300 if we take into account those from more inner parts of the Carpathians. It should be mentioned that these works were completed with a success of discovering significant gas resources.

Magura nappe is the innermost unit of the Western Flysch Carpathians, thrusted over strata of various units of the outer group: Silesian nappe, and Fore-Magura and Dukla units. Together with the Silesian unit they represent the largest nappes of the Polish Carpathians. In its northern part, it forms a cover from several tens to over a thousand meters thick, which is confirmed by borehole columns Sucha IG-1 (3,850 m), Bystra IG-1 (3,787 m), Tokarnia IG-1 (3,936 m) Trzebunia IG-1 (3,053 m), and Trzebunia 2, and in the southern it may reach 1,500 – 2,600 m in thickness: borehole columns Obidowa IG-1 (4,570 m), Chabówka 1 (5,101 m), Słopnice 1 (4,508 m), and Słopnice 20 (4,500 m). Seismic surveys suggest that it may exceed 4,000 m in thickness in the peri-Pieniny zone, and the drilling Jarošov-1, made in Moravy, was stopped at the depth 4,578 m still in strata of that unit.

Flysch strata of the Magura nappe, mainly representing Upper Cretaceous and Paleogene, markedly differ from their time equivalents in other units of the Outer Carpathians. In Poland, the oldest rocks – Albian dark shales and Cenomanian variegated green shales are known from margins of the Mszana Dolna tectonic window (7) and borehole Obidowa IG-1 only. They are overlain by Turonian variegated shales, known from more numerous localities. The Senonian and Paleocene are mainly developed as thin-bedded sandstones and shales (normal flysch) of the Ropianka Beds (Inoceramian Beds) throughout the Magura nappe. Towards the north, the strata pass into sedimentologically similar ones, known as the Biotite or Biotite-Feldspar Beds ("Biotite Cretaceous"). Between Rabka and Nowy Sącz, the Lower Senonian comprises strata of the Kanina Beds, representing a variety of the normal flysch. The Upper Senonian and Paleocene of the Ropianka Beds comprise thick-bedded, often conglomeratic muscovite Szczawina sandstones with features of typical fluxoturbidites. Magura nappe sections of the peri-Pieniny zone display Jarmuta sandstones and conglomerates, occuppying the same stratigraphic position (1).

Laramide movements changed Late Cretaceous and Paleocene configuration in the Magura part of basin of the Flysch Carpathians. A new configuration, further modified in the Eocene and Oligocene times, resulted in differentiation of a number of facies zones in this area. Tectonic structures overprinted on the zones make it possible to identify several tectono-facies zones in the Magura nappe (19, 29, 26, 15, 42). In explanations to "The tectonic map of the Carpathians", CBGA, Bratislava, L. Koszarski et al. (14) proposed to differentiate the following subunits in Polish part of the nappe (from the south northwards): 1) Krynica, 2) Bystrica (Sącz zone), 3) Rača (southern Gorlice zone), 4) Siary (northern Gorlice zone), and 5) Harklova.

Sedimentation of variegated shales, initiated in the latest Paleocene, was developing diachroneously in the Magura nappe. It was continuing locally even till the Late Eocene in the Siary subunit, and till the Middle Eocene in the Rača subunit, being limited to the earliest Early Eocene in the Bystrica subunit, and sometimes completely absent in the Krynica subunit. The variegated shales are usually overlain by strata of the normal flysch facies: the Beloveža Beds (Lower Eocene) in the Bystrica subunit and Hieroglyphic Beds typical of the Middle and Upper Eocene in the Rača subunit. Marly-shaly facies of so-called Łącko Marls (the major component of the Łącko Beds) appears in the Middle Eocene of the Bystrica subunit. Upper Eocene Sub-Magura Beds of the Siary zone somewhat resemble the latter in lithology.

Magura Sandstones developed in the muscovite (Orava) facies are most typical of the Paleogene in the Magura series. Their sedimentation started in the Early Eocene in the Krynica subunit, late Middle Eocene in the Bystrica subunit, and Late Eocene in the Rača subunit. In the Polish Carpathians, sedimentation of these sandstones reached its peak in the Late Eocene and at the beginning of Early Oligocene and they reach maximum thickness, often over 1,000 m, in the Krynica (Gorce and Beskid Śląski) and Rača (Beskid Wysoki and Beskid Wyspowy) subunits. A few members characterized by predominance of these sandstones were differentiated for stratigraphic purposes in the Lower and Middle Eocene (1): Piwniczna Sandstones in the Krynica zone of the Beskid Sądecki, and Jaszcze Beds (Magura Sandstones with intercalations of the Beloveža Beds) in the Gorce. The overlaying Middle Eocene sandstones with intercalations of the Łącko Marls and rocks of the Hieroglyphic Beds type were named as the Kowaniec Beds. Two members occuppying stratigraphic position similar to the latter in the Bystrica subunit include the Maszkowice and Jazowsko Beds.

In the Siary zone the Sub-Magura Beds are overlain by sandstones named as glauconitic Magura Sandstones. Actually they represent a separate lithosome. Material for formation of these rocks was coming from northern margin of the Magura basin whereas that for formation of muscovitic Magura Sandstones was coming from alimentary area situated in the north.

The Malców and Supra-Magura Beds, dated at the Lower Oligocene, represent the youngest strata of the Magura Series. The Supra-Magura Beds, similar in lithology to the Sub-Magura Beds, are mainly known the Siary subunit in western part of the Magura nappe, and the Malców Beds – from all the subunits of the nappe east of the Dunajec River, and also the Krynica subunit in Podhale and Orava (9, 23). They represent facies equivalents of the Krosno Beds from the group of outer units. In eastern Slovakia, they often rest on variegated shales, Globigerina marls, and menilitic shales (18).

In the Harklova subunit, known from the Łużna and Harklova tectonic peninsulas only, Eocene variegated shales are overlain by Oligocene strata close inlithology but usually more marly than the Sub-Magura Beds.

The Magura nappe is folded into numerous synclines and anticlines. Moreover, internal loosenings of small amplitude developed in some places. Anticlines are usually narrow, with northern limbs thinned-out and often sliced, and synclines – wide and flat, with southern limbs often overturned to the north. East of the Dunajec River fold structure becomes more regular, synclines narrower, and anticlines steeper. In inner parts of the Magura nappe, especially in the peri-Pieniny zone, strata are often steeply inclined and often overturned to the south. Inversion of relief is a common phenomenon in the Magura nappe. The majority of most prominent crests in the Beskidy part of its distribution are built of syncline-infilling Magura Sandstones. Major fold structures of the nappe are SW – NE oriented west of the Skawa River, and S – W – between the Skawa and Dunajec Rivers, gradually changing their orientation east of the Dunajec River to NW – SE in areas west of the Biała River.

Northern margin of the Magura nappe is erosional. Its course is relatively straight in the west, becoming more diversified east of the Biała River. In the latter area there are differentiated the Łużna and Harklova tectonic peninsulas, and north of the Harklova peninsula – some tectonic caps (also sometimes interpreted as olistoliths in the Krosno Beds of the Silesian nappe). Within the Magura nappe there are developed a few tectonic windows in which crop out strata of units of the Fore-Magura zone. The largest of them is the Mszana Dolna window (4). The remaining, small windows represent in tectonic style scales teared-off from the base and pulled into zones of internal overthrusts within the Magura nappe.

In the south, peripheral part of the Magura nappe, called as the peri-Pieniny zone, directly contacts the Pieniny Klippen Belt – a steeply standing and internally complicated higher order structure. Tectonic contact of the two tectonic units is of the dislocation type and very clear.

Due to post-Paleogene folding phases, the Pieniny Klippen Belt became thrusted over the peri-Pieniny zone in the form of a nappe. In result of subsequent movements a part of steeply standing strata of the peri-Pieniny zone became overturned backwards and locally thrusted over the Pieniny Klippen Belt. In a few places strata of the Magura series form slices within the klippen series whereas brecciated strata of various klippen series are tectonically pulled-in between steep-standing scales of the peri-Pieniny zone at Orava (23).

Tectonic criteria for differentiation of individual subunits of the Magura nappe were repeatedly revised and, as noted by M. Książkiewicz (21, p. 206), differences in facies development of the strata still remain the only key here. Tectonic contacts of individual facies zones not always appear traceable. When represented by loosenings or small-scale overthrusts, they are generally not accentuated by any increase in amplitude, being not larger than overthrusts in internally sliced folds in a given facies zone. Original tectonic reconstructions with overestimated amplitudes of discontinuous deformations are at present corrected with reference to results of new, more detailed geological mapping, carried out taking into account facies changes and interfinging between individual zones. The mapping revealed existence of transitional zones between individual subunits, e.g. between the Krynica and Bystrica subunits in the Orava area (19, 21), the Sieniawa Gate, western part of the Gorce, as well as Beskid Sądecki and Beskid Niski (42). The situation was found to be similar at the contact of the Bystrica and Rača subunits in western Beskid Wysoki, and the latter and Siary subunit north-west of Nowy Sącz. Moreover, some facies changes have been found along the strike of structures in the Magura nappe. Significant differences in relation to Polish part of the nappe, found in eastern and western Slovakia, further complicate delineation of boundaries between individual subunits.

Discoveries of new localities of the Supra-Magura and Malców Beds previously misidentified with older strata in several areas, resulted in reinterpretations of local fold structures in western Beskid Wyspowy, Nowy Sącz area, and Dukla Pass. The discovery of the Malców Beds in Podhale and Orava had a decisive influence on reinterpretation of structure of the peri-Pieniny zone in this region (23, 9). In the Nowy Targ area, the zone has the form of a wide syncline, refolded and infilled with strata of the Malców Beds as far as its contact with the Pieniny Klippen Belt. In western Slovakia and Orava, the zone displays stronger internal tectonic deformations and, in its southern part, slicing. The infilling Malców Beds are partly covered with Neogene and Quaternary of the Orava – Nowy Targ Basin. The contact of the Malców Beds and Magura Sandstones along the outcrops of the former at right bank of the Dunajec River (line Dział – Niwa – Wżar) was previously interpreted as an overthrust of quite large amplitude. The interpretation appeared invalid and the contact – sedimentary in character when the question of age of the Malców Beds was solved.

Studies on stratigraphic position of the Malców Beds showed that the strata and underlaying Menilitic Shales and Eocene variegated shales represent normal stratigraphic cover of the Upper Eocene of the Magura series, as previously assumed by M. Książkiewicz and B. Lesko (18). Therefore, assignation of these strata to a separate Rychwałd tectonic unit, emerging from beneath the Magura nappe in tectonic windows according to H. Świ-

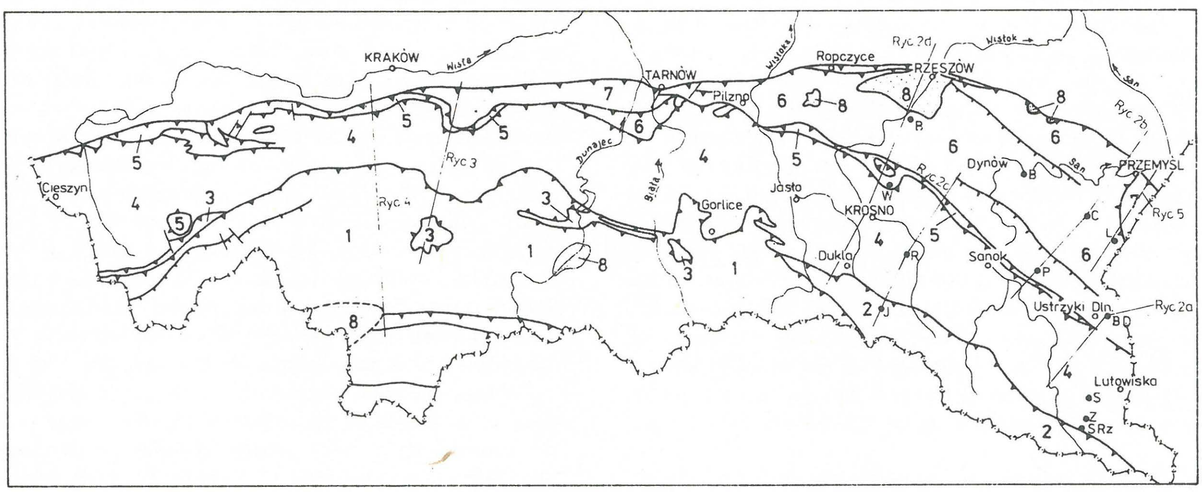
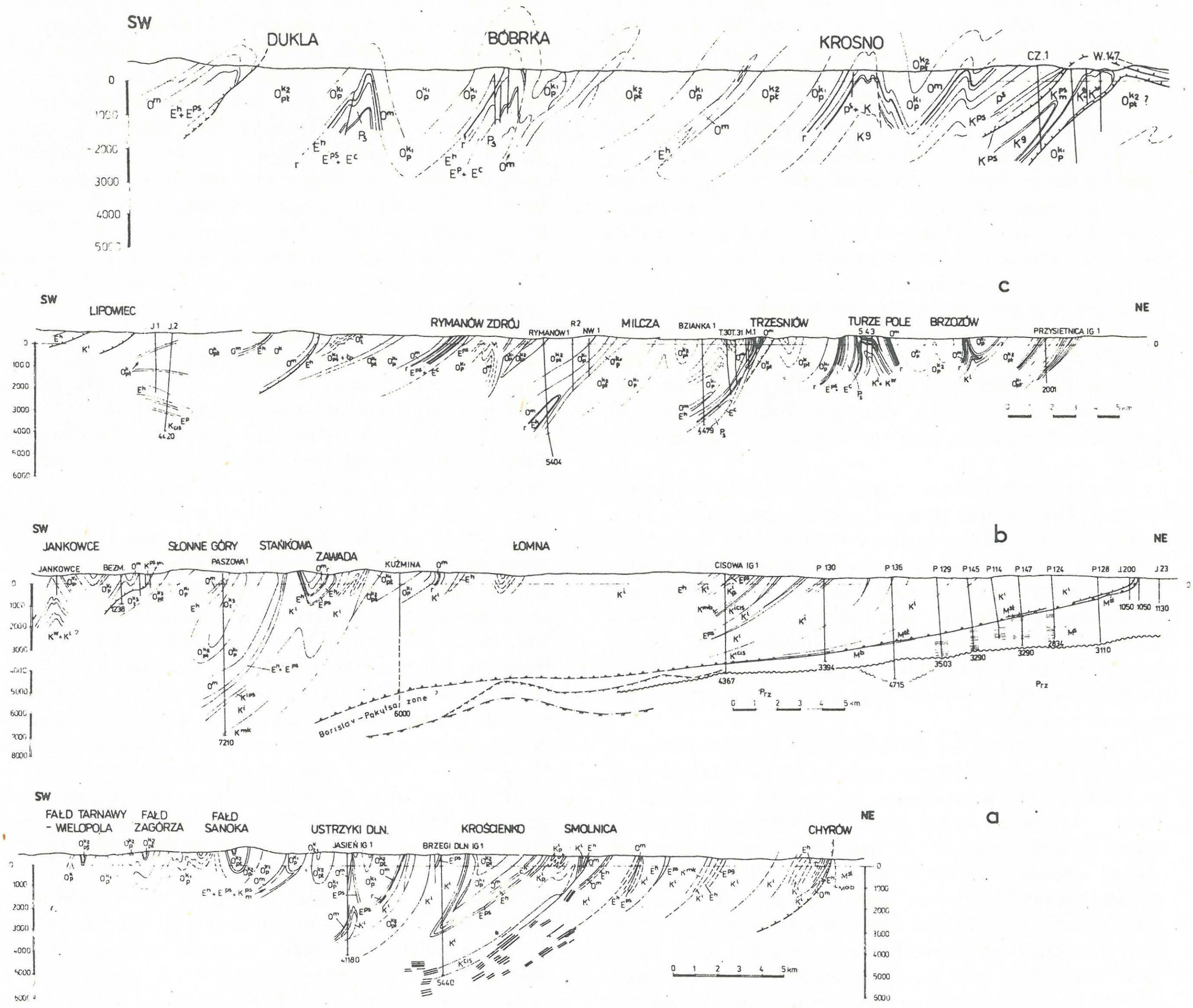


Fig. 1. Tectonic sketch of the Polish flysch Carpathians

1 – Magura nappe, 2 – Dukla unit, 3 – units of Fore-Magura zone, 4 – Silesian nappe, 5 – Subsilesian unit, 6 – Skole nappe, 7 – Stebnik unit, 8 – Miocene on the flysch.

