South-vergent structures observed in the western part of the Krivánska Fatra Mts. (Central Western Carpathians)

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Juhovergentná tektonika západnej časti Krivánskej Fatry (Centrálne Západné Karpaty)

Abstract: This paper deals with the reverse (south-vergent) structures observed in the western part of the Krivánska Fatra Mts., developed during the Cenozoic evolution of the Western Carpathians. Geological setting of the Krivánska Fatra Mts. is interpreted on the basis of geological mapping and observation of mesoscopic and map-scale structures. Pre-Cenozoic nappe structure (from the bottom to the top: Tatric, Fatric, and Hronic units) of the study area was intensively affected and overprinted by a younger tectonic phase, which led to the formation of the present geological setting. Geological structure is typical by the NE–SW oriented structures with the top to the S–SE tectonic displacement. The age of this tectonic event – south-vergent backthrusting is considered to be the Early Miocene because affected also the sediments of the Central Carpathian Palaeogene Basin.

Keywords: Central Western Carpathians, Krivánska Fatra Mts., Cenozoic evolution, backthrusting, geological mapping

1. INTRODUCTION

The Krivánska Fatra Mts. (Fig. 1) is situated in the northern part of the Central Western Carpathians within the Tatra-Fatra mountain belt (Vass et al., 1988). The position of the Krivánska Fatra Mts. is attractive due to immediate tectonic contact with the Pieniny Klippen Belt – an extremely complicated tectonic zone at the boundary of the Western Carpathian Externides and Internides (*sensu* Mišík et al., 1985). Despite all this, since 1979, a minimum attention was paid to this territory. For the tectonic interpretation of this area without drilling, not many previous geophysical survey and quarries, revision of a geological map was necessary. The paper describes geological and structural setting of the western part of the Krivánska Fatra Mts. obtained from detailed geological and structural mapping.

2. KRIVÁNSKA FATRA MOUNTAINS

The Krivánska Fatra Mts. is composed by the several superposed palaeo-Alpine (Cretaceous) tectonic units – the lowermost Tatric Unit, which is overthrusted by the nappes of the Fatric and Hronic tectonic units (Fig. 1). This palaeo-Alpine tectonic structure is typical top to the north-northwest tectonic displacement. It was documented in the eastern part of the Krivánska Fatra Mts., where so called "Lysica duplex" occurred in Mesozoic sequences of the Fatric Unit (Matějka, 1931; Haško & Polák, 1978, 1979). However, another dominant structure of the Krivánska Fatra Mts. (Medzirozsutce reverse fault) shows the opposite – southward vergency (Uhlig, 1902; Matějka, 1931, 1932; Harčár, 1958; Haško & Polák, 1978; 1979; Marko et al., 2005). Along this generally W-E trending structure, the northern block of the Malý Rozsutec consisting of the Hronic Triassic dolomites and the Fatric Cretaceous marls and shales were thrust southward over the block of the Veľký Rozsutec which is composed of the Palaeogene sediments and the Hronic Triassic carbonates (Fig. 1). An immediate tectonic contact between the Jurassic and Cretaceous successions of the Kysuca Group (Pieniny Klippen Belt) and the Triassic carbonates of the Hronic Unit is located in the western part of the mountain range (*sensu* Haško & Polák, 1979). Other south-vergent structures are documented within the Central Carpathian Palaeogene sediments and the lithotectonic units of the Pieniny Klippen Belt as well as tectonic units of the Externides in the northern surrounding of the study area. The age of the south-vergent structures is considered to be the Early Miocene (e.g. Polák et al., 1977; Potfaj et al., 1993; Marko et al., 2005; Král et al., 2007; Pešková & Hók, 2008; Pešková et al., 2009). The approach based on detail geological and structural mapping, kinematic analysis and constructing a series of geological cross-sections reveal southward structures also in the western part of the Krivánska Fatra Mts.

3. GEOLOGICAL SETTING

According to the geological mapping at the scale of 1: 10 000, the geological structure of the study area is composed of three tectonic units of the Central Western Carpathians – Tatric, Fatric and Hronic units, and locally also by the Manín Unit and sediments of the Central Carpathian Paleogene Basin (Fig. 2).

