Development of Polish Flysch Carpathians revealed in outcrops and landscape

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The Flysch Carpathians are the outermost part of the Carpathian orogen (Książkiewicz, 1977). In Poland they occupy the area between the Pieniny Klippen Belt in the south and the Carpathian Foredeep with its folded parts (Stebnik and Zgłobice units) in the north (Fig. 1). Their sediments were formed in the flysch basins of the Outer Carpathians. Sedimentation took place from the late Jurassic (Tithonian — the oldest known deposits) to early Miocene folding and thrusting. Diversity of rocks controls the present-day morphology and relief of the Carpathians, i.e. ancient geologic events and processes are evidenced in the present landscape.

The history of the flysch basin of the Outer Carpathians commences in the Tithonian by deposition of clayey facies with significant fraction of olistostrome (lower Cieszyn shales), known from the Silesian succession (Słomka, 1986). Then, at the turn of the Jurassic and Cretaceous, calcareous flysch (Cieszyn limestones — Fig. 2) was deposited. The latter strata are signs of extension (probably associated with rifting), which led to formation of the basin of diversified depths where sedimentation of the deposits originating from uplifted zones and shelves predominated (Poprawa, Malata, 2006).

From the Valanginian, sedimentation of deep-water turbiditic limestones has been replaced by fine rhythmitic clayey-sandy sequence being primarily carbonate (upper Cieszyn shales, Grodziszcze shales) and then clayey deposits (Verovice beds). Coarse-clastic inserts — Grodziszcze sandstones (Fig. 3) are present only sporadically. The basin of the Outer Carpathians is deep, poorly oxygenated, thus, black clayey deposits prevail. The deposits of the considered period reveal the post-rift phase of thermal subsidence (Poprawa, Malata, 2006), when sedimentation in the basin became unified and a rate of clastic material supply to the basin decreased. The general pattern outlined above was periodically disrupted in the Albian, when, locally, the material originating from the northern margin of the basin was rapidly supplied and the sedimentation rate increased (Poprawa et al., 2006). The latter events are evidenced by the lower Lgota beds and Gaize beds (Figs. 4, 5). In the late Albian and Cenomanian the sedimentation was again calm and unvarying (Lgota beds, variegated shales), but, oxic conditions in the basin have changed, so that dark deposits of the Lower Cretaceous became replaced by red and green claystones of the Cenomanian with inserts of siliceous deposits.

The Outer Carpathian basins, which were relatively weakly diversified during the early Cretaceous, were remodelled significantly in the Late Cretaceous (from the Turo-

