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SHORT COMMUNICATION

Fault contact of the Pieniny Klippen Belt with the Central Carpathian Paleogene Basin (Western Carpathians): new data from a unique temporary exposure in Ľutina village (Eastern Slovakia)

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Abstract: An exceptional, briefly exposed section across the boundary between the Pieniny Klippen Belt (PKB) and the Central Carpathian Paleogene Basin (CCPB) in Eastern Slovakia showed that the contact is formed by a single, subvertical fault plane. Whereas the Oligocene CCPB deposits exhibit only weak deformation with S-verging fold-and-thrust structures, the Cretaceous PKB sediments are internally strongly sheared with scaly fabric and numerous calcite veins. It is inferred that the PKB suffered strong thrusting- and wrenching-related deformation in pre-Oligocene times, while the Early Miocene oblique backthrusting resulted in exhumation of the PKB and formation of its steep fault boundaries.

Key words: Western Carpathians, Klippen Belt, regional tectonics, lithology, stratigraphy, structures.

Introduction

During the field geological mapping in summer 2012, a distinctive exposure of the contact between the south-western margin of the Pieniny Klippen Belt (PKB) and sediments of the Central Carpathian Paleogene Basin (CCPB) was by chance discovered, documented and sampled. The about 25 m long, continuous profile was temporarily outcropped during ground works in a newly rebuilt place of pilgrimage near the Basilica Minor in the village of Ľutina near the town of Sabinov in north-eastern Slovakia (Figs. 1, 2A), GPS coordinates N 49°10.006′, E 21°02.745′. Six samples for palynology (Lut1–Lut6), and seven for foraminifers (Lu1-1–Lu1-7) were taken. The purpose of this short article is to provide information regarding the lithology, age and structure of rocks occurring in this outcrop because it is important from the point of view of PKB tectonics.

Geological situation

The studied section is located in the western part of the Slovak Šariš sector of the PKB, below the SW slopes of the Čergov Mountains (Fig. 1A). This PKB part is characterized by a distinctively straight fault boundary trending NW-SE (ca. 120°) that separates the PKB from the CCPB. Andrusov (1968) named it as the Podhale fault. On its SW side, the adjacent part of the CCPB is composed of several hundred meters wide belt composed of soft shales and less sandstones of the Oligocene Huty Fm.

Further to the SW within the CCPB, the PKB trend is followed by a conspicuous structure — the Šambron-Kamenica Belt. This is a hilly zone formed by an en echelon array of large brachyantiforms exposing the Šambron Beds composed of huge bodies of chaotic conglomerates (Soták et al. 2001). The antiform axes are oriented somewhat oblique to the trend of the PKB and indicate slightly oblique backthrusting with dextral component along the PKB in post-Oligocene times (Plašienka et al. 1998).

Further north-west in Poland, the contact zone of the PKB with the partial Podhale Basin of the CCPB was studied in detail by Mastella (1975) and Mastella et al. (1988). They distinguished three structural zones within the Podhale Basin that are parallel to the W-E trending PKB: 1) the strongly imbricated and disturbed contact zone directly adjacent to the PKB passing to a km-wide belt with moderately to steeply S-dipping Szaflary beds (corresponding to the Šambron Beds in Slovakia) and with numerous S-dipping normal faults; 2) steep zone of the “Peri-Pieniny flexure” indicating a S-vergent thrust fault in the basement; 3) zone of gentle dips in the Zakopane beds (equivalent to the Huty Fm) that neighbours the axial zone of the “Podhale synclinorium”. This situation would indicate the original sedimentary contact of the CCPB formations with the PKB, which was affected by Early Miocene backthrusting and exhumation of the PKB.