3.1. Tatric Unit

The Tatric Unit is the lowermost tectonic unit, which is represented by the Upper Palaeozoic (Carboniferous) crystalline

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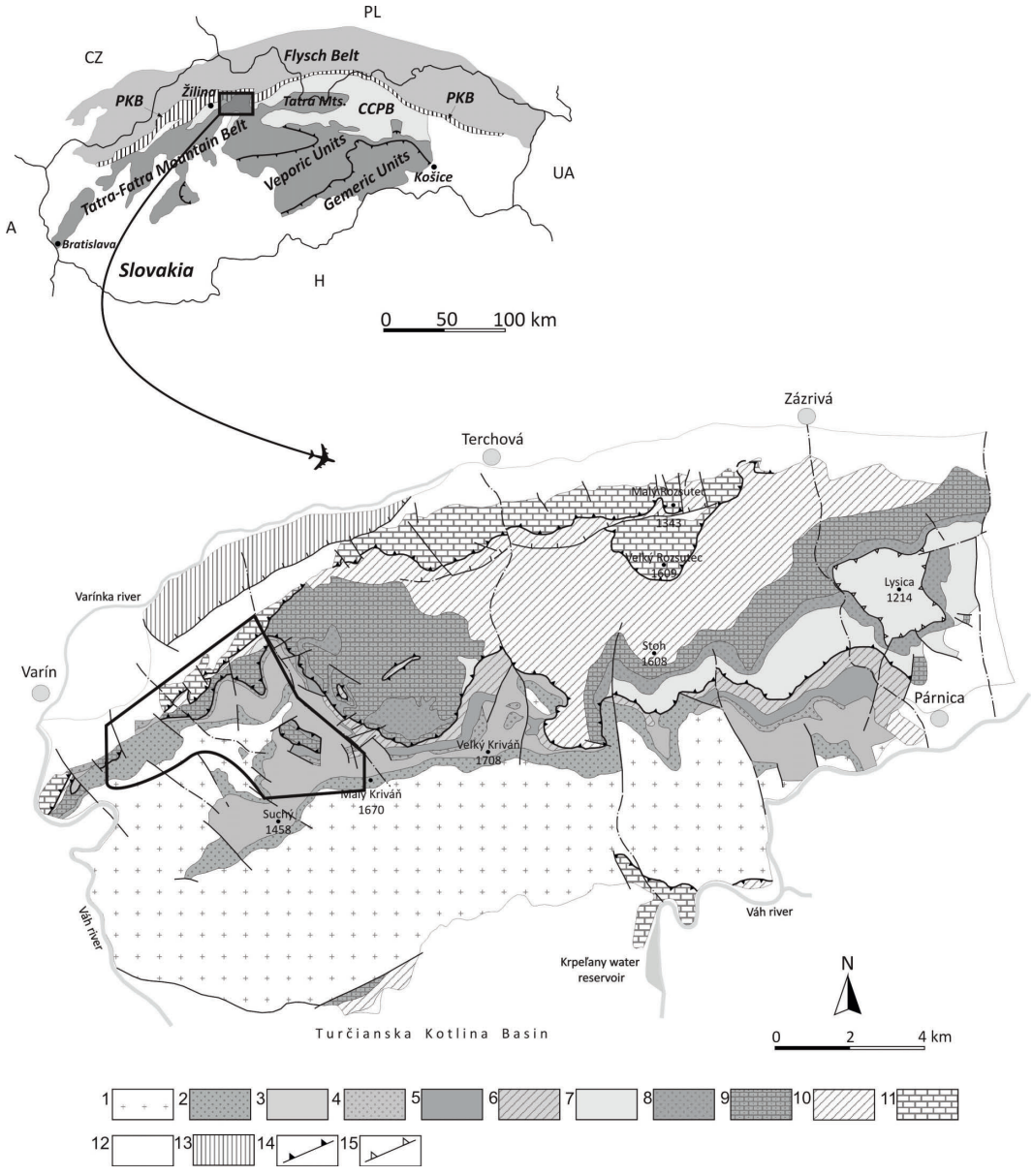

Fig. 1. Localization of the study area (outlined by the inserted polygon) and geological map of the Krivánska Fatra Mts. (according to Haško & Polák, 1978). Tatric Unit: 1 – crystalline basement, 2 – Lower Triassic Fm., 3 – Middle Triassic Fm., 4 – Upper Triassic Fm., 5 – Jurassic Fm., 6 – Cretaceous Fm; Fatric Unit: 7 – Middle Triassic Fm., 8 – Upper Triassic Fm., 9 – Jurassic Fm., 10 – Cretaceous Fm; Hronic Unit: 11 – Middle Triassic Fm., 12 – Palaeogene sediments undivided, 13 – Pieniny Klippen Belt undivided, 14 – nappe lines, 15 – thrusts, 16 – Medzirozsutce reverse fault, 17 – faults, 18 – assumed faults, 19 – geological boundaries.