Ryc. 1. Szkic tektoniczny polskich Karpat fliszowych.

1 – płaszczowina magurska, 2 – jednostka dukielska, 3 – jednostki strefy przedmagurskiej, 4 – płaszczowina śląska, 5 – jednostka podśląska, 6 – płaszczowina skolska, 7 – jednostka stebnicka, 8 – miocen na fliszu.



dziński (35), appears invalid similarly as the Rychwałd unit as defined by H. Świdziński.

In the Polish Flysch Carpathians, two major **intramontane basins** developed in the Magura nappe: Orava – Nowy Targ and Sącz basins infilled with Neogene and Quaternary sediments. Origin of these basins is regarded as related to existence of deep fractures in basement of the Carpathians (...). The former basin, also comprising some parts of the Pieniny Klippen Belt and The Central Carpathian Flysch, is developed in zone where the above mentioned deep fractures maximally converge. The maximum thickness of its infill approaches 1,000 m as shown by the borehole Czarny Dunajec IG-1. Origin of the other, Sącz basin, was determined by the existence of transversal dislocations overprinted on the peri-Carpathian fracture zone. Thickness of its infill may be up to c. 700 m as shown by geophysical data and borehole Nowy Sącz IG-1.

Dukla unit occupies a transitional position between the Magura and Silesian units. The Upper Cretaceous and Paleocene comprise strata analogous at those of the Magura nappe, i.e. the Ropianka (Inoceramian) Beds, except for the development of lithosome of thick-bedded Cisna Sandstones, typical of the Dukla unit. In turn, Upper Paleogene strata show strong affinities with the Silesian unit, being represented by the Menilitic and Krosno Beds. The Menilitic Beds are characterized by development of lithosomes of thick-bedded Mszanka and Cergowa sandstones, typical of the Dukla unit. Extent of these strata also comprises a part of the fore-Dukla zone, resulting in some differences in interpretation of the course of northern boundary of the Dukla unit west of Osława.

The Dukla unit is most strongly uplifted in its eastern part, mainly built of Upper Cretaceous and Paleocene strata, plunging north-westwards. Its southern extent is difficult to delineate, because of the cover of Magura unit strata. However, taking into account data from the Smilno area (Smilno tectonic window and a borehole) it should be assumed that it extends far to the south beneath the latter, and it may be over 40 km wide south of Dukla.

Within the unit, there may be differentiated two subunits (30), separated by major thrust plane and differing in tectonic style and, partly, lithofacies development. The differences are found to increase towards north-west. The outher subunit is built of steeply rising or even overturned backwards scales (as confirmed by boreholes at Wetlina and Jaśliska – Fig. 2c) but dips decrease along with increase in depth (borehole Jaśliska 2 – see 31). The inner subunit is characterized by presence of less steeply rised, sliced folds which attain the form of floes thrusted d

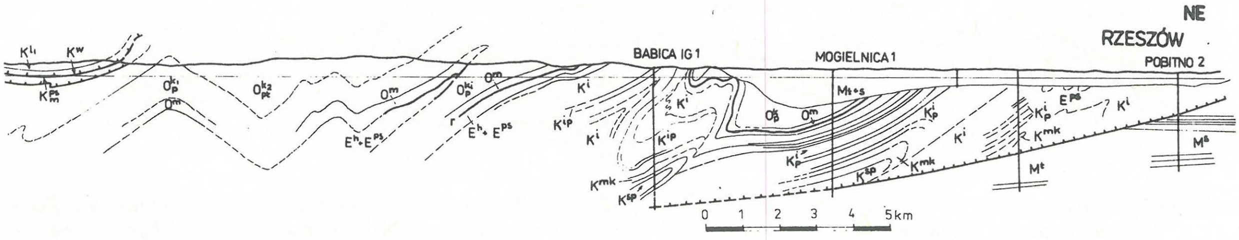


Fig. 2a, b, c, d. Geological cross-sections of eastern part of Polish Flysch Carpathians, by S. Wdowiarz.

Silesian nappe: K^w – Verovice Beds, K^l – Lgota Beds, K^{ps} – Godula shales, K^s – Lower Istebna Sandstones, p^s – Upper Istebna Sandstones, P^s_l – Istebna Shales, P^{ps} – Variegated Shales, O^m – Menilitic Shales; Krosno Beds: O^{kl}_p – sandstone horizon, O^{k2}_{pl} – sandstone-shale horizon; Sub-Silesian unit: K^{ps} – Godula shales, K^{ps}_m – Węglówka Beds, E^{ps} – Variegated Shales, E^h – green-gray shales, O^m – Menilitic Shales; Krosno Beds: O^{kl}_p – sandstone horizon, O^{k2}_{pl} – sandstone-shale horizon; Skole nappe: K^{sp} – Spas Shales, K^{ps} – variegated shales, K^{mk} – Siliceous Marls, K^i_{cis} – Cisowa Beds, K^i_p – Inoceramian Beds (thick-bedded sandstones), K^i – Inoceramian Beds, E^{ps} – Variegated Shales, E^h – Hieroglyphic Beds, E^{po} – Popiele Beds, r – hornstones; Krosno Beds, O^{kl} – sandstone horizon, O^{k2}_{pl} – sandstone-shale horizon, O^{k3}_l – shale horizon; Stebnik unit; M^{ab} – Aquitanian-Burdigalian (salt-bearing clays), M^{st} – Carpathian – Stebnik Beds, M^{bl} – Balice Beds, M^b – Badenian, M^s – Lower Sarmatian; autochtonous Miocene: M^b – Badenian, M^s – Lower Sarmatian; Platform substratum: P^r – Riphean variegated phyllitic shales).

Ryc. 2a, b, c, d. Przekroje geologiczne wschodniej części polskich Karpat fliszowych wg S. Wdowiarza.

Płaszczowina śląska: K^w – warstwy wierzchowskie; K^l – warstwy lgockie, K^{ps} – łupki godulskie, K^s – piaskowce istebniańskie dolne, P^s – piaskowce istebniańskie górne, P^s_l – łupki istebniańskie, P^{ps} – pstre łupki, O^m – łupki menilitowe; Warstwy krośnieńskie: O^{kl}_p – kompleks piaskowcowy, O^{k2}_{pl} – kompleks piaskowcowo-łupkowy. Jednostka podśląska: K^{ps} – łupki godulskie, K^{ps}_m – warstwy węglowieckie, E^{ps} – pstre łupki, E^h – zielono-szare łupki, O^m – łupki menilitowe; warstwy krośnieńskie: O^{kl}_p – kompleks piaskowcowy, O^{k2}_{pl} – kompleks piaskowcowo-łupkowy. Płaszczowina skolska: K^{sp} – łupki spaskie, K^{ps} – łupki pstre, M^{mk} – margle krzemionkowe, K^i_{cis} – warstwy z Cisowej, K^i_p – warstwy inoceramowe (gruboławicowe piaskowce), K^i – warstwy inoceramowe, E^{ps} – pstre łupki, E^h – warstwy hieroglifowe, E^{po} – warstwy popielskie, r – rogowce; warstwy krośnieńskie O^{kl} – kompleks piaskowcowy, O^{k2}_{pl} – kompleks piaskowcowo-łupkowy, O^{k3}_l – kompleks łupkowy. Jednostka stebnicka: M^{ab} – akwitan – burdygał (iły solonośne), M^{st} – karpatien – warstwy stebnickie, M^{bl} – warstwy balickie, M^b – baden, M^s – dolny sarmat; miocen autochtoniczny: M^b – baden, M^s – dolny sarmat; podłoże platformowe: P^r – ryfej – pstre łupki fyllitowe.

on one another. The subunits are separated by relatively flat laying thrust plane. In the Zakarpacie, the plane presumably corresponds to that separating the Bereźnia (Dusin) and more external, Stawian zones.

The knowledge of nature and extent of thrust of the Dukla unit over more external, Silesian one, is highly important for analysis of tectonics of the former. The thrust plane is very clear in eastern part of the Dukla unit, separating two different facies zones. When strata encountered in deeper part of the borehole Zboj 1 (13, 12) actually represent the fore-Dukla zone, the scale of the overthrust would exceed 15 km in the Wetlina area. Northern boundary of the unit becomes less clear westwards. This is partly due to a marked reduction of marginal fold of the Dukla unit. North of Jaśliska, core part of the becomes diapiric in character. The fold becomes completely squeezed out in some places and the Krosno Beds of this unit directly contact those of the fore-Dukla zone. This was explained in terms of disappearance of the thrust plane in that area. However, the Krosno Beds reach the inferred thrust line at some angle, which speaks against that interpretation.

The above mentioned reduction of the marginal fold may be due to a local thinning out of the Cergowa Sandstone complex. Close to the western end of the unit (Skalnik fold), the thrust plane disappears and the Krosno Beds from the foreland seem to merge with those of the Dukla unit. Taking into account undoubtful overthrust in more eastward parts, it should be assumed that either the Dukla unit became subjected to marked sinistral rotation after the Oligocene or eastern part of the Silesian unit rotated dextrally, thrusting under the former. It is also possible that northward motion of the Dukla unit started already before the Oligocene, leading to a marked overthrust of its Cretaceous and Eocene strata on the foreland and that the movement was synsedimentary in character. Subsequent, post-Oligocene tectonic movements resulted in breaking of the continuity of Oligocene cover in places where it is thinner (i.e. in the east), and pushing movements.

West of Dukla, the Dukla unit completely plunges beneath the Magura nappe, emerging further to the west in a number of tectonic windows, including the Szczawa or even Mszana Dolna windows. The windows actually represent tectonic exotics, cut-off of the basement, folded together with the Magura nappe, and displaced northwards. The identification of the Tylawa Shale horizon in strata hitherto regarded as the Krosno Beds in the Grybów N window shows that they represent shaly-sandstone facies of the Cergowa Beds. This seems to support the view that the windows display strata of the inner subunit, characterized by this type of development of the Cergowa Beds.

The relation of the Dukla and Słopnice – Obidowa units still remains insufficiently known (10). The latter most probably represents merely a facies variety of the former (9), characterized by intense development of the Mszanka Sandstones and marked share of dark shales.

Units of the Fore-Magura zone, as interpreted here, include the Fore-Magura unit s.s., units of the Mszana Dolna and Klęczany – Pisarzowa tectonic windows, and the Grybów unit, encountered in drillings beneath the Magura nappe.

Fore-Magura unit sensu stricto (2) was differentiated in the front of the Magura nappe between Sporysz near Żywiec and Koniaków and Istebna near the Czechoslovakian boundary, in western part of the Polish Flysch Carpathians. Further westwards, in Czechoslovakia, it is tectonically broken up and occurs in the form of isolated

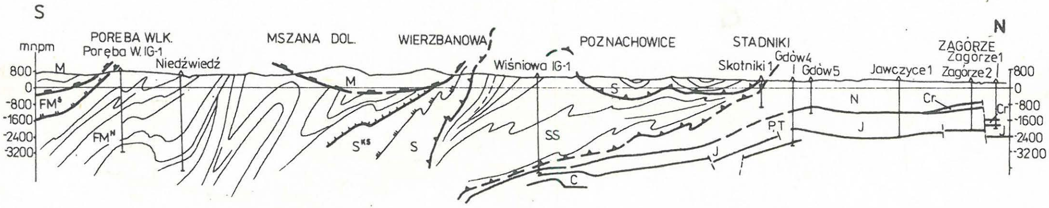


Fig. 3. Geological cross-section of Flysch Carpathians units south of Wieliczka by J. Burtan 1984.

Flysch Carpathians: M – Magura Nappe, FM^S – Southern Fore-Magura unit, FM^N – Northern Fore-Magura unit, S^{KS} – Silesian Nappe – Kurów Scale, S – Silesian Nappe, SS – Sub-Silesian unit. Carpathian Foredeep: N – Neogene (miocene), J – Jurassic, P+T – Permo-Triassic, C – Carboniferous.

Ryc. 3. Przekrój geologiczny przez jednostki tektoniczne Karpat fliszowych na południe od Wieliczki wg J. Burtan 1984.

Karpaty fliszowe: M – płaszczowina magurska, FM^S – jednostka przedmagurska południowa, FM^N – jednostka przedmagurska północna, S^{KS} – płaszczowina śląska – łuska Kurowska, S – płaszczowina śląska, SS – jednostka podśląska. Zapadlisko przedkarpackie: N – neogen (miocen), I – jura, P+T – permo-trias, C – karbon.

patches, and east of Sporysz it disappears from the surface.

Upper Cretaceous and Paleocene of the Fore-Magura unit are represented by "biotite Cretaceous" between Sporysz and Koniaków, similarly as in marginal zone of the Magura nappe. Lower part of the section comprises thin-bedded sandstones and shales resembling typical facies of the Ropianka Beds, and the upper – mainly feldspar-biotite sandstones with intercalations of fucoid marls in top part of that member.

Paleocene and Lower Eocene of the northern series are represented by variegated and gray marls, and Middle and Upper Eocene – successively by variegated shales, thin Hieroglyphic Beds, and green shales and Globigerina Marls. The Menilitic Beds (brownish shales with thin hornstone horizon in lower part), a transitional member of the Barutka Marls, and the Krosno Beds appear in the Oligocene. The Krosno Beds are built of thick-bedded sandstones of the fluxoturbidite type, sometimes with intercalations of conglomerates, in the lower part, and sandstones and shales in the upper.

Eocene of the southern series comprises variegated shales and marls with intercalations of thick-bedded sandstones of the Ciężkowice type, thin packets of the Hieroglyphic Beds, the Grójec conglomerates, and coarse-grained sandstones with nummulites. Oligocene is represented by Koniaków (Łużan.) detrital limestones and coarse-splitting shales with intercalations of sandstones lithologically close to the sub-Magura Beds.

The northern series represents fairly regular scale traceable along the whole length of the Fore-Magura unit and thrusted over the Beskid Śląski-building series of the Magura nappe. The southern series is preserved in the form of broken-up and strongly deformed tectonic elements squeezed into the northern series.

The Mszana Dolna tectonic window, recently studied in detail by J. Burtan (7, 4), is the largest of those found in Polish part of the Magura nappe. The window, surrounded by strata of the Bystrica and Rača subunits of the Magura nappe, displays two tectonic elements of the Fore-Magura unit: northern and southern. The southern unit comprises strata assigned to the Lgota Beds of the Albian – Cenomanian age, Cisna Beds (Senionan), "biotite Cretaceous" (Senonian – Maastrichtian), Paleocene dark shales with siderites, Eocene variegated shales and Oligocene Łużana Limestones and Krosno Beds. It is tectonically broken-up and reduced and its large fragments are known from northern and southern margins of the window. The northern unit, lower and folded at the surface, is represented by Oligocene strata only: Grybów Shales, Cergowa Beds, Menilitic Shales and Krosno Beds. Moreover, "black Eocene" strata, Hieroglyphic Beds, variegated shales, and underlaying "biotite Cretaceous" are known from deep drillings Poręba Wielka IG and Niedźwiedź 1.