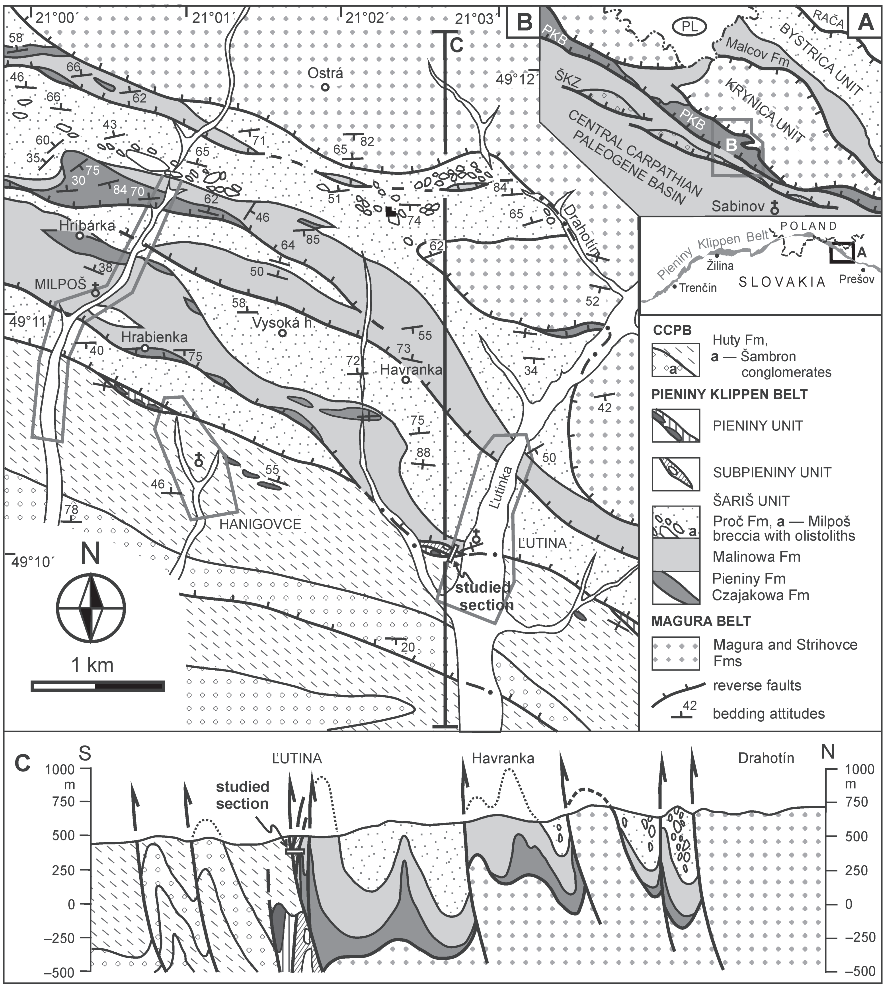
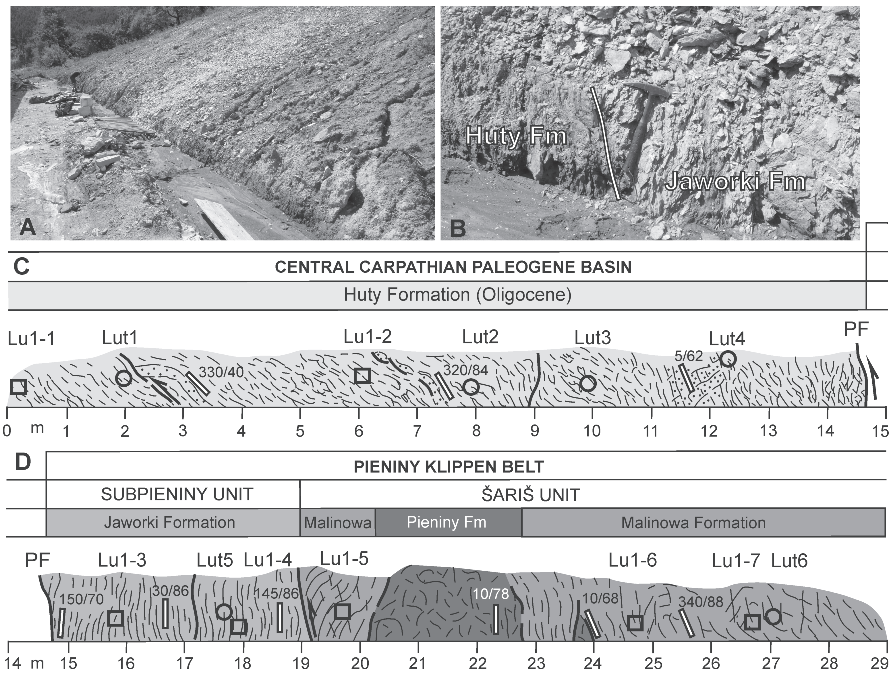


Fig. 1. Geological setting of the studied section: **A** — general scheme of the East Slovak PKB and adjacent zones (ŠKZ — Šambron-Kamenica Zone); **B** — geological map of the Ľutina village surroundings; **C** — geological cross-section.