basement and the Mesozoic sedimentary cover ranging between the Early Triassic and Early Cretaceous, with the stratigraphic hiatus in the Rhaetian (cf. Haško & Polák, 1979). The crystalline basement is formed by two intrusive granitic bodies: (i) the older granite body is represented by hybrid biotite – oligoclase granite, (ii) the younger one is the so-called Magura type granite (Ivanov & Kamenický, 1957 ex Broska et al., 1997). The Tatric Mesozoic cover begins with the Lower Triassic quartzites conglomerates and variegated shales of the Lúžna Formation (Fm.), followed by Middle Triassic carbonate complexes (Gutenstein limestone and Ramsau dolomite) and the Upper Triassic quartzites and conglomerates (Carpathian Keuper Fm.). Jurassic formations in the study area are represented by the complexes of Liassic sediments (Trlenské and Allgäu fms.); uppermost members are only Upper Jurassic – Lower Cretaceous limestones, marlstones and shales with cherts (Lučivná Fm.).

3.2. Fatric Unit

The Fatric Unit is a general term for units derived from a Mesozoic palaeogeographical zone located and eliminated between the present Veporic and Tatric units (e.g. Andrusov et al., 1973; Plašienka, 1999, 2003). The Fatric Unit in the Krivánska Fatra Mts. is formed by the classical "Krížna nappe s.s.", which is the main component of the Fatric nappe system. The oldest rocks, occurred in the study area, are Middle Triassic carbonate complexes (Gutenstein limestone and Ramsau dolomite). The Upper Triassic Carpathian Keuper Fm. is predominantly represented by variegated shales and dolomites, unlike as quartzite – rich the Carpathian Keuper in the Tatric Unit. The presence of the Rhaetian sediments (Fatra Fm.) is very sporadic and best noticeable in the area of Bačin village. Jurassic formations are composed of different facies of the marine limestone (Kopienec