The Mszana Dolna window is a tectonic elevation of basement of the Magura nappe. It is delineated in the south by a dislocation up to 1,000 m in amplitude. Towards the west of Raba Niżna and Olszówka, it gradually plunges, being traceable as far as the Skawa line. Strata of the Menilitic-Krosno series, represent the basement, have been recorded at depths c. 700 m in boreholes Rabka IG-1 and 2, and at depth c. 1000 m in borehole Skomielna 1.

In **the Klęczany – Pisarzowa tectonic window,** situated north of Nowy Sącz, J. Burtan differentiated two tectonic scales representing different series of strata. In the southern scale, the fore-Magura unit is represented by a series of strata known from the windows in the Grybów area, which makes it similar to the northern zone of the Mszana Dolna window: Eocene and Oligocene strata represented by variegated shales, Hieroglyphic Beds, sub-Grybów Beds, Cergowa Sandstones, Grybów Shales, Menilitic Shales with hornstones, and Krosno Beds. The northern element – the Kurów scale – comprises Cretaceous strata represented by the Upper Cieszyn Shales, Grodzisko Beds, Lgota Beds and Upper Cretaceous platy sandstones, Eocene Klęczany Beds, and Krosno Beds.

Grybów unit has been discovered by drillings Obidowa IG-1, Chabówka 1, and Słopnice 1 and 20, at depths c. 1500 – 2000 m, beneath overthrusted Magura nappe. It is thrusted over the Obidowa – Słopnice unit, and strongly refolded and sliced. Its thickness is varying from c. 500 m in borehole Obidowa IG-1 to over 1000 m in borehole Słopnice 1.

Lithostratigraphic inventory of the Grybów unit from the above mentioned boreholes comprises the Hieroglyphic, sub-Grybów, and Cergowa Beds, and Grybów Shales. Due to disturbances the strata often repeat in borehole columns. The finding of the Grybów unit beneath the Magura nappe in both the Słopnice and Obidowa areas indicates its vast distribution in western part of the Polish Flysch Carpathians.

Obidowa – Słopnice unit is known in the Polish Carpathians from deep drillings Obidowa IG-1 (4,570 m), Chabówka IG-1 (5,101 m), Słopnice 1 (4,508 m), and Słopnice 20 (4,500 m) only (10). It comprises Senonian – Paleocene Ropianka (Inoceramian) Beds with Lower Senonian sandstones resembling those of the Cisna Beds, and Maastrichtian exotic mudstones called as the Obido-

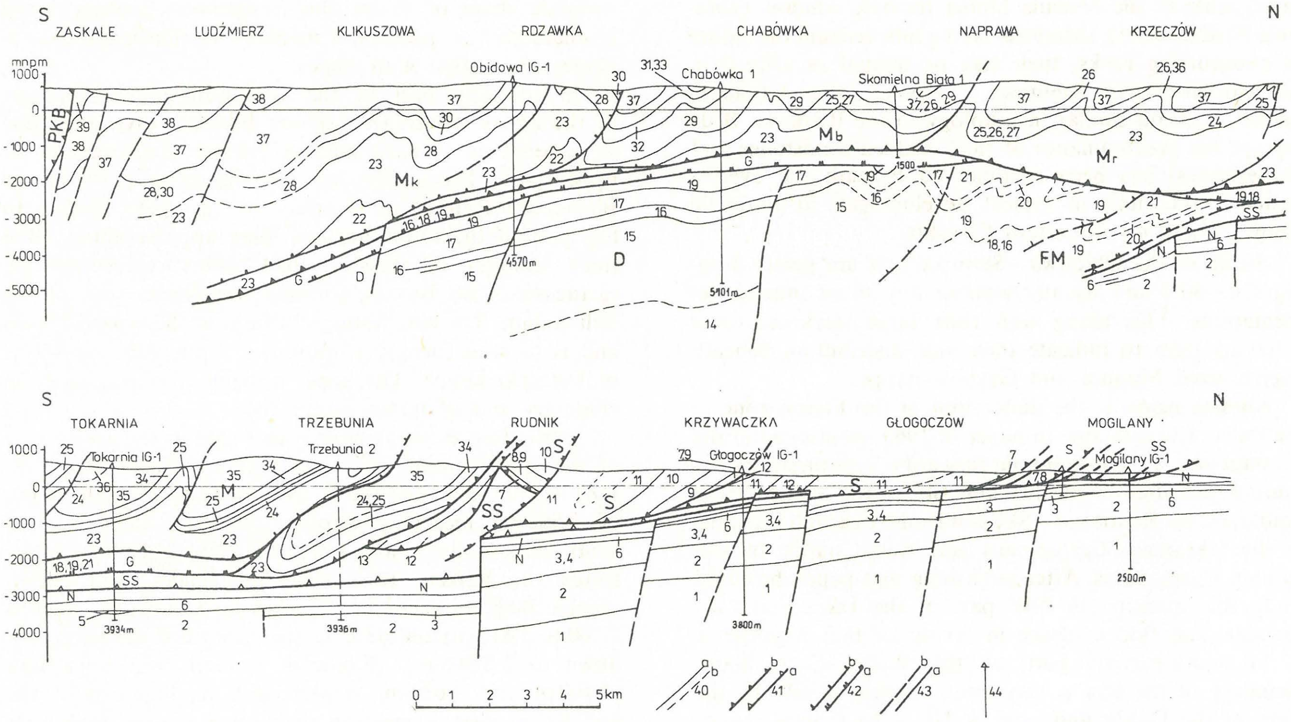


Fig. 4. Geological cross-section of Flysch Carpathians south of Cracow by W. Sikora et all 1980 corrected by M. Cieszkowski.

Carpathian Foredeep. Basement of Carpathian Foredeep. 1 – Cambrian, 2 – Middle and Upper Devonian, 3 – Lower Carboniferous, 4 – Lower and Upper Carboniferous, 5 – Permian, 6 – Middle and Upper Jurassic. Molassic deposits of Carpathian Foredeep: Neogene (Miocene).

Flysch (Outer) Carpathians: SS – Subsilesian unit: Cretaceous and Palaeogene, S – Silesian nappe: 7 – Grodziszcze Beds, 8 – Verovic Beds, 9 – Lgota Beds, 10 – Godula Beds, 11 – Istebna Beds, 12 – Ciężkowice sandstones and variegated shales, 13 – Krosno Beds.

FM – Fore-Magura unit, G – Grybów unit, D – Dukla unit (Obidowa – Słopnice unit): 14 – Lower cretaceous deposits, 15 – Ropianka (Inoceramian) Beds, 16 – Hierogliphic Beds, 17 – Rdzawka Beds ("Black Eocene"), 18 – Sub-Grybów Beds, 19 – Cergowa Beds, 20 – Grybów shales, 21 – Krosno Beds. M – Magura nappe: 22 – Albian and cenomanian deposits, 23 – Ropianka Beds, 24 – Ciężkowice sandstones, 25 – variegated shales, 26 – Hierogliphic Beds, 27 – Beloveza Beds, 28 – Jaszcze Beds, 29 – Łącko Beds, 30 – Kowaniec Beds, 31 – variegatet shales in various horisonts, 32 – Maszkowice Beds, 33 – Jazowsko Beds, 34 – Submagura Beds, 35 – Magura glauconitic sandstones, 36 – Above-Magura Beds, 37 – Magura Beds, Magura (muscovitic sandstones), 38 – Malcov Beds.

40 – Lithostratigraphic limits; a – controlled, b – inferred, 41 – Main overthrusts: a – Flysch Carpathians overthrust, b – Magura Nappe and Silesian nappe overthrust, 42 – Second order overthrusts: a – overthrusts of second order units, b – overthrusts of scale, 43 – Faults: a – controlled, b – inferred, 44 – Deep boreholes.

wa Beds. Among exotics of the Obidowa Beds there were identified fragments of Triassic and Cretaceous carbonate rocks in facies typical of the Inner Carpathians, and biotite-rich granitoids. The Obidowa Beds are overlain by the Bukowiec Wielki glauconitic sandstones of the Paleocene age and Eocene Hieroglyphic Beds with Lower Eocene horizon of variegated shales. The Upper Eocene comprises the Rdzawka Beds ("black Eocene") developed as thin-bedded sandstones with intercalations of black shales alternating with complexes of thick-bedded conglomeratic quartz sandstones and silty gravelstones. The

Ryc. 4. Przekrój geologiczny przez Karpaty fliszowe na południe od Krakowa wg W. Sikory et al. 1980 uzupełniony przez M. Cieszkowskiego.

Zapadlisko przedkarpackie. Podłoże zapadliska: 1 – kambr, 2 – dewon środkowy i górny, 3 – karbon dolny, 4 – karbon dolny i górny, 5 – perm, 6 – jura środkowa i górna. Utwory molasowe zapadliska: N – neogen (miocen).

Karpaty Fliszowe (zewnętrzne): SS – Jednostka podśląska; kreda – paleogen nierozdzielone utwory. S – Płaszczowina śląska: 7 – warstwy grodziskie, 8 – warstwy wierzowskie, 9 – warstwy lgockie, 10 – warstwy godulskie, 11 – warstwy istebniańskie, 12 – piaskowce ciężkowickie i łupki pstre, 13 – warstwy krośnieńskie.

FM – jednostka przedmagurska, G – jednostka grybowska, D – jednostka dukielska (jednostka Obidowej – Słopnic): 14 – utwory kredy dolnej, 15 – warstwy ropianieckie (inoceramowe), 16 – warstwy hieroglifowe z poziomami pstrych łupków, 17 – warstwy z Rdzawki („czarny eocen"), 18 – warstwy podgrybowskie, 19 – warstwy cergowskie, 20 – łupki grybowskie lub łupki menilitowe, 21 – warstwy krośnieńskie. M – płaszczowina magurska: 22 – utwory albu i cenomanu, 23 – warstwy ropianieckie, 24 – piaskowce ciężkowickie, 25 – pstre łupki, 26 – warstwy hieroglifowe, 27 – warstwy belowskie, 28 – warstwy z Jaszczego, 29 – warstwy łąckie, 30 – warstwy z Kowańca, 31 – pstre łupki w różnych ogniwach eocenu, 32 – warstwy z Maszkowic, 33 – warstwy z Jazowska, 34 – warstwy podmagurskie, 35 – piaskowce magurskie w facji glaukonitowej, 36 – warstwy nadmagurskie, 37 – piaskowce magurskie w facji muskowitowej, 38 – warstwy malcowskie.

40 – Granice litostratygraficzne: a – stwierdzone, b – przypuszczalne, 41 – Główne nasunięcia, a – nasunięcie Karpat fliszowych, b – nasunięcie płaszczowiny magurskiej i płaszczowiny śląskiej, 42 – Nasunięcia mniejsze: a – nasunięcia mniejszych jednostek, b – nasunięcia łusek, 43 – Uskoki: a – stwierdzone, b – przypuszczalne. 44 – Głębokie wiercenia.

Cergowa Beds developed in shaly facies are the uppermost member in this succession.

The sedimentary sequence of the Obidowa – Słopnice unit appears close in facies to that of the Dukla unit, differing in presence of c. 500 – 700 m complex of "black Eocene" strata only. Similar strata have been found at depth about 3,000 m in the series of northern (Fore-Magura) scale in the Mszana Dolna tectonic window (borehole Niedźwiedź 1), therefore, taking into account the nature of cooccurring rocks, they may be treated as affined in facies to those of the Obidowa – Słopnice unit. A 1,000 m packet of strata similar in lithology to the Rdzawka Beds (except for predominance of thick-bedded sandstones and gravelstones) has been encountered beneath the overthrusted Dukla unit in typical development, in borehole Zboj 1 (5,001 m) in eastern Slovakia.

Strata of the Obidowa – Słopnice unit are gently dipping (20 – 30°) and usually without any more intense deformations. This along with their large thickness (over 2,500 m) seem to indicate their vast distribution beneath overthrusted Magura and Grybów nappes.

Silesian nappe is the major unit in the Flysch zone in the Polish Carpathians. In paper of 1963, mentioned in the introduction, S. Wdowiarz put forward a hypothesis of continuous distribution of this unit SE of the Polish-Soviet boundary, as Kostrzyca – Skupowa and Czarnohora units in the Ukrainian Carpathians and Audia nappe in Romanian Carpathians. After publishing that paper, he could study this question in NW part of the Ukrainian Carpathians and find evidence in favour of that hypothesis.

In south-eastern part of the Polish Carpathians, boundary of the unit is very clear, marked at SW by the front of the Dukla unit, and at NE – by frontal rise of Lower Cretaceous strata in the vicinities of Sanok and Lesko. Further to south-east, it is traceable as a narrow streak of marls and variegated shales. The strata soon disappear and in the section up to the eastern boundary of the state, only the Lower Krosno (Raba) Beds are found.

The whole transversal section (27 km wide) through the eastern state boundary adjoining part of the Polish Carpathians is built of the Krosno Beds only. The strata do not represent a separate tectonic element (33) but an extension of the Silesian unit, forming so called Central Carpathian Synclinorium. The synclinorium is here built of 7 secondary structural elements. Reconstruction of all the elements in area from the eastern state boundary to the Gorlice meridian, i.e. at distance of 125 km, showing their axes and separating synclines, is presented elsewhere (S. Wdowiarz, in print). Despite of fairly monotonous development of the Krosno Beds, it appeared possible to differentiate at least three horizons on the basis of lithological and morphological data. The lower horizon, about 2000 m thick and characterized by gray colours, comprises packets of thick-bedded sandstones with subordinate share of shales and, sometimes, packets mixed in character, i.e. packets of medium- or thin-bedded sandstones alternating with shales.

In southern part of the synclinorium, development of the above mentioned horizon becomes diversified due to appearance of hard massive (Otryt) sandstones in its upper part. The sandstones, forming crest parts in the Bieszczady Range, are overlain by the Jasło Shales. In top part of the lower horizon there appears about 50 m thick complex of massive, thick-bedded glauconite-rich (glauconitic) sandstones, forming foundation soils of the Solina dam. The next horizon belongs to the typical Flysch and is of crest-forming importance south and south-west of Ustrzyki Dolne. The upper horizon is mainly shaly in character and of minor importance.

Some deep drillings have been made in the above part of the synclinorium. Of these, borehole Suche Rzeki (S. Rz.) did not penetrate the Krosno Beds down to the depth of 3,502 m, recording strong backward inclination of south-western limb, and borehole Zatwarnica (Z.) penetrated the Krosno Beds, Menilitic Shales, and Hieroglyphic Beds, to encounter Ciężkowice Sandstones (depths 2,760 to 2,812 m) and underlaying variegated shales (depths down to 2,820.6 m). Boreholes Smolnik and Lutowiska (4,400 m and 4,634 m, respectively), made north of the San River, were stopped in the Lower Krosno Beds, not penetrating them (9).