The Slovak Pieniny and Šariš sectors of the PKB are composed of three principal thrust sheets of the Oravic affiliation — the Pieniny, Subpieniny and Šariš Units from top to bottom (Plašienka & Mikuš 2010; Plašienka 2012; Plašienka et al. 2012). The Pieniny Unit is characterized by the presence of the deep-water Jurassic–Cretaceous succession and forms a SE-ward narrowing strip along the southern PKB margin. The underlying Subpieniny Unit involves several shallow-marine successions — in addition to the most typical, ridge-related Czorsztyn Succession, it also embraces some "transitional" successions (Niedzica, Czertezik) derived from slope environments. Both the Pieniny and Subpieniny Units are strongly reduced in the Ľutina area, where they only occur as narrow shreds along the south-western PKB margin.

A substantial part of the PKB in the area concerned is formed by the Šariš Unit (Fig. 1B), which was defined by Plašienka & Mikuš (2010) as the structurally lowermost element of the Eastern Slovak PKB. The Šariš Unit largely corresponds to the Grajcarek Unit of the Polish Pieniny Mts (e.g. Birkenmajer 1977), as far as the lithostratigraphic succession is concerned. It includes deep-marine sedimentary formations of the Jurassic to Early Eocene age. The oldest rocks exposed are Middle Jurassic deep-marine clastic deposits, followed by Middle–Upper Jurassic radiolarites (Czajakowa Fm), maiolica-type cherty limestones (Pieniny Fm), various mid-Cretaceous marlstones and black shales, Upper Cretaceous red and greenish-grey pelagic shales (Malinowa Fm), and Maastrichtian–Paleo-

Fig. 2. Field drawing and photos of the studied section: **A** — general view of the profile (note that exposure is restricted to the lowermost edge of the slope only); **B** — discrete fault boundary between the CCPB Huty Fm and the PKB Jaworki Fm; **C** — drawing of the southern part of the profile; **D** — northern part. Positions of foraminiferal samples are indicated by squares, palynological by circles. Bedding attitudes are shown as dip direction/dip angle. PF — Podhale fault. South is to the left.

cene to Lower Eocene synorogenic, coarsening- and thickening-upward flysch sequence (Jarmuta and/or Proč Fm). This is terminated by chaotic breccias including numerous large sedimentary klippen — olistoliths of Jurassic to Lower Cretaceous limestones derived predominantly from the overriding Subpieniny Unit (Milpoš Breccia — Plašienka & Mikuš 2010). While the pre-Paleogene formations occur in tight anticlinal cusps, the up to a thousand meters thick Proč flysch forms wide lobate synclines (Fig. 1C).

Lithology and stratigraphy

In the section studied, three different lithological sequences can be distinguished (Fig. 2). The southern part of the section exhibits sediments of the CCPB that are composed of dark grey, weakly calcareous shales weathered to brownish colours. Occasional turbiditic, siliciclastic, fine-grained, thin-bedded and often laminated sandstone beds are 5–15 cm thick, only one bed is up to 50 cm thick. Two washed-out shale samples for foraminifers were negative (Lu1-1 and Lu1-2, Fig. 2C), but four palynological samples (Lut1–Lut4) yielded, among others, dinoflagellate cysts *Chiropteridium lobospinosum*, *Chiropteridium* sp., *Wetzeliella* sp. A sensu Gedl (2000) and *Wetzeliella gochtii* suggesting the Late Rupelian age. The time-span, taxonomical composition and palynofacies composition allow for affiliation of this sequence to the CCPB Oligocene Huty Fm (i.e. the Zakopane beds in Polish terminology).

