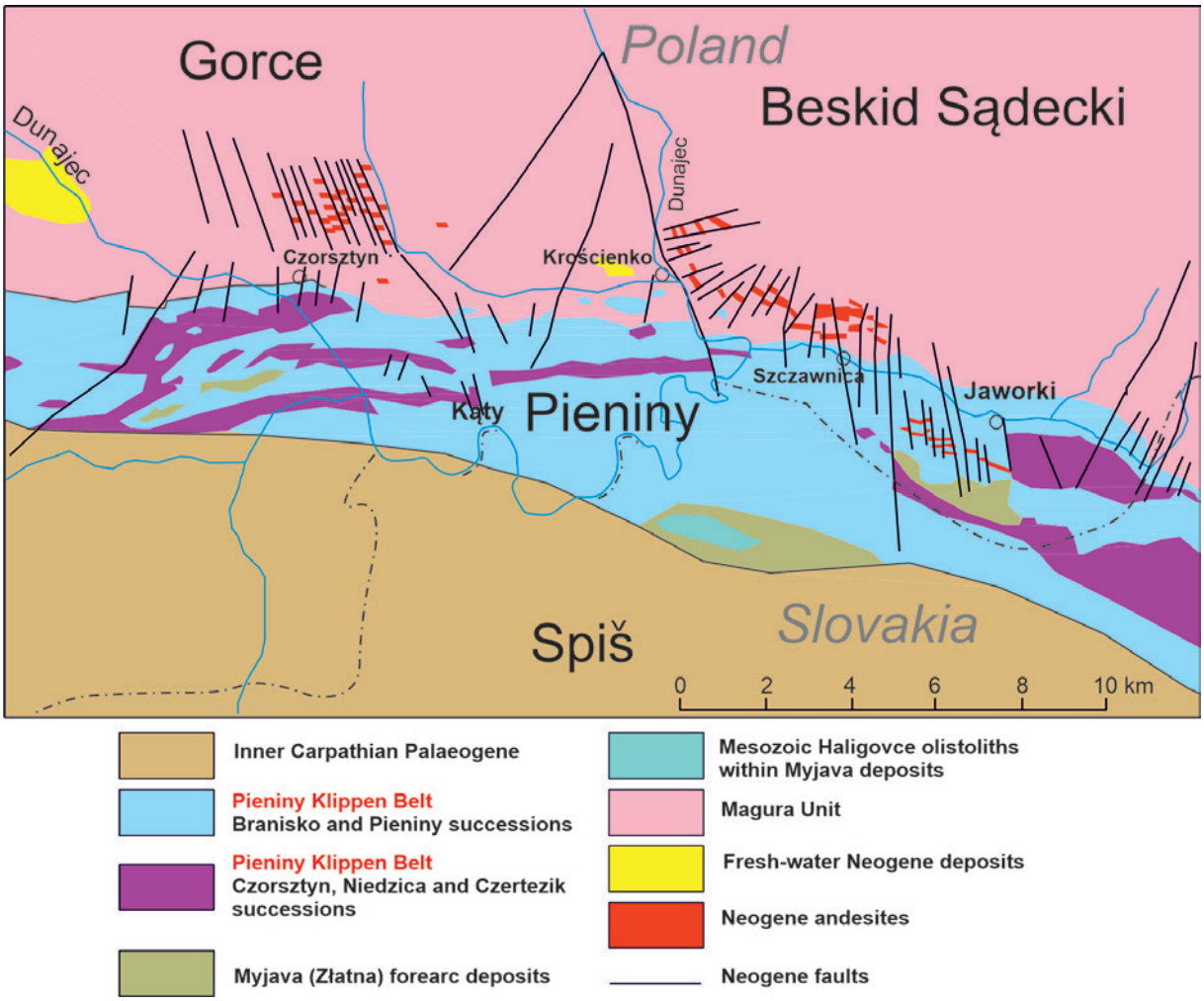

Fig. 12. Geological sketch of the Pieniny Klippen Belt (Polish sector) and surrounding regions (after Birkenmajer, 1979 – simplified)

DESCRIPTION OF THE TRIP

Passage: Kraków – Rzyki – Leszna Górna – Wisła – Szczawnica

(*Jan Golonka*, *Michał Krobicki*)

The field trip starts in AGH University of Krakow parking lot and leads southward to the Carpathians. In Krakow and its vicinity the Mesozoic rocks of the North European Plate are exposed. The platform is dissected by numerous faults into several horsts and grabens. The grabens are filled with the Miocene Molasse deposits, while horsts elevate the Upper Jurassic rocks. These rocks are represented mainly by Oxfordian cyanobacterial-sponge buildups with associated nodular, chalky and micritic limestones (Matyszkiewicz, 1997). Passing the bridge on Wisła River we can observe the hill of Wawel with the Polish Royal Castle on the top. The Royal Castle was built in 10th century and remodeled several times. The most important remodeling was done by Queen Bona and her team of Italian architects in 16th century giving the castle its Renaissance character. The Wawel hill is built by the white-weathering Upper Oxfordian massive limestones. These limestones are horst elevated and shaped by karst phenomena. Following southwards the road crosses the Carpathian Foredeep filled with Miocene molasse deposits. Springs of hydrosulphuric mineral waters are connected with the Miocene deposits (Cieszkowski & Ślączka, 2001). These mineral waters are being utilized at spas Mateczny and Swoszowice located within Krakow City limits. After a few kilometers the route passes over the frontal thrust-faults of the Outer Carpathian flysch belt.