A new tectonic elements (Bystre slice), representing a part of the fore-Dukla unit, appears in the Hoczewka Creek spring basin, inner part of the synclinorium. The presence of Upper and Lower Cretaceous sequences beginning with the Upper Cieszyn Shales (i.e. developed in the Silesian facies), is the major feature of that element. The strata are traceable at 10 km distance and the element extends to NW. At distance of about 18 km core part of the element is built of the Menilitic Shales only but borehole data also show presence of Eocene strata in Silesian facies at its extension. In a section 20 km long, called as the Iwonicz Zdrój fold, there were found 4 horizons of Ciężkowice Sandstones alternating with variegated shales and Istebna Beds and the element achieves the form of a flat NE-oriented thrust with amplitude over 2 km (Wisłok River valley), and fold core becomes complicated by transversal and longitudinal dislocations. The fold becomes more and more steep west of Iwonicz. This is accompanied by plunging of the Eocene and, subsequently Menilitic Shales so the fold becomes finally marked in the Lower Krosno Beds in the Wisłoka River

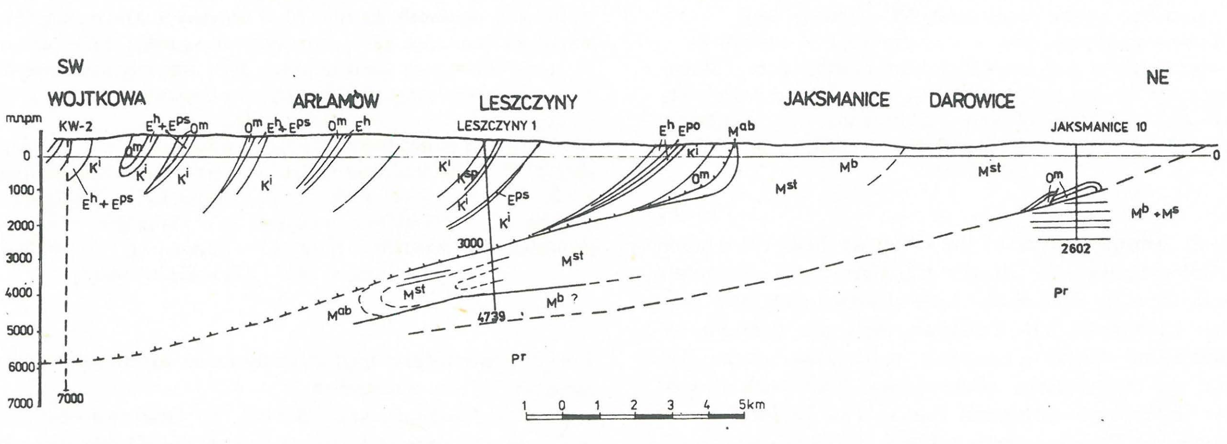


Fig. 5. Geological cross-section of Skole nappe and Stebnik unit south of Przemyśl, by S. Wdowiarz. Explanations like for ryc. 2.

Ryc. 5. Przekrój geologiczny płaszczowiny skolskiej i jednostki stebnickiej na południe od Przemyśla, wg S. Wdowiarza. Objaśnienia jak dla ryc. 2.

section. This indicates large amplitude of vertical displacements, estimated by me in the Iwonicz – Wisłoka River section at 2,000 m or more.

SE of the Bystre scale, markedly backwards overturned Suche Rzeki fold, about 5 km wide, forms foreland of the Fore-Dukla unit. The fold narrows to 2 km 35 km further to NW and its core begins to display narrow outcrops of the Menilitic Shales, traceable at 25 km distance. The shales disappear in 15 km section in the Wisłok River basin to reappear in the core. The core rises over 3000 m in section from Iwonicz to the Jasiołka Creek valley; the section of which displays 4 horizons of the Ciężkowice Sandstones, variegated shales and, subsequently, Istebna Sandstones. Fold core is here complicated by some transversal and longitudinal dislocations. The fold is latitudinally oriented and markedly asymmetric in a 10 km section up to the Wisłoka River valley: its southern limb, built of the Krosno Beds, is 3 km wide, and the northern reduced to 0.5 km. Borehole data confirmed complex structure of the core at Osobnica, NW of the Wisłoka River, where a secondary culmination of the fold has been found.

Central part of the synclinorium is occuppied by an element mainly built of massive thick-bedded sandstones which form the Otryt crest (938 m a.s.l.) along upper section of the San River. This element was traced at distance of some tens km SE of the state boundary in geological maps compiled before the w.w. II. It represents a scale thrusted to NE and the above mentioned borehole Smolnik, localized at its limb 2 km from the front, penetrated the Otryt Sandstones down to the depth of 1,200 m, which casts some light on the scale of the thrust. The discontinuity has been traced to NW as far as the Wisłoka River valley. The fold appears complex in character due to 2 – 3 refoldings, becoming up to 8.5 km wide in proximity of the state boundary. Drillings made in the Osława Creek valley showed that a syncline is deeply pulled into core part of the fold, and the overthrust plane also comprises strongly reduced NE limb. Transitional strata and even Eocene variegated shales crop out at the surface in the fold (Besko – Targowisko fold) core in 25 km section of the Pielnica Creek valley and also the Wisłoka River drainage basin.

Sections important for understanding deep structure of the above element include the Rymanów (with borehole Rymanów 1, 5,404 m deep), and Łubno (in which three drillings, including one 3,004 m deep, penetrated the fold). In the former, amplitude of the northward thrust exceeds 4 km, and in the latter – 5 km. Drillings which penetrated the fold core recorded green-gray or variegated Eocene shales, a reversed limb built of Menilitic Shales and Krosno Beds, and in the latter, a synclinal bend beneath the fold. Borehole Rymanów 1 (R.) penetrated a 1,000 m sequence of the strata beneath the bend, not encountering the old Flysch (Fig. 2c). The lack of the Ciężkowice Sandstones in the latter section is important from the point of view of tectonics as well as facies development of the Eocene. Taking this into account S. Wdowiarz put forward a hypothesis that the Ciężkowice (and possibly Istebna) Sandstones, known from marginal (northern and southern) furrows of this unit, are completely missing in central part of the synclinorium, which may be the reason of the above discussed style of the element.

Despite of some differences in development of the Krosno Beds and form of individual elements, outer part of the central synclinorium may be interpreted as a single large refolded tectonic element. The above mentioned borehole Lutowiska is one of several made in that zone, especially in the Osława Creek section. Some drillings made in the latter area reached depths over 2,500 m (and the deepest even 3,081 m), not reaching strata older than the Krosno Beds. As explained above, the front of the Silesian unit passes along the Raba – Równia – Olszanica – Załuż fold. NE of Lesko, core of the fold displays Upper Cretaceous strata (variegated marls), and subsequently Lower Cretaceous ones developed in the Lgota Beds facies, forming frontal rise of the whole unit. Borehole data show that it is thrusted over the Krosno Beds of the next unit.

In NW, Lower Cretaceous strata display marked tectonic complications, well known from drillings in the Grabownica oil field. In the next element, passing parallel to the above rise in SW, the Menilitic Shales and, subsequently, Eocene strata (but without the Ciężkowice Sandstones) crop out at the surface in vicinities of Sanok. The fold is characterized in that area by structure of the chimney type and drillings showed presence of the Upper Cretaceous in the red shale facies, and Lower Cretaceous in the black shale and Lgota Beds facies in its deep-seated core. It is cut by numerous transversal and vertical dislocations NW of Sanok, and Upper Istebna Sandstones crop out at the surface of its core 20 km from the latter area.

The frontal rise of Lower Cretaceous strata (Grabownica fold) is NW-oriented as far as Domaradz, subsequently turning westwards and passing into an overthrust, the amplitude of which increases in the same direction. At the same time a syncline, 3.5 km in width, separating that fold and the neighbouring one (Strachocina) outcrops in such a way that it changes into a southward inclined monocline in the Czarnorzeka section. The section here comprises strata from strongly reduced Lower Cretaceous through Upper Cretaceous with lower part (less than a hundred meters thick) developed in the red shale facies and the upper (800 m thick) represented by a complex of the Istebna Sandstones with marly intercalation in the middle, to Paleocene and Eocene developed in typical Silesian facies, with four complexes of Ciężkowice Sandstones and Menilitic Shales at the top.

Three more internal anticlines are generally more steep than the above ones in area NW of the Polish-Soviet boundary and, at distance of 65 km, they are built of the Krosno Beds only. Their development and internal structure may be best analysed in the classic Osława section. In that locality, the third of the folds (Czaszyn fold), 5 km wide, has a form of monoclinal body dipping to SW. Interpretation of the above mentioned boreholes (M. 100 – 103, Cz. 1, 2, and T.-W. 12 – 15) showed that older Flysch horizons are inaccessible here because of structural conditions. A change in this bunch of folds is marked in the Trześniów area, where borehole B. 1, 2.5 km distant from the fold axis and 4479 m deep, recorded Istebna sandstones and (thin) shales, Eocene strata with 2 intercalations of Ciężkowice Sandstones, and Menilitic Shales. This element, 700 m wide, is characterized by presence of intra-fold syncline, traceable down to the depth of 1500 m.

Further to the north, core of the above fold is built of the Menilitic Shales at distance of 30 km and, in culmination, of Eocene strata with 2 complexes of Ciężkowice Sandstones. Several drillings showed that structure of this fold is complicated by numerous transversal dislocations and a characteristic disharmony, connected with chimney-like structure of its upper part, and presence of an intra-fold syncline, deeply wedged-in in the upper part and gaining a gentle form in the lower. In the lower part it is built of the Istebna Sandstones, not penetrated by drilling down to the depth of 3300 m. Boreholes R. 31 and R. 32, made east of Jasło, penetrated 1200 m sequence of the sandstones, not reaching their base.

The loop of the Węglówka tectonic window (north of Krosno), repeatedly described in the literature, is related to frontal part of the Silesian nappe. In the tectonic loop, three units are superimposed: the Silesian unit (mainly represented by the Bonarówka patch), rests on the sub-Silesian which, in turn, rests of the Skole unit. The Bonarówka patch, ovate in outline and 6 × 5 km in size, is built of the Lgota Beds underlain by Wierzów Beds, and marked in terrain morphology as a flat elevation with steep slopes, well visible from large distances. Further to WNW in the Wisłok River valley, frontal part of the Silesian unit is built of crest-forming Upper Cretaceous strata (Istebna Sandstones), underlain by Lower Cretaceous ones and widely distributed NE of Brzostek. It should be noted here that a borehole localized at southern limb of the frontal fold at Frysztak (Wisłok River section), penetrated its base at the depth of 2615 m and, after passing 200 m sequence of the sub-Silesian unit, penetrated complete section of the Skole unit: from the Krosno Beds to upper part of the Inoceramian Beds.

At the Wisłoka River line, NW of Brzostek, the front of the Silesian nappe becomes torn apart to show strata of the Skole unit at 5 km distance. From that area to the Biała Creek, the front part of the nappe is built of shaly Lower Cretaceous strata, truncated by SW – NE oriented dislocation, traceable along 15.5 km distance and responsible for marked reduction of the unit. At the back of the unit, west of the Wisłok River, there is developed an anticlinal element mainly built of the Istebna Sandstones and marked in terrain morphology as a large forested ridge (Bzianka – Liwocz). The element is translocated in NE – SW direction by dislocation at the Biała Creek line, merging with the next one from the south, Ciężkowice – Rożnów element. It should be noted that is represents an extension of the above discussed Osobnica element, which continues as a narrow complex fold towards Ciężkowice. The latter was traced along with the central synclinorium at distance of about 110 km.

The Gorlice fold appears most important of secondary elements of the nappe, found east of the Wisłok River. It is delineated by two peninsulas of the Magura nappe: Harklova in the east, and Łużna in the west and its complex structure has been reconstructed on the basis of some deep drillings: the core is built of the Istebna Sandstones, truncated from below by a thrust plane, along which they contact the Krosno Beds of a deeper-seated, separate tectonic element.

The borehole Gorlice 11, the deepest in this area, was localized 1.9 km south of the fold front. It penetrated the fold down to the depth of 1100 m. The borehole Gr. 2, situated 2.1 km further to the south, penetrated it still deeper, down to 2.3 km. Thrust plane here dips southwards at the angle of 25°. Taking into account 40° dip of the fold limb, it may be assumed that the fold displays a trend to unrooting in that direction. The former of the above boreholes reached depth of 5236 m, penetrating 4136 m sequence of the Krosno Beds representing a syncline rolled up beneath the fold, and subsequently southern limb of the Biecz fold, found 7 km from that place. It follows that incomplete section of the strata (? Krosno Beds) is here 2,500 m thick.

The above fold is covered by 6 km packet of the Magura nappe west of Gorlice. It emerges from beneath the strata to divide into 2 steep, narrow folds which plunge towards the Dunajec River valley.

A wide Bobowa syncline, filled with the Krosno Beds, represents the westernmost part of the Central Carpathian Depression. The Jankowa anticline, situated S of the former, is known from a few boreholes. Of these, boreholes Łyczana 5 (2,826 m) and Łyczana 10 (2,035 m) penetrated the Menilitic-Krosno series to enter 3 horizons of the Ciężkowice Sandstones and Istebna, Godula, and Czarnorzeki beds. Northern limb of the Bobowa syncline passes into anticlinal structure of the Rożnów – Ciężkowice fold. At the Dunajec River line, core of the fold is built of the Godula Beds, and southern, southwards monoclinally dipping limb – the Istebna and Ciężkowice Sandstones. This is evidenced by borehole Siekierczyna IG-1 (4,809 m), penetrating almost 4,500 m sequence of the Istebna and Godula beds and underlaying Lower Cretaceous strata (including Cieszyn Beds) and, thereafter, those of the Skole nappe. The Rożnów fold is thrusted over the Czchów one, recorded by boreholes Iwkowa 1 (3,247 m) and Czchów 1 (3,216 m). Anticlinal front of the latter is built of the Lgota and Godula beds, and a syncline from its back is filled with the Istebna Beds.

The Czchów fold and the Zakliczyn one, situated north of it, pass into the Rzepienniki fold. West of the Dunajec River, both the Bobowa syncline and Rożnów anticline plunge beneath the thrust of the Magura nappe, the margin of which passes far to the north between Tęgoborza and Iwkowa.

West of the Dunajec River, at the Skawa River line, the Silesian nappe becomes divided by a dislocation into two parts differing in tectonic sand lithofacies development. Between the Dunajec and Skawa rivers, in areas comprising Pogórze Wielicko-Wiśnickie and Lanckrońskie, Paleocene strata, especially the Krosno Beds may still represent important components of geological structure, whereas Cretaceous strata are of decisive importance west of the Skawa River, where they built the Beskid Mały and Beskid Śląski ranges.

The Silesian nappe and sub-Silesian unit are very well known thanks to detailed geological studies and mapping and supplementary analysis of seismic profiles and borehole data, which covered areas south of Bochnia and Brzesko (24, 25) and further, as far as Cracow and Myślenice (4, 8, 5), as well as between Lanckorona and Soła (16, 17, 21) and in the Beskid Śląski and Beskid Niski ranges and adjoining areas (6, 17, 21, 22).

The lithostratigraphic inventory of Cretaceous strata appears most complete in development in western part of the Silesian unit, especially in the Cieszyn Silesia.

The Cieszyn Beds developed as the Lower Cieszyn Beds (pre-Flysch) of the Tithonian age, Cieszyn Limestones of the Upper Tithonian – Berriasian, and Upper Cieszyn Shales of the Valanginian – Hauterivian are the oldest strata in the Silesian series. They are overlain by the Grodzisk Beds of the Hauterivian, developed in the marly-shaly facies and replaced towards the east by the Grodzisk Sandstones, also locally replaced by the black Wierzów shales of the Barremian and Aptian. The Lgota Beds of the Albian and Lower Cenomanian age, are presented in lower part by thick-bedded, often conglomeratic sandstones, in middle part by thin-bedded sandstones and green, black or variegated shales, and in the upper – by spongiolites called as the Mikuszowice hornstones, overlain by a horizon of so-called radiolaritic beds. The horizon, about 1 m thick, comprises shales with manganese nodules and radiolarites. Tripartite Godula Beds comprise strata varying in age from the Upper Cenomanian to Lower Senonian, and up to 2,000 m thick in the Beskid Śląski range. Variegated Godula shales may replace lower part of the latter in areas east of the Skawa River, or even all of them in the Pogórze Lanckorońskie and Wielickie.