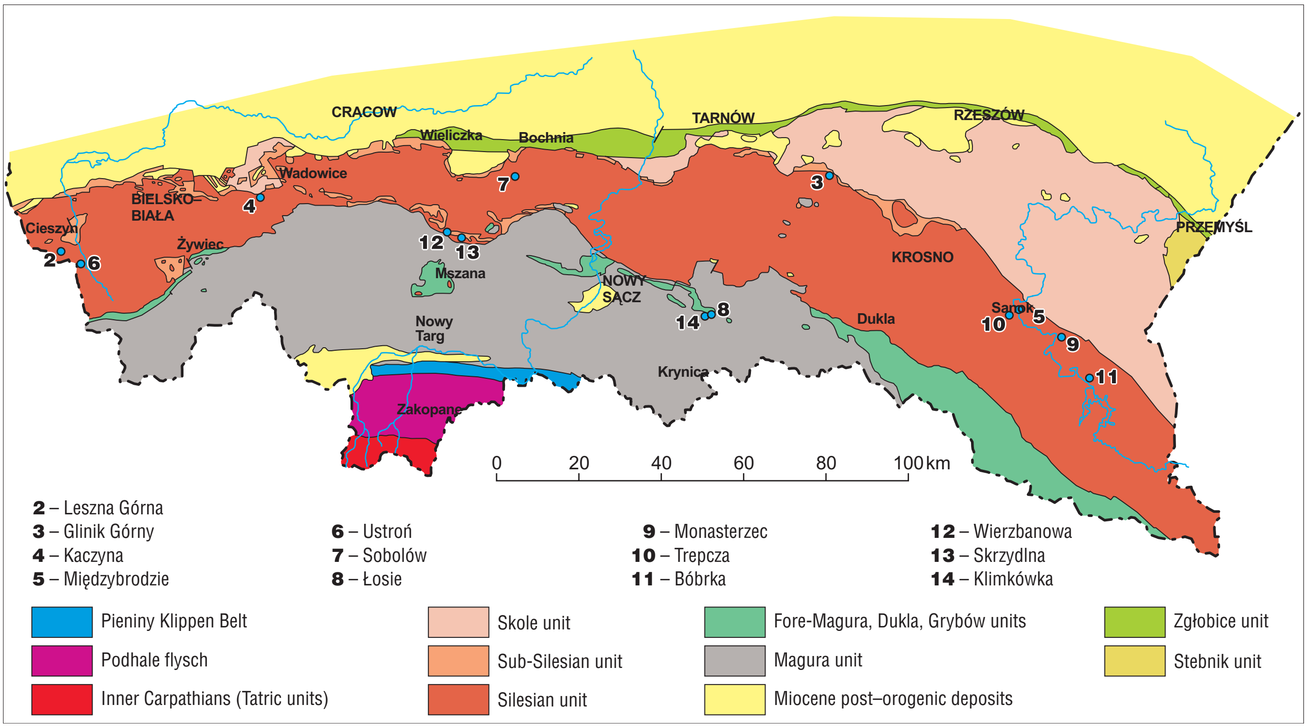

Fig.1. Locality of presented photos on the map of tectonic units in the Polish Carpathians (K. Żytko et al., 1989)

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Fig. 2. Leszna Górna quarry — Cieszyn limestones (Tithonian–Berriasian) — turbiditic limestones

Fig. 4. An old quarry in Kaczyna — Lgota beds (Albian). Figs. 2, 4 photo by M. Krawczyk

Fig. 3. An old quarry in Glinik Górny — Verovice Beds with thick-bedded Grodziszcze sandstones (Barremian–Aptian)

Fig. 5. Outcrop of the Gaize beds (Albian) at the right bank of the San River in Międzybrodzie near Sanok Figs. 3, 5 photo by T. Malata

nian). As a result it became subdivided into fairly deep basins (Magura, Dukla, Silesian and Skole sub-basins) separated by land (Silesian cordillera) or by submarine ridges (Węglówka ridge). The basin comprised the zones of intensive clastic sedimentation (Godula and Istebna beds in the Silesian sub-basin — Figs. 6, 7), zones of rhythmic flysch sedimentation, being often calcareous (Inoceramian Beds in the Magura and Dukla sub-basins, Inoceramian Beds with Siliceous marls and Fucoid marls in the Skole sub-basin), as well as the zones of clayey-marl sedimentation (variegated shales and Węglówka marls on the Węglówka ridge). The morphological differentiation of the basin results from compression in the Carpathian orogen and genetically corresponds with thrust-and-fold movements in the Inner Carpathians. At that time due to the collisional uplift, active thrust-and-fold belt was formed between the Dukla and Silesian sub-basins (i.e. Silesian Cordillera, Poprawa, Malata, 2006). It was the zone of the Earth's crust shortening as well as the source of clastic material which was filling-up its flexural subsided foreland that is the Silesian sub-basin. At that time, the Silesian sub-basin was a foreland basin in respect to the Silesian cordillera. Two incidents of specific tectonic activity in the zone of the Silesian cordillera, namely the Turonian and Campanian/Maastrichtian, can be easily identified in the rocks.

The differences in the basin topography and the distance from the source area result in a great diversity in sediment thicknesses and sedimentation rates: from 100–150 m thick clayey-marl upper Cretaceous deposits on the Węglówka ridge to several thousand-meter-thick series of the Godula and lower Istebna beds in the western part of the Silesian basin. Simultaneously, deposits of submarine slumps occur in the zones proximal to alimentation areas.

Paleogeography and sedimentation in the early Paleocene is continuation of the Late Cretaceous conditions. In the Dukla sub-basin, the short-lasting but rapid sedimentation of clastic deposits, derived from the north (Cisna sandstones), takes place. The activity of the Silesian cordillera ceases during the late Paleocene–early Eocene. In the whole area located north of the Cordillera (Silesian and Skole sub-basins) the rate of clastic material supply decreases. The series of turbidity and fluxoturbidity sediments are replaced by red and green clayey deposits (variegated shales) which only locally contain coarse-clastic inserts (Ciężkowice sandstones). At the same time, activity of the southern margin of the flysch basin increases — from the turn of the Paleocene/Eocene the South-Magura ridge rapidly begins to supply coarse clastic material (Magura beds) to the southern part of the Magura basin (Oszczypko et al. 2006). Relocation of the Earth's crust shortening zone from the Silesian cordillera to the south takes place.