Authors' editorial note

The material presented in this description is based upon the publications printed in: "Geotourism" journal (2023, vol. 20, iss. 3–4), and other materials of international geological excursions (e.g., IGCP 589'2017) and "Przegląd Geologiczny" ("Geological Review"), cited partly in extenso with permission of editors.

Stop 1 – Rzyki village – Lower Cretaceous dark grey/black heterolithic deposits (Veřovice Formation) (Figs 8, 13, 14–18)

(*Piotr Łapcik*)

The Zagórnik-Rzyki section is situated south of Andrychów in the western part of the Silesian Nappe. The section commences where the uppermost part of the Veřovice Formation (ca. 24 m thick) is cropping out along the incised Wieprzówka stream (starting point GPS coordinates: N 49° 50′ 00.6″; E 19° 22′ 16.9″; ±6 m). The strata exhibit a gentle southerly dip and are characterised by minor tectonic disruptions, although the overall stratigraphic order remains intact. The Zagórnik-Rzyki section is an excellent representation of Lower Cretaceous deposits in deep water setting, which remains a permanent point of geological field trips in the Polish Outer Carpathians (e.g., Cieszkowski *et al.*, 2001, 2003; Uchman & Cieszkowski, 2008; Uchman *et al.*, 2022).

The Veřovice Formation is dominated by dark grey and black mudstones and siltstones. These non-calcareous, partially siliceous lithologies frequently incorporate heterolithic sandstone-mudstone facies, irregularly interbedded with thin to medium beds of fine-grained sandstone. Heterolithic deposits show complex but hierarchical internal structure organised into nine heterolithic divsions A1–A9 with varied tractional depositional structures (Łapcik, 2023). This sediments are interpreted as a spectrum of waxing, waning and pulsating waxing to waning turbulent flow and transient turbulent flow deposits with possible hyperpycnal flow origin (Łapcik, 2023). The cooccurring sandstone beds exhibit planar parallel-lamination and/or ripple cross-lamination as a part of classic Bouma T_b and T_c sequences. Ferruginous concretions appears throughout the section. Exposed Veřovice Formation include alternating mud-dominated successions and intervals with increased proportion of sand and heterolithic deposits, each a several metres thick. Previously these deposits were considered as basin plain facies that were periodically influenced by bottom currents (e.g., Uchman & Cieszkowski, 2008; Waśkowska *et al.*, 2009), however recent detailed sedimentological studies revealed their proximal depositional setting with a relatively dynamic seafloor environment on the flank of mud-dominated depositional lobe (Łapcik, 2023). Non-calcareous nature of the sediments along with analyses of foraminiferal assemblage suggest deposition within the lower bathyal zone (Książkiewicz, 1975; Szydło, 1997).

The uppermost part of the Veřovice Formation in the Zagórnik-Rzyki section was dated with dinocyst *Cerbia tabulata* to the Lower Albian stage (Gedl, 2001, 2003). The dark mudstones represent organic-rich deposits that accumulated plant detritus sourced from neighbouring terrestrial source. High phytoplankton productivity also likely contributed to the organic content, with TOC values reaching approximately 4% (Strzeboński *et al.*, 2009; Pavluš & Skupien, 2014; Wójcik-Tabol & Ślączka, 2015). Deposits of the Veřovice Formation were claimed as associated with the Lower Cretaceous oceanic anoxic events and perhaps related with early Aptian Selli Event (OAE 1a) or the early Albian Paquier Event (OAE 1b). Nevertheless, macroscopically it is challenging to distinguish the episodes of oxygen depletion and episodes of improved oxygenation that separates the OAEs. Ichnological data partially supports the interpretation of anoxic conditions in the Veřovice Formation (Uchman, 2001b, 2004) and most deposits lack trace fossils and exhibit primary lamination. However, bioturbated intervals occur repetitively indicating at least poor delivery of oxygen, perhaps with the subsequent flow events (Uchman *et al.*, 2022). Localised occurrences of bioturbated horizons, less than 1 centimetre thick, are observed at the top of some sedimentary sequences. These horizons display a slightly lighter colour and contain a limited assemblage of ichnotaxa dominated by *Phycosiphon incertum*, *Chondrites intricatus* and *Ch. targionii*, *Planolites* isp., *Palaeophycus* isp and rarely *Thalassinoides* isp. Additionally, bivalve burrows identified as *Protovirgularia pennata* and *P. obliterata* are locally abundant and concentrated within a zone a few centimetres below the *Chondrites* occurrences (e.g., Uchman *et al.*, 2022). Presence of *Protovirgularia* in the lowest tier, distinctly below the *Chondrites* assemblage, suggests these burrows were produced by chemosymbiotic bivalves capable of burrowing in anoxic sediments (Uchman *et al.*, 2022). Similar examples include the solemyacid bivalve *Solemya* (Seilacher, 1990) and specific lucinid and thyasirid bivalves (Powell *et al.*, 1998) is occasionally present as well. The Early Cretaceous anoxic events likely hindered the colonization of the deep-sea floor by the irregular echinoids responsible for generating *Scolicia* trace fossils (Tchoumatchenco & Uchman, 2001). Notably, *Scolicia* is absent within the Veřovice Formation and older Carpathian formations. Consequently, the trace fossil assemblage at Zagórnik-Rzyki is likely influenced by global events associated with the Cretaceous anoxic episodes.

A transitional zone to the Lhoty Beds is marked with the first appearance of thin-bedded, green-grey, bioturbated, non-calcareous mudstone shales. Succession of transitional beds, 5.5 m to 6 m thick, appears approximately 160 m upstream from the designated starting point. The frequency of green-grey mudstones and the overall contribution of sandstone beds progressively increase up the section. Notably, sideritic concretions are present at intervals of roughly 1.5 m both above and below the first green-grey layer.