The Istebna Beds represent a huge complex characterized by predominance of coarse-grained and conglomeratic sandstones of the fluxoturbidite type, and numerous conglomeratic intercalations. The Lower Istebna Beds are dated at the Senonian, and the Upper, comprising two complexes of dark shales (sometimes with intercalations of variegated shales), separated by a sandstone complex – at the Paleocene. The Ciężkowice Sandstones, similar to the former in lithology, are of the Upper Paleocene – Lower Eocene age. West of the Dunajec River, the latter form two horizons of lenses in variegated shales. The Hieroglyphic Beds, represented by thin-bedded sandstones and shales, overlain by a horizon of green shales, are dated at the Middle and Upper Eocene. The strata may comprise from one to three horizons of variegated shales.

The Globigerina Marls are in places known from the Eocene – Oligocene boundary. The Oligocene is represented by the Menilitic Beds, developed as hornstones in lower part, and brownish shales in the upper. The strata also display some tuff horizons as well as sandstones known under various local names. Sedimentation of the Silesian series ended with the Krosno Beds. In western part of the Polish Carpathians, thin-bedded sandstones and shales predominate in the Krosno Beds, whereas thick-bedded sandstones prevail in their lower part only.

In area delineated by the Dunajec and Skawa Rivers, the Silesian nappe divides into two units synclinal in character: upper, represented by the Lanckorona highlands floe, and lower developed as the major trunk of the nappe in the Wielicz and Wiśnicz highlands. A refolded, NW – SE oriented syncline, filled up with the Krosno Beds, is marked along the Uszew – Zakliczyn line in its eastern part. The syncline has been recorded in some drillings, including boreholes Uszew 1 (2,522 m), which penetrated Paleogene strata of the Istebna and Godula beds and a thin scale of the sub-Silesian unit, to encounter Jurassic strata of the foredeep basement, and Złota 2 (2,802 m), which encountered Miocene and Jurassic strata beneath the base of the nappe. Towards the west, several basins or flat synclines filled up with the Krosno or Hieroglyphic Beds, are marked in the lower unit: e.g. Trzciana – Leszczyna, Strzyżyc, and Polanki – Sieprawie basins. The forms are separated from one another by anticlinal structures usually built of the Istebna and Godula Beds. Along northern margin of the unit there are also exposed Lower Cretaceous strata, including Cieszyn Shales.

Disrupted fragments of the sub-Silesian unit may be traced along the front of the Silesian nappe, along which they have been thrusted over the Miocene of the Carpathian Foredeep. The front of the nappe retreats southwards between Wieliczka and Bochnia, forming so-called Gdów Embayment. South of that embayment there is marked the Strzyżyc depression, and still further in that direction – a southward bend of margin of the Magura nappe. Drillings made in area south of Wieliczka and Bochnia penetrated various members of the Silesian nappe. The nappe is here less than 2,000 m thick. The boreholes Łąkta 24 (3,150 m), situated south of Bochnia, and Wiśniowa 4 (2,599 m), situated south of Wieliczka, penetrated base of the nappe at the depths of 2,296 m and 2,100 m, respectively, to enter strata of the sub-Silesian unit and their Miocene basement. The nappe is 200 – 800 m thick between Głogoczów and its northern margin in area south of Cracow (W. Sikora et al., 1980). The borehole Głogoczów IG-1 (3,800 m) recorded its base at about 750 m. The nappe becomes thicker (up to 1,500 m thick) southwards but boreholes Trzebunia IG-1 and Trzebunia 2 (3,936 m), made at distance of 4 km from overthrust of the Magura nappe, showed that it is missing in the basement.

The Lanckorona highlands floe is thrusted over strata of the lower unit. The former represents a syncline filled up with the Istebna and Godula Beds. The syncline becomes narrower east of the Skawa River dislocation zone to disappear in the Myślenice region.

Both the lower and upper units are delineated at the south by anticlinal structure called as the Lanckorona – Żegocin zone of tectonic windows. The structure has a form of steep, complex fold, representing westward extension of the Czchów fold. Its northern limb is built of strata of the Wierzów, Lgota, and Godula beds, the core displays the sub-Silesian unit in numerous small tectonic windows, and southern limb, sheared from below and thrusted over the core part, displays the Krosno Beds and various members of the Paleocene and Lower Cretaceous. Structure of this element is known from borehole column Wiśniowa IG-1 (2,931 m), showing strongly tectonically disturbed strata of the sub-Silesian unit underlain at the depth of 2,268 m by the Miocene and, subsequently, Jurassic and Paleozoic (5).

West of the Skawa River dislocation zone, margin of the Silesian nappe retreats 10 km to the south along the dislocation. The area between the Skawa and Olza Rivers and further westwards, is characterized by highly intense development of the Godula and Istebna Beds (total thickness of which may here approach 3,500 m), and presence of the Lower Cieszyn Shales and Cieszyn Limestones, the oldest members of the Silesian nappe, unknown from other regions.

The above discussed development and rigidity of the Godula Beds and disharmonious folding of the underlaying Cieszyn Beds resulted in origin of a great decollement between them. Moreover, the Silesian nappe became differentiated into two elements: a higher, Godula nappe, and lower, Cieszyn nappe. The former is further differentiated into partial nappes thrusted over one another. East of Bielsko-Biała it becomes narrow and narrower and gradually disappears. The latter, Godula nappe is subdivided by transversal dislocations into three blocks: Beskid Mały, Beskid Śląski, and Beskid Jabłonkowski. The borehole Potrójna IG-1 (3,701 m), situated south of Wadowice, recorded strata of the Silesian nappe down to the depth of 1,162 m, and those of the sub-Silesian unit – down to the depth of 2,031, entering thereafter underlaying Miocene strata and Upper Paleozoic ones. The borehole Sucha IG-1, situated south of the latter, penetrated strata of the Magura nappe to enter those of the Silesian nappe in depth interval 1,760 – 2,214 m. Lower parts of the latter are tectonically disturbed and sliced together with underlaying strata of the sub-Silesian unit in this borehole column. Beneath the strata the borehole encountered over 1,000 m packet of Miocene, including a conglomeratic series which forms a cover on Upper Paleozoic basement.

Sub-Silesian unit. Although distribution of this unit appears more limited than in the case of all the remaining units of the Flysch zone, close relations with the Silesian nappe and a passage of Upper Cretaceous facies of that unit to the Silesian one in the Sanok area markedly impede its interpretation. In south-eastern part of the area, the unit may be traced along external boundary of the Silesian unit west of Ustrzyki Dolne in a narrow streak of variegated shales and marls, which widens and becomes more clearly individualized north-east of Lesko. Four drillings made in a transversal section at 1.5 km distance from front of a fold in the latter area, penetrated the fold to encounter the Krosno Beds of the Skole unit. From Załuż, where the Lower Cretaceous crops out at the surface, the Upper Cretaceous is represented by thin packet of variegated marls developed in the Węglówka facies. The strata delineate the puy in NE as far as the San River, where they have been found beneath the Silesian unit in the borehole Trepcza 6. In that section, Lower Cretaceous is represented by exotics of the sub-Silesian unit, known from outer streak of the marls. The strata were traced further to NW where (Grabownica area) they form a distinct Lower Cretaceous core in the sub--Silesian unit, at external side of the Silesian unit. Wdowiarz found them in similar position north of Brzozów and at Domaradz (37). West of the latter, the sub-Silesian unit is evidenced in the Węglówka tectonic window, in which two fold cores built of Lower Cretaceous strata are surrounded by Cenomanian – Turonian greenand red shales and, subsequently, Senonian marls. Middle part of the window is covered by the Bonarówka patch. Numerous drillings made in connection with exploitation of oil create a basis for analysis of deep geological structure of this form in details. Because of strong reduction of the reserved limb (Eocene and Menilitic Shales), the whole unit rests on the Krosno Beds of the Skole unit and amplitude of thrust is estimated at about 8 km. Top of the Lower Cretaceous is lowering down to 1,000 m at 8 km distance and appears disturbed by some transversal and longitudinal translocations, with which oil accumulations are related.

The sub-Silesian unit becomes very strongly reduced in the section east of the Wisłok River, where it is known from depth interval 2,808 – 2,936 m (and where Lower Cretaceous is merely 64 m thick), and amplitude of thrust exceeds 7 km. The above mentioned borehole Frysztak 1, situated 1.5 km west of the Wisłok River, penetrated 2,615 m section of the Silesian unit and 200 m thick Węglówka Marls (but without the Lower Cretaceous).

Between the Wisłok and Wisłoka Rivers, the presence of the sub-Silesian unit is indicated by occasional occurrences of the Węglówka Marls in front of the Silesian unit, which also displays an elongate tectonic window. Geological mapping (36) showed its presence west of the Wisłoka River. Interpretation of the mapping, supported by results of drilling Kowalowy (4,261 m), makes it possible to that the Silesian unit is folded together with the sub--Silesian, which seems to be disrooted further within the Carpathians. The unit, thruncated at major oblique dislocation of the Biała River line, reappears in the west but not closer than the Bochnia region and a tectonic window in southern part of the Silesian unit.

West of the Dunajec River, **the sub-Silesian unit** is the outermost one of the Flysch Carpathians. It appears widely distributed beneath overthrusted Silesian nappe, often strongly tectonically disturbed and disrupted or grinded. Its outcrops form two discontinuous belts: a northern, continuing along the front of the Silesian nappe from Brzesko to Cieszyn area, and southern, represented by numerous small tectonic windows in the Żegocin – Lanckorona zone between the Dunajec and Skawa Rivers and in the Żywiec basin.

Lithostratigraphic inventory of the sub-Silesian series appears rich and diversified. Sediments formed at markedly smaller depths than those of the Silesian series are markedly varying in lithofacies (6, 17). They markedly differ from coeval strata of the latter, especially in the case of the Upper Cretaceous and Eocene.

The oldest member of the sub-Silesian unit comprises the Cieszyn Beds from area west of the Dunajec River, represented by the Upper Cieszyn Shales (Hauterivian) only. Higher part of the Lower Cretaceous section comprises the Grodzisko Sandstones and Wierzów Shales. The Albian and Cenomanian are represented by the Gaize Beds (gaize sandstones with intercalations of shales), and the Turonian – by overlaying variegated shales.

Diversified marly rocks of the Senonian are highly typical of the sub-Silesian unit. They include variegated or, more often, green marls, widely-distributed gray Frydek marls or white marls with hornstones, known as Żegocin marls. The influence of the Silesian facies in the Upper Senonian is reflected by locally present intercalations of the Istebna sandstones and conglomerates. In western part of the sub-Silesian unit the Upper Senonian displays the Szydłowiec sandstones with remains of bryozoans and Lithothamnium fragments, and in the Wadowice and Lanckorona region – the Gorzeń Beds developed as thin-bedded glauconitic sandstones with intercalations of shales. Glauconitic sandstones and conglomerates with exotics, possibly up to 600 m in thickness, developed in the Żegocina area and known as the Rybie Sandstones, may be of similar age.

In several areas the whole Paleocene and Eocene of the sub-Silesian series are represented by variegated marls and shales, forming together with underlaying Senonian variegated shales a single marly complex. In the vicinities of Żywiec, the Szydłowiec sandstones are overlain by Paleocene and Lower (and partly Upper) Eocene represented by glauconitic sandstones and brownish-green shales. The Eocene – Oligocene boundary beds are developed as the Globigerina Marls horizon, and the Lower Oligocene – by the overlaying Menilitic Beds: hornstones and overlaying brownish shales. The youngest member of this unit is formed by the Krosno Beds, here mainly developed in shaly facies.

Between the Dunajec River and Brzesko, the sub--Silesian unit is represented by shreds of variegated deposits, thrusted over the Krosno Beds of the Skole nappe. The next outcrops of this unit are known from area west of Bochnia, wherefrom is known the Gierczyce scale, built of Cretaceous marls of the Menilitic and Krosno Beds. The Chorowice – Sygneczów – Biskupice and Ochojno – Janowice scales, characterized by predominance of the Godula variegated shales and Węglówka Marls, were found south of Swoszowice and Wieliczka (4). In area west of Skawinka there were found minor occurrences of strata of this unit (mainly Węglówka Marls) only.

In area between Wieliczka and Bochnia, strata of the sub-Silesian unit are often tectonically disturbed along with those of the Silesian nappe and, therefore, difficult to discriminate from the latter. The sub-Silesian unit is often missing in area between margin of the Silesian nappe at the Brzesko – Bochnia line and the Lanckorona – Żegocin zone, and the latter unit rests directly on the Miocene of the Carpathian Foredeep or platform Mesozoic rocks as shown by e.g. borehole Uszew 1 (2,522 m). The borehole, situated south of Brzesko, encountered Jurassic and Cretaceous rocks at the depth of 1,915 m.

In tectonic windows of the Lanckorona – Żegocin zone strata of the sub-Silesian unit are strongly tectonically disturbed. They display almost the whole lithostratigraphic inventory of this unit but their succession is difficult to reconstruct because of slicing and disruption of folds. J. Burtan differentiated two to three scales in the windows between Myślenice and Rybie Nowe. They are best known from the borehole column Wiśniowa IG-1 (2,931 m). The borehole, situated in the Wiśniowa tectonic window, penetrated 2,268 m sequence of strata of the Silesian unit, to enter Miocene, Jurassic, Carboniferous and Lower Paleozoic. The sub-Silesian unit was recorded beneath the Silesian nappe by drillings Głogoczów IG-1 and Potrójna IG-1, and beneath the overthrust of the Magura nappe – in drillings Trzebunia IG-1, Trzebunia 2, Tokarnia IG-1, and Sucha IG-1. The two latter boreholes are about 30 km distant from the northern margin of the Carpathians.

Distribution of the sub-Silesian unit becomes much wider than in the above mentioned areas in proximity of the Skawa River. In the latter area there are differentiated the Bachowice scale (comprising strata from the Upper Cretaceous to Eocene) and a higher one, Woźniki scale, comprising strata of the Lower Cretaceous (including Cieszyn Shales) and Upper Cretaceous and plunging southwards beneath overthrust of the Silesian nappe. West of Skawina the Woźniki scale is reduced.

The sub-Silesian unit is about 12 km wide at the meridian of Wadowice. Its northern part is built of Lower and Upper Cretaceous rocks folded, sliced and mixed-up with various Paleogene ones, and the Szydłowiec scale is thrusted over it from the south. In area between the Soła and Olza Rivers, the unit is preserved in the form of minor scales of Upper Cretaceous and Eocene variegated shales and marls. Beneath overthrusted Silesian nappe, strata of the latter are often mixed up with those of the sub-Silesian unit due to tectonic disturbances.

In the Żywiec tectonic window, strata from the Upper Cieszyn Shales of the Valanginian age to Oligocene ones are folded and arranged into steeply inclined scales (3). South of the window borehole Bystra IG-1 (3,787 m) found strata of the sub-Silesian unit resting on Miocene directly overlaying metamorphic basement.