After a discrete fault contact, the PKB involves two sequences — behind the contact there is a zone of Upper Cretaceous variegated marlstones and marls about 5 m thick (Fig. 2D). The cherry-red marls yielded pelagic foraminifers *Macroglobigerinelloides* cf. *prairiehillensis* (Pessagno), *Heterohelix* sp., *Globotruncana insignis* (Gandolfi), *Globotruncana arca* (Cushman), *Globotruncana linneiana* (d'Orbigny), *Globotruncana orientalis* El-Naggar, *Globotruncanita stuartiformis* (Dalbiez) pointing to the Late Campanian–Early Maastrichtian age (sample Lu1-3, Fig. 2D). This lithology corresponds to the Pustelnia Marl Member of the Jaworki Formation sensu Birkenmajer (1977). Greenish-grey calcareous shales next to red marlstones are assigned to the Lower Turonian *Helvetoglobotruncana helvetica* Zone on the basis of their planktonic foraminiferal assemblage represented by *Dicarinella hagni* (Scheibnerova), *Dicarinella oraviensis* (Scheibnerova), *Helvetoglobotruncana helvetica* Bolli, *Praeglobotruncana gibba* Klaus, *Marginotruncana* cf. *schneegansi* (Sigal), *Marginotruncana* sp., *Whiteinella baltica* Douglas & Rankin, *Whiteinella aprica* (Loeblich & Tappan), *Whiteinella brittonensis* (Loeblich & Tappan) — sample Lu1-4. A single sample Lut5 yielded very rare dinoflagellate cysts, from which co-occurrence of *Palaeohystrichophora infusorioides* and *Dinogymnium* sp. points at the Early Turonian–earliest Maastrichtian age. The age and lithology of this Turonian interval match the main characteristics of the Macelowa Marl Member of the Jaworki Fm (Birkenmajer 1977). About ca. 100 m to the NW, a small hill with a stone cross is composed of massive sandy-crinoidal limestones. Most likely, this klippe and the variegated marls in the section belong to the Czorsztyn-type succession of the Subpieniny Unit.

The third sequence consists of calcite-poor, purple-red shales that only contain deep-water agglutinated foraminifers (DWAF) of the *Uvigerinammina jankoi* Zone (samples Lu1-5 and 6, Fig. 2D). Besides the common index species *Uvigerinammina jankoi* Majzon, various other agglutinated foraminifers were identified: "*Rhabdammina*" sp., *Rhizammina* sp., *Nothia* sp., ?*Psammosphaera* sp., "*Saccammina*" spp., *Pseudonodosinella* spp., *Subreophax* sp., *Reophax* sp., *Calamopsis grzybowskii* (Dylążanka), *Caudammina ovula* (Grzybowski), *Ammodiscus tenuissimus* (Grzybowski), *Ammodiscus cretaceus* (Reuss), *Glomospira* spp., *Bulbobaculites problematicus* (Neagu), *Haplophragmoides* spp., *Tritaxia gaultina* (Morozova), *Gaudryina pyramidata* Cushman, *Spiroplectinella dentate* (Alth), *Spiroplectammina navarroana* Cushman, *Paratrochamminoides* spp., *Trochamminoides* spp., *Gerochammina* spp., *Trochammina* sp., *Recurvoides* spp., *Pseudobolivina* sp. Scarce occurrence of planktonic foraminifers *Marginotruncana coronata* Bolli, hedbergellids and calcareous benthic foraminifers was also noticed. Grey-green shales at the end of the section were barren of both foraminifers (sample Lu1-7) and palynomorphs (sample Lut6). A body of brecciated Pieniny-type limestones of Early Cretaceous age about 3 meters thick is inserted within the shales (Fig. 2D). Lithology, facies and age of the variegated pelagic shales reveal their affiliation to the Malinowa Fm, which forms here, along with limestones of the Pieniny Fm, the core of a tight anticline (Fig. 1C). Several tens of meters towards the NE, the debris is composed of fragments of calcareous sandstones typical for the Proč Fm. We therefore assign this sequence to the Šariš Unit.

Structural elements

From the structural point of view, the exposed section showed several interesting and partly unexpected features. First of all, the CCPB vs. PKB contact is formed by a single, nearly vertical and smooth fault plane lacking any slip-sense criteria (Fig. 2B). The CCPB deposits of the Oligocene Huty Fm are internally slightly disturbed with small reverse faults and a metric, SW-verging drag fold (Fig. 2C). Bedding is moderately to steeply NW-dipping, but almost vertical and N-dipping directly at the contact with the PKB sediments. Though the shales are strongly weathered, obviously no important internal deformation occurred, except tilting and some brittle crushing.