Fig. 6. An old quarry of the thick-bedded Godula beds (Turonian) in Ustroń-Poniwiec. Figs. 6, 7, 8 photo by M. Krawczyk

Fig. 7. Sobolów quarry — Istebna sandstones (Maastrichtian–Paleocene)

Fig. 8. Magura sandstones (Wątkowa glauconitic sandstones) in Łosie — outcrop at the left bank of the Ropa River below Klimkówka dam

Fig. 9. Menilite beds in Monasterzec near Lesko. Figs. 9, 10, 11 photo by T. Malata

Fig. 10. Thick-bedded Krosno sandstones (lower Krosno beds, Lesko facies) in Trepcza near Sanok

Fig. 11. Ostre sandstones (upper Krosno beds) in an old abandoned quarry at Bóbrka on Myczkowce Lake

In the Eocene the coarse clastic sedimentation of the Magura beds in the Magura sub-basin (Fig. 8) expanded northward and by the end of the Eocene covered almost the whole sub-basin area. Fairly thick, fine-bedded rhythmic series of turbidity deposits (Hieroglyphic beds) formed in the Dukla sub-basin. On the contrary, similar deposits in the outer zone of the basin (Silesian and Skole sub-basins) were characterized by a small thickness and low sedimentation rate. On the Węglówka ridge a very slow sedimentation of variegated hemipelagic deposits went on from the Cenomanian to the end of the Eocene.

Until the end of the Eocene, the Outer Carpathian basin was relatively deep especially in the zone of sub-basins. This setting changed at the turn of the Eocene and Oligocene. In the larger part of the Carpathian basin, the shallow water facies of the Menilite beds (Fig. 9) appeared (Olszewska, Malata, 2006). These were mainly brownish bituminous shales overfilled with organic matter, and with packages of massive glauconite sandstones, siliceous rocks and marls. Significant changes occurred in the source areas. The activity of the South-Magura ridge ceased while the source area located north of the Magura sub-basin (sedi-

Fig. 12. Eastward view from Wierzbanowa. Forested hills are built of the Menilite and Krosno beds of the Silesian unit. The depressions leftward of the hill are developed on the Skrzydlna tectonic window (Sub-Silesian unit). The highest summit on the left (Kostrza) is a tectonic cap of the Magura unit

Fig. 13. Westward view from Skrzydlna. Forested hill in the centre is built of the Krosno beds (Oligocene, Silesian unit) while the depression to the right is built of the Menilite beds. The ridge with the summit of Wierzbanowska Góra is formed by overthrusted rocks of the Magura unit

Fig. 14. Klimkówka reservoir on the Ropa River. The ridges to the left and right are built of the glauconite facies of the Magura beds (Wątkowa sandstones, Oligocene). The depression filled with an artificial lake is developed on the Sub-Magura beds and variegated shales (Eocene). Figs. 12, 13, 14 photo by M. Krawczyk

mentation of Wątkowa sandstones) became active as well as the zone of the Silesian became reactivated. In the eastern part of the Polish Carpathians the Maramures (Bukowiec) cordillera developed which began to supply coarse clastic material (different from that supplied from the Silesian cordillera) into the Silesian sub-basin (Otryt sandstones). With time, menilite facies has been replaced by the Krosno beds (Figs. 10, 11), which are diachronic in the considered profile — i.e. they appear earlier in the inner zones (early Oligocene) and later in the outer zones (early Miocene in the Skole sub-basin). Their sedimentation is associated with a northward spread of the accretion prism of the Carpathians near the close of early Miocene sedimentation in the flysch basin.

This brief outline of sedimentation and tectonic processes in the Carpathian flysch basin points to a significant genetic and lithologic homogeny of Outer Carpathian deposits (predominance of siliciclastic turbiditic deposits). On the other hand, tectonic processes in the basin and in its surrounding resulted in alternation of ratios between sandy and clayey deposits in the Carpathian profiles, diversity of grain-sizes and changes in oxygenation of the basin (leading to different colors of the deposits). The sub-basin deposits were folded and thrusted during the Miocene orogenesis. Due to interaction of all processes mentioned above, the mountain range of complicated geology formed which is reflected in diversified topography and landscape (Figs.12, 13,14).

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