Andrychów klippen. Five large klippen rest on strata of the sub-Silesian unit and beneath the overthrusted Silesian nappe. They are built of crystalline rocks (mylonites and granitogneisses) and Senonian, Paleocene and Eocene limestones. The Jurassic is here represented by stratified Oxfordian and Tithonian limestones with hornstones and Tithonian reef limestones. The rocks are transgressively overlain by Senonian conglomerates and limestones and marls. The Paleocene and Lower and Middle Eocene is represented by organogenic limestones. The klippen most probably come from an elevation of basement, delineating sedimentary basin of the sub-Silesian unit in the south. They have been torn-off by northwards moving Silesian unit, transported at its base and thrusted over on the sub-Silesian unit along with this nappe (20).

Skole nappe, known before the w. w. II as the Skiba Unit, occurs in the contact zone of the Flysch and Carpathian Foredeep in large part of the Polish Carpathians. The contact zone is the major trap, with which appear connected methane-rich gas deposits in the Badenian, especially Lower Sarmatian, so it has been favoured in prospecting for gas. The other zone, in which the deepest (as for the Carpathian standards) drillings have recently been initiated, is that of eastern part of the Przemyśl – Ustrzyki Dolne area (sensu lato). Analysis of the available data and results of both exploratory and economic drillings made in NW Ukrainian Carpathians suggest that the Borysław – Pokucie unit, the major oil-bearing zone in the Carpathians, should extend into the area of that zone in Poland.

The available data show that boundary of the Skole nappe and Silesian and sub-Silesian units is difficult to draw with accuracy as the latter loose their characteristic lithostratigraphic and tectonic features in this area. The zone was undoubtedly characterized by the maximum downwarp of the basement and, therefore, the maximum depth of the Flysch basin. It was reached by minor quantities of material forming lower part of the Flysch section only. The Krosno Beds, known to be mainly formed due to supply of material from the west and north-west, evened the resulting differences in lower part of the section. Influence of material supplied from outer frames of the Flysch basin becomes clearly when we move to in outer part of the Skole nappe.

It should be repeated here that section of the Skole unit begins with Hauterivian marls and overlaying Barremian – Albian Spas shales. Upper Cretaceous Inoceramian Beds, underlain by variegated shales (usually about a dozen meters thick) and siliceous marls (about 200 m thick), are the major member of this unit. Moreover, the Cisowa Beds develop SW of Przemyśl. The Inoceramian Beds of middle part of the nappe display thick-bedded sandstones (1 – 3 complexes) and, at the top of the latter, Baculites marls. Total thickness of the strata is varying from 1000 to 2000 m (SW of Rzeszów). The Eocene is represented by variegated shales and Hieroglyphic Beds, and the Oligocene – by Menilitic Shales and Krosno Beds. The age of the uppermost part of the latter and, therefore, the time of uplift and major folding of the Carpathian Flysch zone are beyond the scope of this paper.

The Skole nappe may be easily subdivided into two parts differing in structure: an inner, characterized by predominance of the Krosno Beds strata and older ones limited to cores of steep narrow anticlines, and outer, mainly built of Upper Cretaceous strata arranged in anticlines which pass into scales in marginal zone of the nappe.

Three drillings made in the inner part markedly contributed to the knowledge of its structure. The borehole Jasień IG, localized in proximity of the innermost narrow and vertical fold SE of Ustrzyki Dolne, penetrated the Inoceramian Beds of its core at the depth of 3,885 m to encounter Krosno Beds down to the depth of 4,518 m. The latter is regarded as related to a syncline marked NE of the fold (Fig. 2a). The suggestion of K. Żytka (1972), according to which they may be treated as belonging to a deep-seated element of the Borysław – Pokucie zone, appears inacceptable in the light of structural analysis of the area.

The borehole column Paszowa 1 (P.), the deepest in the Polish Carpathians (7,210 m deep), is of decisive importance for understanding structure of the area. The borehole was localized at the first fold of the unit, 3.4 km NE of Lesko. Down to the depth of 4,300 m it was drilled in the Krosno Beds (including 2,000 m sequence belonging to reversed limb of the fold), entering thereafter strata of normal, south-western limb of the second fold: at the depth of 4,300 m – Krosno Beds, at 5,000 m – Menilitic Shales with Kliwa sandstones, at 5,220 m – Hieroglyphic Beds and Eocene variegated shales, at 7,050 m – Inoceramian Beds, with intercalations of colourful shales in upper part, and at 7,210 m – siliceous marls, known to represent the lowermost member of the Inoceramian Beds in several sections of this unit (Fig. 2b).

The lithostratigraphic succession of the borehole Paszowa 1 downwards from the depth of 2,000 m is undoubtedly normal of the Skole unit, and familiar from numerous sections in this part of the country and adjoining areas SE of the state boundary. It may belong to two folds: Wańkowa Kopalnia and Chwaniów – Wara. Inner part of the Skole unit is characterized by a trend to backward lean in near-surface part of SW limb, responsible for origin of interesting oil trap along the Wańkowa fold.

Of the results of the drilling Paszowa 1, attention should be mainly paid to the finding that inner part of the unit plunges at large depths, making difficult estimations of depth at which the base of the Flysch may be encountered (at 10 km depth?). In the Leszczawka syncline, outside of the Chwaniów fold, 8 km NE of Lesko, there is situated another borehole, Kuźmina. Deep outline of that form seems to confirm that base of the Flysch is actually situated at large depths.

The third borehole important for the knowledge of geological structure of the zone, Brzegi Dolne IG (B.D.), 5,440 m deep, was localized in a shallow syncline between the Wańkowa Kopalnia and Chwaniów folds, 4.2 km NE of Ustrzyki Dolne. It penetrated to the depth of 2,740 m (Fig. 2a) and, after passing through a narrow synclinal wedge, it encountered the Inoceramian Beds down to its base. Lower part of the latter was interpreted as the Cisowa Beds (from the depth of 5,023 m downwards). The borehole is 17.4 km distant from the margin of the Carpathians and the cross-section shows arrangement of reflexes consistent with that of the strata, not revealing base of the Flysch nor the Borysław – Pokucie zone, penetration of which was the aim of the borehole.

It should be stated that the above mentioned fold marks the onset of changes in the style of structure of the Skole unit, continuing up to contact of the unit and foreland. Upper Cretaceous strata, especially those of the Inoceramian Beds, dominate there. They built wide folds, attaining form of scales (skiba) separated by narrow synclines filled up with Eocene rocks and Menilitic Shales. In some folds the Spas shales and, occasionally, Lower Cretaceous Bełwin marls occur in cores or in direct foreland. This scale (skiba) style becomes typical of outer part of the Ukrainian Carpathians and is the reason of naming it as the "skiba" unit. Seven elements of that type were differentiated in the Strwiąż (Ustrzyki Dolne – Chyrów) cross section.

The scale (skiba) fold bunch widens up to 29 km in the Przemyśl transversal section. The skiba style remains distinct in outer part of that zone, 22 km wide, whereas synclinal forms (Bircza) appear in the inner part. The latter widens to NW as far as the San River bend near Dynów. In area 18.5 km SW of Przemyśl and 12.5 km of the southern margin of the Carpathians, borehole Cisowa IG-1 (4,367 m deep) began exploration of deep structure of the Skole unit (38). The borehole penetrated the Flysch strata at the depth of 4.010 m, confirming their skiba structure and under cutting of individual elements by thrust plane. The Stebnik unit is merely 70 m thick there, resting directly on 248 m thick autochtoneous Upper Badenian strata representing cover of Precambrian phyllitic shales. The borehole Leszczyny was made a few years later 5.2 km from the Carpathian margin. It penetrated the Flysch at depth of 3,000 m, and the Stebnik unit at 4,300 m. This shows that both drillings failed to encounter the Flysch of the Borysław – Pokucie unit, which will be discussed below.

Another important borehole, Bachórzec 1, was localized 21 km W of Przemyśl and 15 km SW of the Carpathian margin. After penetrating the Flysch sequence (with about 1,300 m packets of the Spas shales at the base), it entered Precambrian phyllitic shales at the depth of 4,050 m, marking inner boundary of extent of the autochtoneous Miocene (41). North and north-west of the area there were made over a hundred drillings in connection with search and exploitation of gas. The drillings penetrated the Flysch sequences making it possible to compile a map of isobaths of the base of the Skole unit and to extend it over areas as far as W state boundary (S. Wdowiarz, 1976). The map has been compiled on the basis of data from over 160 drillings.

The Carpathian margin is widely known to set 26 km forward to the north at the Dobromil – Przemyśl line, forming so-called Przemyśl sigmoid. Taking all the details aside for a moment, we would like to cite an opinion from 1976 (l.c.): (the latter) "is most probably due to sudden reduction in thickness of the Istebna Beds westwards of a transversal rise nowadays buried beneath the Flysch". External elements of the Flysch are set forward to the north, in direction of Rzeszów, which is accompanied by some reduction of their inner parts and, therefore, in width of the whole unit to about 25 km. In the Przemyśl – Rzeszów section the course of thrust planes in the Flysch remains undisturbed and first northward shifts are found at the outskirts of Rzeszów.

Borehole data explained several questions concerning thickness and development of Miocene strata resting on the Flysch in the form of so-called Rzeszów embayment, 15 km wide and up to 1,000 m deep in the south. The borehole Mogielnice, situated in that area, penetrated the Flysch at the depth of 3,250 m, and the Geological Institute borehole Babica (3,426 m deep) showed that deep structure of the Flysch may be explained in terms of two folds of Cretaceous rocks superimposed on one another. Core of the deeperseated fold appeared to be built of the Spas shales with 5% share of sandstones (Fig. 2c). Similarly, the base of the Flysch was recorded at 3,300 m depth in borehole Zgłobień, west of Rzeszów. SW of that town inner part of the Skole unit forms a depression (Strzyżew depression), up to 15 km wide and almost exclusively infilled with the Krosno Beds.

The Skole unit forms about 10 km wide puy built of Cretaceous rocks and displaying secondary synclined filled up with the Eocene, as far as the Wisłoka River valley. Basal surface was recorded in a few drillings in this 75 km section. Borehole Szufnarowa, situated between the Wisłok and Wisłoka Rivers, penetrated 3,770 m sequence of the Flysch, and borehole Kowalowy, situated SW of Pilzno, 3,570 m sequence. The former further penetrated 500 m of the Badenian to encounter Malm and Dogger rocks, and the latter – 690 m of the Badenian with 150 m packet of conglomerates at the base. The thurst plane, steep in front part of the Skole unit, becames markedly gentler inclined towards the interior of the Carpathians. In western part of the area, the Skole unit is almost completely obscured by a thick (up to 1,000 m thick) Badenian cover at distance of over 5 km.

The Skole unit crops out at the surface due to above mentioned oblique dislocation of the Biała River line. In that area it is almost exclusively built of Cretaceous rocks, mainly the Inoceramian Beds, which rest on the Badenian. Disturbances traceable at the surface are partly accompanied by large dislocations which cut basal part of the unit. A trend to complete disrooting of the unit may be noted (borehole Brzozowa 1). The unit completely disappears in the Tarnów – Brzesko section and, taking into account its lack in borehole columns situated firther to the west, S. Wdowiarz treats this section as western boundary of the Skole basin.

The Skole unit forms the Carpathian margin at distance of about 200 km so the recorded phenomena and relations to the basement may be treated as representative for the whole question of the contact of the Carpathians and their foredeep in Poland. S. Wdowiarz (1976) presented the following conclusions. The surface of the Carpathians (Skole unit) overthrust is continuous, except for three places in the Rzeszów and Tarnów region. Shape of the surface generally depends on the basement but appears independent from it in details. Depth of occurrence of this surface decreases from the east westwards but all the culminations and depressions marked in the Flysch are most probably accidental as the original Carpathians have been formed some tens km further to the south, under unknown structural conditions, and subsequently displaced to their present position.

Stebnik unit plays important role in structure of the direct foreland of the Ukrainian and Romanian Carpathians. Because of its geometry it should not be assigned to the Carpathian Foredeep (inner part of the foredeep as interpreted by Soviet geologists) but rather the Carpathian orogen. In Poland it crops out SE of Przemyśl and attains 17 km in width at the state boundary. Borehole data show that it is thrusted over autochtoneous Upper Miocene strata on both sides of the boundary.

Section of the Stebnik unit comprises (from the base upwards): salt-bearing clays of the Worotyszcze Beds (Aquitanian? and Burdigalian), Stebnik Beds about 2,000 m thick (Carpathians), and Badenian and Upper Sarmatian (?) strata of similar thickness. In area of Poland the strata build three anticlinal elements (41), separated by synclines and strongly inclined to NE. I regard Menilitic Shales found at the base of frontal part of this unit in SE as olistolites. The Stebnik Beds represent the major component of the section.

The above mentioned borehole Leszczyny appears also important for reconstruction of western extension of the Stebnik unit. S. Wdowiarz states that the borehole penetrated beneath the Flysch a 1,300 m sequence of the Stebnik Beds which undoubtedly form a laying synclinal bend (Fig. 5). The strata rest on rocks most similar to the Badenian but the age of which remains disputable because of the lack of micropaleontological record. The above data make it possible to assume that the Stebnik unit wedges out westwards of the boreholes Cisowa IG. (l.c.) and Leszczyny 1. However, this is not the case of marginal part of the Carpathians as borehole data show presence of a narrow streak of the Stebnik Beds (or rather its upper part – the Balice Beds) along the front and beneath the Flysch NW of Przemyśl. The strata contact those of autochthoneous Lower Sarmatian, gently dipping northwards. Strata of the Stebnik unit reappear in the same position east of Rzeszów (Albigowa) whereas clay Lower Badenian strata appear in place of the Balice Beds in area of that town. The strata possibly represent a separate unit which extends southwards as a packet some tens m thick directly beneath the Flysch.

The Balice Beds were found further westwards at Ropczyce, where they locally form a southwards disrooted exotic several hundred m thick. Towards Tarnów the role of the Stebnik unit is taken by intensively folded Badenian strata. The zone widens to a few kilometers west of the Dunajec River, where salt deposits appear at its base. The Balice Beds were found once more between the Flysch and that zone at Brzesko, 30 km west of Tarnów. The extension of this unit of the folded Miocene is represented by the widely described Gdów "embayment", where Lower Badenian strata are over 1,000 m thick, and the Wieliczka folds.

Analysis of over a dozen geological cross sections compiled by me (four of which are shown here) indicates that the hypothesis of gravitational tectonics of the Carpathian Flysch zone, put fowards by some authors, cannot be accepted. S. Wdowiarz fully accepts M. Książkiewicz (1972) doubts concerning these interpretations.

The question of NW extension of the Borysław – Pokucie zone in the Polish Carpathians has been widely discussed in the last thirty years, especially when some deep drillings were made in the Przemyśl – Ustrzyki Dolne zone. The drillings showed that the zone may be most probably encountered SW of the above mentioned borehole Leszczyny, i.e. towards the interior of the Carpathians from the Stebnik zone.

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STRESZCZENIE

IV Kongres Karpacko-Bałkańskiej Asocjacji Geologicznej, który w 1963 r. odbył się w Polsce, przedstawił dorobek Polskiej Geologii przede wszystkim w dziedzinie stratygrafii utworów fliszowych, ich sedymentacji oraz odtworzenia warunków paleogeograficznych i batymetrycznych zbiornika fliszowego. Wynikiem tych prac stała się wydana na kongres znakomita praca pięciu autorów „Stratigraphie des Karpathes externes polonaises" – F. Bieda et al. (1963) oraz „Atlas geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Zeszyt 13, Kreda i starszy trzeciorzęd w polskich Karpatach zewnętrznych" opracowany przez 14 autorów pod redakcją M. Książkiewicza.