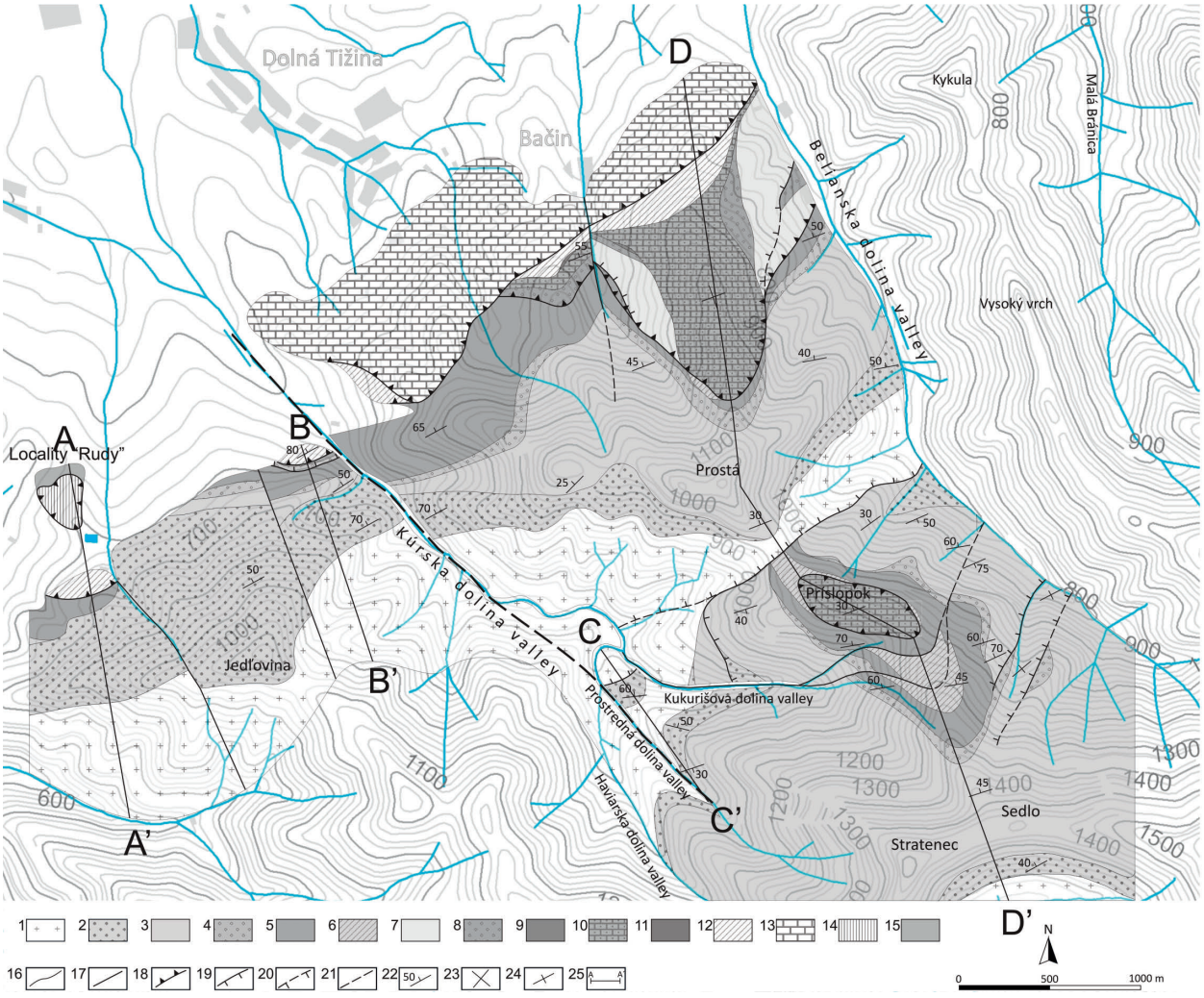

Fig. 2. Geological map of the western part of the Krivánska Fatra Mts. (Sentpetery, orig. fig.) Tatric Unit: 1 – crystalline basement, 2 –Lúžna Fm., 3 – Middle Triassic carbonate, 4 – Carpathian Keuper Fm., 5 – Trlenské & Allgäu fms. 6 – Lučivná Fm; Fatric Unit: 7 – Middle Triassic carbonate, 8 – Carpathian Keuper Fm., 9 – Fatra Fm., 10 – Kopienec & Allgäu fms. 11 – Ždiar Fm., 12 – Mráznica Fm., Hronic Unit: 13 – Middle Triassic carbonate, Manín Unit: 14 – Cretaceous carbonate complex with the intercalations of volcanic rock bodies, Palaeogene sediments: 15 – Biely potok Fm. 16 – geological boundaries, 17 – faults, 18 – overthrust boundaries, 19 – reverse faults, 20 – assumed reverse faults, 21 – assumed faults, 22 – dip direction and dip off bedding, 23 – subhorizontal bedding position, 24 – subvertical bedding position, 25 – geological cross-section.

and Allgäu fms.) and deep water radiolarian limestones and radiolarites (Ždiar Fm.). The uppermost member of the Fatric stratigraphic sequence is the Uppermost Jurassic – Lowermost Cretaceous limestone, marlstone and shales without cherts (Mráznica Fm.).

3.3. Hronic Unit

The occurrence of the Hronic Unit in the western part of the Krivánska Fatra Mts. is very limited. Only the Middle Triassic Ramsau dolomites overlie different members of the Fatric Unit, and on one occurrence even the Tatric sedimentary cover.

3.4. Manín Unit

Lower Cretaceous carbonate complex with the intercalations of volcanic rocks bodies at the "Rudy" locality between Varín village and Jedľovina Mt. (1035 m a.s.l.) is presented (Fig. 2). Tectonic affiliation of the Lower Cretaceous rock complex to tectonic unit of the Central Western Carpathians is still uncertain, with respect to different interpretations of the previous authors (e. g. Zorkovský, 1956; Haško & Polák, 1978; Hovorka & Spišiak, 1988; Fisherová, 1993; Sláviková, 2008). Based on the latest/recent research (Fisherová l. c.), these rocks were considered as a part of the Manín Unit. Tectonic position and lithostratigraphy of the Manín Unit is still under discussion (e. g. Andrusov, 1938, 1968; Rakús, 1977, 1978[a], 1978[b]; Reháková & Michalík, 1992; Plašienka, 1995; Rakús & Hók, 2004).

3.5. Sedimentary succession of the Central Carpathian Paleogene Basin (CCPB)

Sediments of the CCPB are presented only in a few outcrops situated in a spectacular position below the Cretaceous rocks complexes of the Manín Unit at the "Rudy" locality (Fig. 3). The Palaeogene sediments belong to the Biely potok Fm., and represent the uppermost part of the Podtatranská skupina Group (sensu Gross et al., 1984).