Bedding within both the variegated marlstones of the Subpieniny Unit and variegated shales of the Šariš Unit is nearly vertical, dipping either steeply to the NW-N-NE, or occasionally to the SE (Fig. 2B,C,D). The stratification is locally strongly disturbed with scaly foliation and numerous irregular and deformed calcite veins. Foliation planes are smooth and sometimes polished. However, no measurable striae were observed. Veinlets, frequent in the Subpieniny marlstones in particular, are filled with whitish blocky and fibrous calcite, mm to 1 cm thick, but only several cm long. They are irregularly oriented and often truncated by the foliation planes. Slickenfibres are frequently present, but, due to a younger brittle crushing, their original orientation was difficult to establish and measure. Therefore no data relevant for the paleostress analysis could be gathered.

Discussion

The described section exposes juxtaposition of two regional units of higher order — the Oligocene strata of the CCPB showing a comparatively low degree of internal distortion, and various Cretaceous formations of the PKB, in which the moderate ductile/brittle strain is visible macroscopically. These structural elements, as well as their orientation, match those described from the adjacent parts of the PKB further to the NW (Plašienka & Mikuš 2010; Plašienka 2012). According to these works, structural evolution of the eastern PKB progressed in four distinct deformation stages from: 1) foreland-propagating detachment and thrust stacking of the Oravic units from the latest Cretaceous up to the Early Eocene, followed by post-stacking dextral transpression; 2) "cross folding" probably related to the formation of the Carpathian arc (Middle Eocene?); 3) extensional collapse of the overthickened thrust wedge accompanied by subsidence and deposition of the Upper Eocene to Oligocene, and likely up to Lower Miocene formations of the CCPB; 4) backthrusting and formation of the post-Oligocene Podhale fault bounding the PKB from the SW. This corresponds to an oblique-slip, dextral reverse fault related to backthrusting of the innermost Krynica Subunit of the External Carpathian Magura Belt over the PKB and marginal parts of the CCPB (see also Nemčok 1984). This late (Early to Middle Miocene), N-S to NNE-SSW shortening event affected by folding also the internal structure of the PKB (Fig. 1A,B), as well as the adjacent parts of the CCPB (Šambron-Kamenica anticlinal zone — Plašienka et al. 1998). As a result, the PKB was exhumed from below the overstepping Oligocene and Lower Miocene complexes and attained its present linear trend in Eastern Slovakia. The section studied records all the above mentioned deformation events and documents a discrete juxtaposition of the PKB and the CCPB sediments. The latter only show deformation structures related to the last deformation stage described under 4).

In comparison with the Polish part of the PKB vs. CCPB contact zone (see Mastella 1975; Mastella et al. 1988) we may conclude that the described section reveals stronger N-S to NE-SW shortening and backthrusting indicated by a uniform steep northern dip of younger CCPB strata (Huty Fm analogous to the Zakopane beds) below the southward thrust PKB. Unlike the Podhale synclinorium, the Peri-Klippen part of the CCPB is formed by an anticlinal zone exposing the Šambron-Szaflary beds (Fig. 1C).

Conclusions

Temporary section in the Ľutina village in Eastern Slovakia exposed the boundary between the PKB and the CCPB. Three lithological sequences have been distinguished. They also correspond to three principal tectonic units of the area, two of them within the PKB. The Oligocene deposits of the CCPB Huty Fm, dated palynologically by dinoflagellates, exhibit only weak internal deformation with occasional S-verging fold-and-thrust structures. The contact with the Cretaceous PKB sediments is formed by a single, subvertical and smooth fault plane. A sequence about 5 meters thick next to the PKB boundary fault is composed of red marls and green-grey calcareous shales with Upper Campanian–Lower Maastrichtian foraminifers and Lower Turonian foraminifers (*Helvetoglobotruncana helvetica* Zone) and dinoflagellates, respectively. This imbricated sequence is affiliated to the Czorsztyn-type succession of the Subpieniny Unit. Marls are internally strongly sheared with scaly fabric and numerous calcite veins. The third sequence consists of variegated, poorly calcareous shales with DWAF indicating Late Turonian–Coniacian age (*Uvigerinammina jankoi* Zone). Together with an inserted body of Pieniny-type limestones, this sequence represents the Šariš Unit, which is the most widespread tectonic unit in this part of the PKB. Based on structures in this section and the regional tectonic circumstances, it is inferred that the PKB units suffered strong thrusting- and wrenching-related deformation in pre-Oligocene times, while the Early Miocene oblique backthrusting resulted in exhumation of the PKB and formation of its steep fault boundaries.

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