Wieloletnie prace kartograficzne w Karpatach znalazły swój wyraz w Mapie geologicznej Karpat polskich w skali 1:200 000 opublikowanej w 1958 r. przez Instytut Geologiczny (część zachodnia S. Sokołowski, część wschodnia H. Świdziński). Na mapie tej dokonano po raz pierwszy rejonizacji tektonicznej strefy fliszowej. Za jej objaśnienie można uważać tom „Karpaty" w Regionalnej Geologii Polski z 1953 r. z tekstami M. Książkiewicza i H. Świdzińskiego.

W 1963 r. syntezę tej strefy w Karpatach północnych i wschodnich podał S. Wdowiarz, a M. Książkiewicz w 1972 r. szczegółowo scharakteryzował tektonikę Karpat polskich. W ramach prac KBAG dla mapy tektonicznej Karpat i Bałkanów L. Koszarski, W. Sikora i S. Wdowiarz (14) przygotowali odpowiednią mapę jak również i tekst. Za ostateczne można uznać nazwy poszczególnych elementów strefy fliszowej i brzmią one następująco: 1) płaszczowina magurska, 2) jednostka przedmagurska, 3) jednostka dukielska, 4) płaszczowina śląska, 5) jednostka podśląska, 6) płaszczowina skolska, 7) jednostka fliszu zewnętrznego, 8) jednostka stebnicka.

Od przygotowania ostatniej pracy doszło wiele nowych danych z coraz głębszych otworów górnictwa naftowego i Instytutu Geologicznego (Oddział Karpacki). Uznano zatem za celowe podanie uczestnikom XIII Kongresu Karpacko-Bałkańskiej Asocjacji Geologicznej uzyskane wyniki, w tym również w podłożu zewnętrznej części strefy fliszowej, jak i w zapadlisku przedkarpackim. O ilości napływających materiałów może świadczyć ponad 160 otworów wykorzystanych przez S. Wdowiarza w pracy

Polska delegacja na XI Kongres Karpacko-Bałkańskiej Asocjacji Geologicznej w Kijowie w 1977 r. Od lewej: A. Radomski, J. Czernicki, I. Gucwa, P. Karnkowski, S. Wdowiarz, J. Kotlarczyk, D. Poprawa, E. Jawor, S. Jucha, A. Jerzmańska, K. Żytko, S. Gąsiorowski

z 1976 r. Do dzisiaj liczba ich, uwzględniając również otwory zlokalizowane ku wnętrzu Karpat, zbliży się do 300. Od strony przemysłowej wysiłek ten uwieńczyło odkrycie znacznych zasobów gazu.

Płaszczowina magurska jest najbardziej wewnętrzną jednostką wyższego rzędu w polskich Karpatach fliszowych nasuniętą na utwory jednostki dukielskiej na E oraz płaszczowiny śląskiej i jednostek strefy przedmagurskiej w części środkowej i zachodniej. Najstarsze jej utwory poznane w rejonie okna tektonicznego Mszany Dolnej i w otworze Obidowa IG-1 reprezentują alb i cenoman. W turonie wykształciły się łupki pstre, a w senonie i paleocenie szeroko rozprzestrzenione warstwy ropianieckie (inoceramowe). Wyróżnienie w eocenie stref facjalnych, na które w czasie fałdowania osadów nałożyły się struktury tektoniczne, pozwoliło wydzielić w płaszczowinie magurskiej pięć podjednostek.

Począwszy od S są to podjednostki: krynicka, bystrzycka, raczańska, Siar i harklowska. Podjednostkę krynicką charakteryzuje obecność w całym eocenie piaskowców magurskich w facji muskowitowej. Podjednostkę bystrzycką wyróżniają warstwy beloweskie i warstwy łąckie (margle), a raczańską warstwy hieroglifowe. We wszystkich tych podjednostkach w górnym eocenie występują piaskowce magurskie w facji muskowitowej.

W podjednostce Siar w dolnym i środkowym eocenie rozwinęły się pstre łupki, natomiast w eocenie górnym i oligocenie litologicznie podobne do siebie warstwy podmagurskie i nadmagurskie rozdzielone piaskowcami magurskimi w facji glaukonitowej. Strefa harklowska posiada zbliżony profil, lecz brak w niej ogniwa piaskowców magurskich, a osady eocenu górnego i oligocenu są bardziej margliste. Na E od Dunajca najmłodszym ogniwem we wszystkich podjednostkach są warstwy malcowskie, stanowiące facjalny odpowiednik warstw krośnieńskich. Ostatnio zostały one wyróżnione także na Podhalu i Orawie w podjednostce krynickiej.

Płaszczowina magurska pofałdowana jest w liczne synkliny i antykliny, a ponadto w niektórych miejscach w jej obrębie rozwinęły się wewnętrzne zluźnienia. Antykliny są na ogół wąskie i często złuskowane, synkliny zaś szerokie i płaskie. Na W od Skawy osie struktur fałdowych przybierają kierunek SN – NE, pomiędzy Skawą a Dunajcem W – E, a na E od Dunajca zaczynają stopniowo skręcać ku S. W najbardziej wschodniej (na terenie Polski) części płaszczowiny magurskiej fałdy przybierają kierunek NW – SE, wykazują dużą regularność i strome ustawienie. W obrębie płaszczowiny magurskiej występuje kilka okien tektonicznych, z których największe jest okno Mszany Dolnej.

Od S płaszczowina magurska oddzielona jest od pienińskiego pasa skałkowego ostrym, stromym kontaktem tektonicznym. Jej północny brzeg natomiast jest erozyjny i posiada urozmaicony przebieg. W części brzeżnej grubość tej płaszczowiny wynosi od kilkudziesięciu do kilkuset metrów, a w bardziej wewnętrznych częściach, w głębokich otworach stwierdzono grubości 1500 – 2600 m, a w strefie przypienińskiej na podstawie danych sejsmicznych ponad 4000 m.

W obrębie płaszczowiny magurskiej rozwinęły się na terenie polskich Karpat fliszowych dwa zapadliska śródgórskie wypełnione osadami neogenu i czwartorzędu. Są to Kotlina Nowotarsko-Orawska i Kotlina Sądecka.

Jednostka dukielska zajmuje położenie przejściowe pomiędzy płaszczowiną magurską a śląską: rozwój kredy górnej i paleocenu jest zbliżony do jednostki magurskiej, a młodszego paleogenu do śląskiej. Wykazuje ona maksimum wypiętrzenia w części wschodniej, nurzając się w kierunku NW i chowając się w końcu pod płaszczowinę magurską. Szerokość tej jednostki przekracza 40 km, a w obrębie jej wyróżnić można dwie podjednostki oddzielone od siebie walną płaszczyzną nasunięcia oraz różniące się stylem tektonicznym. Dane pochodzące z ostatnio wykonanych głębokich wierceń (Jaśliska 2 i Zboj 1 na Słowacji) wskazują, że płaszczyzna nasunięcia początkowo zapada stromo, a następnie, na głębokości poniżej 3000 m wypłaszcza się. Minimalny, stwierdzony zasięg nasunięcia wynosi na S od Wetliny ok. 15 km, natomiast na W od Dukli (fałd Skalnika) praktycznie spada do 0. Wskazywałoby to, że jednostka dukielska w czasie ruchów nasuwczych wykonała rotację lewoskrętną lub przedpole uległo rotacji prawoskrętnej podsuwając się pod tę jednostkę.

W bardziej zachodniej części Karpat jednostka dukielska, a przede wszystkim jej część wewnętrzna ukazuje się w szeregu okien tektonicznych. Reprezentują one w rzeczywistości porwaki tektoniczne przefałdowane wspólnie z płaszczowiną magurską, oderwane od podłoża i przesunięte ku N. Związek jednostki dukielskiej z jednostką Obidowej – Słopnic nie został jeszcze całkowicie wyjaśniony, aczkolwiek istnieje duże prawdopodobieństwo, że ta ostatnia reprezentuje nieco odmiennie wykształconą część jednostki dukielskiej.

Jednostka przedmagurska w zachodniej części Karpat polskich wydzielona jest u czoła nasunięcia płaszczowiny magurskiej pomiędzy Sporyszem koło Żywca na E a Koniakowem i Istebną na W. W jej obrębie wyróżniono dwie serie – północną i południową, budujące dwie odrębne łuski tektoniczne, z których północna nasunięta jest na płaszczowinę śląską, a południowa tektonicznie porozrywana i wprasowana w północną. Senon i paleocen obu serii jest reprezentowany przez warstwy „kredy biotytowej", a wyższa część paleocenu i eocen przez utwory margliste oraz łupkowe, często pstre. W południowej serii w eocenie występują również piaskowce i zlepieńce, oligocen natomiast reprezentują wapienie koniakowskie (łużańskie) i utwory podobne do warstw podmagurskich. W serii północnej oligocen reprezentowany jest przez warstwy menilitowe i krośnieńskie.

W oknie tektonicznym Mszany Dolnej także wyróżniono dwie serie związane z dwoma elementami tektonicznymi. W południowym (zredukowanym tektonicznie) wyróżniono wśród kredowych utworów warstwy lgockie, piaskowce ciśniańskie i warstwy „kredy biotytowej", a w paleogenie pstre łupki, wapienie łużańskie i warstwy krośnieńskie. W serii północnej, która jest sfałdowana w kilka synklin i antyklin, pod serią menilitowo-krośnieńską stwierdzono utwory „czarnego eocenu", warstwy hieroglifowe, pstre łupki i warstwy „kredy biotytowej". Okno tektoniczne Mszany Dolnej jest strukturą stanowiącą tektoniczne wyniesienie podłoża płaszczowiny magurskiej, ograniczone dużą dyslokacją od S, a ku W kontynuujące się pod nasunięciem magurskim po linię Skawy.

W oknie Klęczan – Pisarzowej wyróżniono silnie zaburzoną serię o eocenie i oligocenie litologicznie zbliżonym do północnej serii okna Mszany Dolnej. Obecność w serii menilitowo-krośnieńskiej łupków grybowskich, piaskowców cergowskich i wapieni łużańskich, a w eocenie warstw podgrybowskich świadczy, że seria ta nawiązuje profilem do serii jednostki grybowskiej w oknach tektonicznych w rejonie Grybowa i Ropy. Na N od niej występuje tzw. łuska Kurowa, w której obecne są utwory dolnokredowe wraz z górnymi łupkami cieszyńskimi, a w eocenie piaskowcowo-łupkowe warstwy klęczańskie.

Jednostkę grybowską wyróżniono pod płaszczowiną magurską w głębokich otworach Obidowa IG-1, Chabówka 1, Słopnice-1 i 20, gdzie grubość jej dochodzi od 500 do 1000 m. Fakt ten, jak też odległości między znanymi jej stanowiskami pozwala przypuszczać, że jest ona szeroko rozprzestrzeniona pod nasunięciem płaszczowiny magurskiej.

Z wymienionych wyżej otworów poznana została tektonicznie niższa od grybowskiej jednostka, której nadano nazwę **jednostki Obidowej – Słopnic** (jednostka fliszu zewnętrznego). Rozpoznany profil jej osadów o miąższości ok. 2000 m, obejmujący interwał od senonu dolnego po dolny oligocen, nawiązuje facjalnie do profilu jednostki dukielskiej, a odróżnia się od niej jedynie kompleksem utworów „czarnego eocenu" liczącym 500 – 700 m miąższości. Utwory tej jednostki są nachylone na ogół pod kątem 20 – 30° i nie wykazują silniejszych zaburzeń tektonicznych.

Płaszczowina śląska odgrywa podstawową rolę w budowie geologicznej strefy fliszowej Karpat. W 1963 r. Stanisław Wdowiarz wyraził opinię, że na SE od naszych granic przedłuża się ona w Karpatach ukraińskich (jednostka Kostrzycy-Skupowej i Czarnohory) oraz rumuńskich (jednostka Audia). W tej części wewnętrzną granicę płaszczowiny wyznacza jednostka dukielska, natomiast granica zewnętrzna może być tylko ekstrapolowana w szerokiej na 27 km strefie zbudowanej wyłącznie z warstw krośnieńskich. Ku NW wyznacza ją w fałdzie Rabego wąska smuga łupków i margli pstrych, z której na terenie Załuża wynurza się kreda dolna w facji śląskiej.

Granice te wyznaczają centralne synklinorium Karpat, tj. obniżoną część płaszczowiny śląskiej. Na wschodnim odcinku składa się na nie siedem elementów antyklinalnych, zbudowanych ze zróżnicowanych warstw krośnieńskich, tylko w wewnętrznej części synklinorium nawiercono utwory starsze (Zatwarnica). Stąd ku NW w basenie źródłowym Hoczewki pojawiają się na długości 10 km utwory kredy dolnej i górnej w facji śląskiej jako łuska Bystrego. Aczkolwiek poszczególne elementy zostały prześledzone co najmniej do doliny Wisłoki, to jednak ich budowa ulega znacznym zmianom. Najogólniej ich osie podnoszą się ku NW, a amplituda tych ruchów przekracza na niewielkich przestrzeniach nawet 3000 m.

Charakterystyczna jest budowa elementu Besko – Łubno, który między Wisłokiem a Wisłoką przechodzi w nasunięcie o amplitudzie do 5 km. Natomiast budowę elementów skrajnych w stosunku do osi synklinorium cechuje wybitna dysharmonia wyrażona budową kominową górnych części fałdów w stosunku do spokojnych części jądrowych. Szczegóły tektoniki poszczególnych elementów zostały wyjaśnione dzięki głębokim wierceniom. Utwory kredy dolnej budują czołową część jednostki, która na N od Krosna przybiera charakter nasunięcia o amplitudzie do 10 km. Ta budowa utrzymuje się dalej ku W, przy czym poszczególne elementy ulegają spłyceniu. Dotyczy to również fałdu Gorlic, którego skomplikowana budowa została wyjaśniona po wykonaniu kilku wierceń.

Najbardziej zachodnią część centralnej depresji karpackiej stanowi synklina Bobowej, wypełniona warstwami krośnieńskimi, która ograniczona jest od S antykliną Jankowej, a ku N przechodzi w rozległy fałd Rożnowa – Ciężkowic, w którego budowie istotną rolę odgrywają warstwy godulskie, istebniańskie i piaskowce ciężkowickie,

Fałd Rożnowa nasunięty jest ku N na fałd Czchowa, w którym też dominują utwory górnokredowe.

Pomiędzy Dunajcem a Skawą płaszczowina śląska dzieli się na dwie jednostki o charakterze rozległych synklin wtórnie pofałdowanych. Jednostka północna – dolna rozwinięta na obszarze Pogórza Wiśnickiego i Lanckorońskiego stanowi główny pień płaszczowiny śląskiej. Jest ona rozczłonkowana na wiele niecek i płaskich synklin, wypełnionych warstwami krośnieńskimi, rozdzielonych strukturami antyklinalnymi, zbudowanymi z warstw godulskich oraz istebniańskich. Wzdłuż północnego jej brzegu, ukazują się też utwory dolnej kredy z górnymi łupkami cieszyńskimi włącznie. Jednostkę górną stanowi nasunięta ukośnie na dolną, tzw. Kra Pogórza Lanckorońskiego. Jest to synklina wypełniona warstwami istebniańskimi i godulskimi. Od linii dyslokacyjnej Skawy ku E synklina ta zwęża się, a w rejonie Myślenic zanika.

Zarówno dolna, jak i górna jednostka ograniczone są od S antyklinalną strukturą zwaną strefą lanckorońsko-żegocińską kontynuującą się ku W jako przedłużenie fałdu Czchowa. Stanowi ona stromy fałd, w którego jądrze ukazują się w licznych oknach tektonicznych utwory jednostki podśląskiej. Jego północne skrzydło budują warstwy wierzowskie, lgockie i godulskie, a południowe, które jest często podcięte i nasunięte na jądro fałdu budują warstwy krośnieńskie oraz inne ogniwa paleogenu i kredy.

Na W od Skawy płaszczowinę śląską cechuje najpełniejszy rozwój osadów kredowych. Warstwy cieszyńskie występują tu jako dolne łupki cieszyńskie tytonu, wapienie cieszyńskie beriasu i górne łupki cieszyńskie wieku walanżyn – hoteryw. W górnej kredzie i paleocenie rozwinął się potężny kompleks w przewadze piaskowcowo-

-zlepieńcowy, zbudowany z warstw godulskich i istebniańskich, którego łączna miąższość może osiągać 3500 m. W spągu sztywniejszego kompleksu warstw godulskich doszło do odkłucia ich od niżejległych dysharmonijnie sfałdowanych utworów, wśród których istotną rolę odgrywają łupki cieszyńskie dolne. W ten sposób doszło do rozdzielenia płaszczowiny śląskiej na dolną cieszyńską i górną istebniańską.

Jednostka podśląska jest ściśle związana z jednostką śląską, przy czym przechodzenie w części wschodniej utworów kredy górnej w jedną fację utrudnia rozdzielenie obu jednostek. Ich granicy można się doszukiwać na NE od Leska, gdzie występuje wąska smuga margli węglowieckich po zewnętrznej stronie jednostki śląskiej. Zostały one również przewiercone w profilu Sanu, gdzie stwierdzono obecność w marglach kredy dolnej w formie porwaków. Jednostkę podśląską śledzono następnie w obszarze Grabownicy i Domaradza i dalej na W w Węglówce, gdzie wychodzi ona na powierzchnię w znanym oknie tektonicznym z kredą dolną w podwójnym fałdzie.

Wierceniami stwierdzono, że leży ona na warstwach krośnieńskich jednostki skolskiej, amplituda nasunięcia wynosi tu ok. 8 km. Stwierdzono również, iż jądro dolnokredowe zanurza się ku W i ulega prawie zupełnej redukcji. W profilu Wisłoka zalega ona poniżej 2800 m i ma zaledwie w całości 128 m miąższości przy amplitudzie nasunięcia 7 km.

Między Wisłokiem a Wisłoką sygnalizuje ją sporadyczne wystąpienie margli węglowieckich u czoła jednostki śląskiej lub w oknach tektonicznych. Ten styl utrzymuje się po rzekę Białą, gdzie wielka dyslokacja ucina tę jednostkę. Ukazuje się ona na powierzchni dopiero w okolicy Bochni i w oknie tektonicznym wewnątrz jednostki śląskiej.

Na W od Dunajca jednostka podśląska jest najbardziej zewnętrzną jednostką fliszową Karpat polskich, nasuniętą na utwory miocenu zapadliska przedkarpackiego. Jedynie jeszcze w rejonie Brzeska rozerwane płaty utworów tej jednostki leżą na warstwach krośnieńskich płaszczowiny skolskiej. Litostratygraficzny inwentarz jednostki podśląskiej w jej zachodniej części jest zróżnicowany i wyraźnie odróżnia się swym rozwojem od utworów jednostki śląskiej, a zwłaszcza utworami górnej kredy, paleocenu i eocenu, wykształconymi w facjach marglistych lub ilasto-marglistych.

Na powierzchni jednostka ta ukazuje się wzdłuż północnego brzegu Karpat, u czoła nasunięcia płaszczowiny magurskiej, a także w licznych oknach tektonicznych, w obrębie płaszczowiny śląskiej, z których większość należy do strefy lanckorońsko-żegocińskiej. Jak wykazały liczne wiercenia jest ona szeroko rozprzestrzeniona pod płaszczowiną śląską, jednak bywają obszary, gdzie jej brak lub zachowuje się w postaci drobnych strzępów wskutek rozerwania i wytarcia. Do takich przykładów należy obszar pomiędzy Brzeskiem i Bochnią a strefą lanckorońsko-żegocińską, w którym płaszczowina śląska leży wprost na utworach miocenu zapadliska lub mezozoiku podłoża platformowego.

Pomiędzy Bochnią a południkiem Krakowa u czoła płaszczowiny śląskiej jednostka podśląska występuje w postaci kilku łusek, spośród których dwie większe rozciągają się na S od Swoszowic oraz Wieliczki. Dalej na W po linię dyslokacyjną Skawy ciągnie się ona jedynie w postaci niewielkich wystąpień margli węglowieckich. Dopiero w pobliżu Skawy jednostka podśląska rozszerza się i różnicuje wyraźnie na łuski tektoniczne. Skutkiem cofnięcia ku S brzegu płaszczowiny śląskiej w rejonie Wadowic jednostka podśląska zyskuje szerokość 12 km. Dalej ku W zwęża się a między Sołą i Olzą zachowana jest w postaci małych łusek.

Spośród licznych okien tektonicznych, w których jednostka podśląska ukazuje się na powierzchni, należy duże okno Żywca oraz wiele okien strefy lanckorońsko-żegocińskiej. Na S jednostka ta swym zasięgiem przekracza brzeg nasunięcia płaszczowiny magurskiej. Pod nasunięciem północnej strefy płaszczowiny magurskiej utwory jednostki podśląskiej stwierdzono w profilach głębokich wierceń wraz z wycienioną tektonicznie płaszczowiną śląską bądź też samodzielnie.

W rejonie Andrychowa pod nasunięciem płaszczowiny śląskiej u jej czoła, a na utworach jednostki podśląskiej występują skałki andrychowskie, reprezentowane przez mylonity i granitognejsy, wapienie oxfordu i tytonu, wapienie i margle senonu, paleocenu i eocenu.

Płaszczowina skolska, zwana również skibową, zajmuje czołową pozycję w strefie fliszowej (*sensu stricto*) polskich Karpat między wschodnią granicą państwową a okolicami Brzeska na W kontaktując przeważnie bezpośrednio z zapadliskiem przedkarpackim. Obecność znacznych złóż gazu wzdłuż tego kontaktu spowodowała koncentrację głębokich wierceń, podobnie jak i poszukiwanie przedłużenia strefy borysławsko-pokuckiej w obszarze Przemyśl – Ustrzyki Dolne. Granica zewnętrzna tej jednostki jest więc wyraźna, natomiast z jednostką podśląską jest zamaskowana warstwami krośnieńskimi centralnego synklinorium. Granica ta staje się wyraźna od obszaru Ustrzyk Dolnych ku NW.

W profilu litostratygraficznym najważniejszą rolę w części wewnętrznej odgrywają warstwy krośnieńskie, a w nich wąskie bardzo strome jądro antyklin, a w części zewnętrznej warstwy inoceramowe kredy górnej, które od szerokich antyklin przechodzą w łuski. W pierwszej części najgłębszy otwór polskich Karpat Paszowa 1 (7210 m) przewiercił profil fliszu do margli krzemionkowych włącznie wykazując, że wewnętrzna część jednostki leży bardzo głęboko, natomiast wiele odwiertów w zewnętrznej części przewiercało utwory fliszowe.

Kluczowy okazał się tu otwór Cisowa IG-1 na SW od Przemyśla, który przewiercił 4010 m fliszu, 70 m jednostki stebnickiej, 248 m utworów badenu zalegających bezpośrednio na łupkach fylitowych prekambru. Nie przewiercił natomiast fliszu do głębokości 5440 m otwór Brzegi Dolne IG na NE od Ustrzyk. Położony 21 km na W od Przemyśla otwór Bachórzec przewiercił we fliszu 1300 m łupków spaskich zalegających na łupkach prekambru, wyznaczając wewnętrzną granicę autochtonicznego miocenu. Autor uważa, że wygięcie ku N czoła Karpat (sigmoida przemyska) jest wynikiem potężnej redukcji ku W jednostki stebnickiej.

Podłoże brzeżnej części Karpat podnosi się w kierunku NW, aby ponownie obniżyć się znacznie w rejonie Rzeszowa aż po obszar Tarnowa. Na tej przestrzeni jednostka skolska jest coraz silniej przykryta przez płaszczowinę śląską, jednostkę podśląską, a jej spąg schodzi do głębokości ponad 3700 m. Powierzchnia nasunięcia jest zaburzona tylko przez dyslokację w okolicy Rzeszowa i na E od Tarnowa. Od tego miasta po Brzesko następuje zupełny zanik jednostki, co należy uważać za zachodnią granicę basenu skolskiego.

Jednostka stebnicka o charakterze płaszczowiny odgrywa znaczną rolę, w budowie najbliższego przedpola Karpat ukraińskich. W obszar Polski wchodzi ona na SE od Przemyśla, gdzie nasunięta jest na autochtoniczne utwory górnego miocenu. Podstawowym ogniwem są tu warstwy stebnickie karpatu ok. 2000 m miąższości budujące trzy elementy antyklinalne obalone ku NE. Łupki menilitowe w spągu czołowej części jednostki na SE od Przemyśla S. Wdowiarz uważa za olistolity. W otworze Leszczyny na SSW od Przemyśla przewiercono pod fliszem 1300 m warstw stebnickich budujących leżący skręt synklinalny, wyznaczający zasięg jednostki pod Karpatami. Wzdłuż brzegu Karpat prześledzono ją wierceniami na NW od Przemyśla, na E od Rzeszowa i dalej w Ropczycach, gdzie tworzy ona odkorzeniony ku S porwak tektoniczny. Ostatnie wystąpienia warstw stebnickich stwierdzono w okolicy Brzeska.

Zagadnienie NW przedłużenia strefy borysławsko-pokuckiej w Polsce jest dyskutowane od trzydziestu lat. W świetle analizy materiałów z wierceń w obszarze Przemyśl – Ustrzyki wydaje się możliwe jej nawiercenie na SW od otworu Leszczyny.

РЕЗЮМЕ

VI Конгресс Карпатско-Балканской Ассоцации, который совершился в Польше в 1963 г., представил достижения польской геологии прежде всего в области стратиграфии флишевых отложений, их седиментации, а также восстановления палеогеографических и батиметрических условий флишевого бассейна. Результатом этих работ является изданная по случаю Конгресса работа пяти авторов „Статиграфия внешних Польских Карпат" — Ф. Беда и др. (1963), а также „Геологический атлас Польши, стратиграфически-фациальные вопросы, выпуск 13, мел и старший третичный период во внешних Польских Карпатах" — разработанный 14 авторами под редакцией М. Ксёнжкевича. Результатом картографических работ проводимых в течении многих лет в Карпатах является геологическая карта Польских Карпат в масштабе 1:200 000, составленная в 1958 г. в Геологическом Институте (западная часть — С. Соколовски, восточная часть — Х. Свидзиньски). На этой карте впервые проведено районирование тектонической флишевой зоны. Примечания к этой карте находятся в томе „Карпаты" Региональной геологии Польши изданной в 1953 г., содержащей тексты М. Ксёнжкевича и Х. Свидзинского.

В 1963 г. синтетическую разработку этой зоны в северных и восточных Карпатах сделал С. Вдовяж, а в 1972 г. М. Ксёнжкевич представил подробную характеристику тектоники Польских Карпат. В рамках работ КБАГ для тектонической карты Карпат и Балканов Л. Кошарски, В. Сикора и С. Вдовяж (1974) составили соответственную карту и текст. На основании всех этих трудов можно принять следующие названия отдельных элементов флишевой зоны: 1) магурский надвиг, 2) предмагурская единица, 3) дукельская единица, 4) силезский надвиг, 5) подсилезская единица, 6) скольский надвиг, 7) стебницкая единица.

С того времени, когда были проведены эти работы, прибыло много новых данных полученных из всё более глубоких скважин Нефтяного горного дела и Геологического Института (Карпатское отделение).

Магурский надвиг является наиболее внутренней единицей высшей категории в Польских флишевых Карпатах. Он перемещен к северу на отложения силезского надвига и единиц предмагурской группы на западе и дукельской единицы на востоке. С юга он граничит острым, крутым тектоническим контактом с Пенинской утёсовой зоной. Его отложения представляют главным образом верхний мел и палеоген. Наиболее распространены в ним ропянецкие слои (сенон — палеоцен) и магурские песчаники (верхний эоцен — нижний олигоцен). Самыми молодыми осадками являются надмагурские и мальцовские слои (нижний олигоцен).

Учётывая фациальную разность эоценовых отложений и их тектонику в магурском надвиге выделено пять фациально-тектонических зон. Глубинное тектоническое строение магурского надвига разведано рядом буровых скважин, таких как: Обидова ИГ-1, Хабувка-1, Токарня ИГ-1, Тшебуня ИГ-1, Суха Бескидзка ИГ-1, Быстра ИГ-1.

Дукельская единица находится в переходной позиции между магурским и силезским надвигами: развитие верхнего мела и палеоцена похоже на магурский надвиг, а младшего палеогена — на силезский. Она максимально поднята в восточной части, к северу-западу погружается, скрываясь под магурским надвигом. В дукельской единице можно выделить две подъединицы с разным тектоническим строением, разделённые надвигом, который — как выказали скважины Ялиска 2 и Збой 1 — сперва погружается круто, а на глубине около 3000 м становится более плоским.

Единицы предмагурской зоны представлены пред магурской единицой с.с., выделенной у фронта магурского надвига в западной части Польских Карпат, а также единицами, которые появляются в тектонических окнах магурского надвига и под надвигом (грыбовская единица). Верхний мел и палеоцен этих единиц похож на магурский надвиг, а младший палеоген — на силезский надвиг. Кроме поверхностных исследований эти единицы разведаны глубокими скважинами, такими как Порэмба Велька ИГ-1 и Недзведзь 1 в тектоническом окне Мшаны Дольной и Обидова ИГ-1, Хабувка 1, Слопнице 1 и 20 под магурским надвигом.

Единица Обидовой — Слопниц разведена в вышеприведённых скважинах как тектонически низшая чем грыбовская единица. Её отложения возраста с нижнего сенона до олигоцена фациально близки к дукельской единице, но отличаются от ней большой мощностью осадков „черного эоцена".

Силезский надвиг играет главную роль в геологическом строении флишевой зоны Карпат. По мнении С. Вдовяжа (1963) к юго-востоку от польских границ он продолжается в Украинских Карпатах (единицы: Костшицы — Скуповой, Чарногоры) и в Румынских Карпатах (единица Аудия). Внутреннюю границу силезского надвига определяет дукельская единица, а западную — магурский надвиг. К северу он частично надвинут, вместе с осадками подсилезской единицы, на отложения скольского надвига в восточной части и на осадки миоцена предкарпатского прогиба в западной части. Восточная часть силезского надвига, находящаяся в пределах центрального карпатского синклинория, состоит из семи антиклинальных элементов, сложенных дифференцированными кросненскими слоями. К северо-западу оси складчатых элементов поднимаются, а отдельные элементы становится все более мелкими. К западу от реки Дунаец из-за этих изменений, главную роль в строении надвига играют годульские слои (сенон), а также истебнянские слои (сенон — палеоцен), а к западу от реки Скавы также и старшие отложения, в том числе также цешинские слои, которых самую низкую часть слагают осадки титона. Глубинное строение силезского надвига, особенно к востоку от меридиана Кракова, разведано многими глубокими скважинами.

Подсилезская единица находится у фронта силезского надвига, в тектонических окнах и в его основании. Она сильно тектонически активна, чешуйчатая, разорвана, а местами совсем стертая. Отложения ниж-