4.RESULTS AND INTERPRETATION

4.1. Map pattern

The rock complexes of the palaeo-Alpine tectonic units are arranged in zones with the NE–SW trending. The Tatric Unit is situated on the southernmost part while the Hronic on the northernmost part (besides of the Manín Unit outlier) of the investigated area. The bedding planes are generally dipping to the N–NW and the general strike of structures is approximately

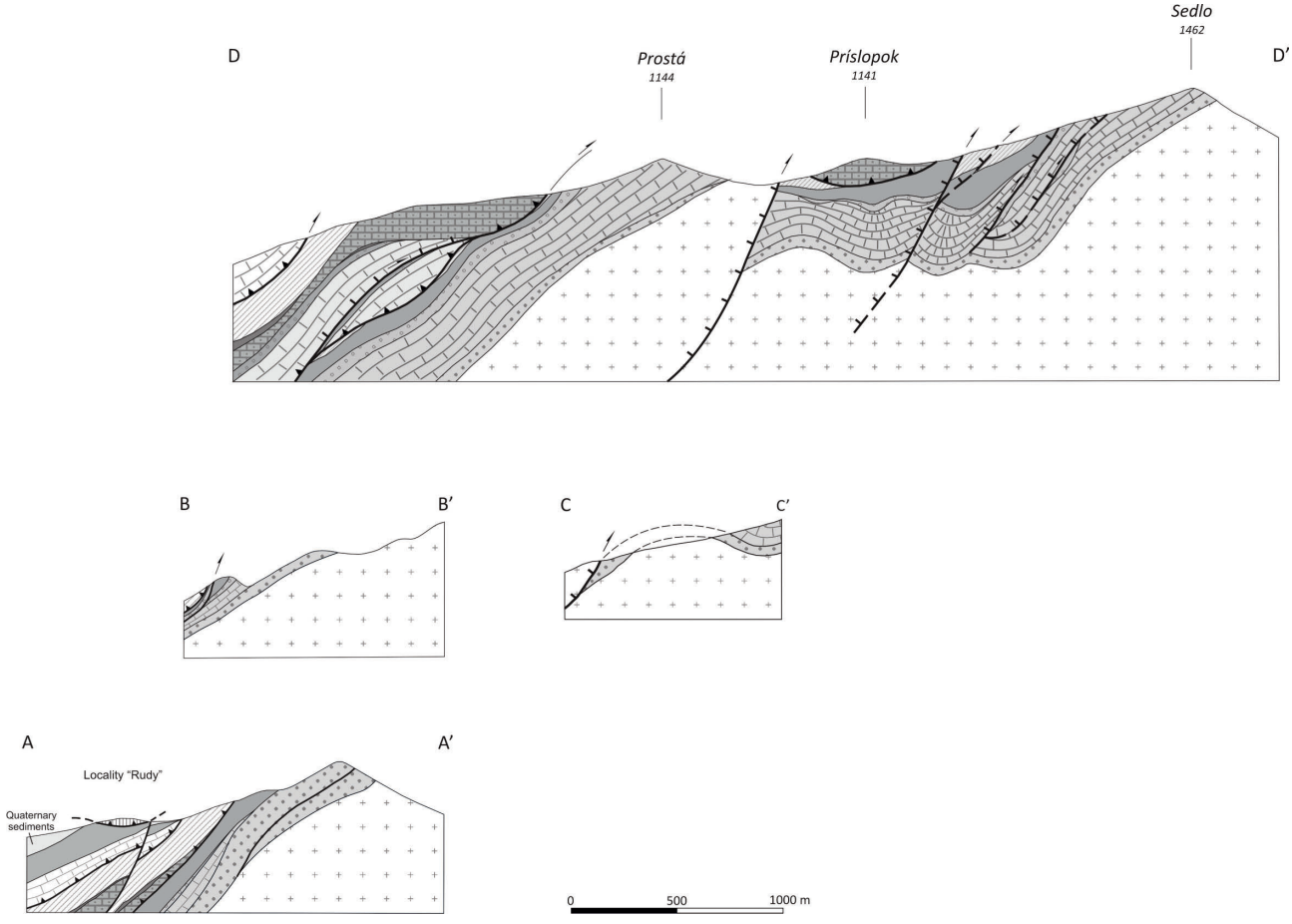

Fig. 3. Structural cross-sections of the studied area (explanation as in Fig. 2)

in the NE–SW direction. To describe and understand the geological structure in the study area is possible in the three key sites (Fig. 2).

4.2. Locality "Rudy" and Jedľovina site

The distribution of the litostratigraphic members in this site is reduced, due to the localization on emerged southwestern block separated by the Kúrska dolina fault. In the northern ridge of Jedľovina Mt. (1065 m a. s. l.), a steeply northwest – dipping reverse fault imbricates the Tatric sedimentary cover formations (Carpathian Keuper and Liassic limestones). This structure was overthrusted by the Cretaceous Mráznica Fm. of the Fatric Unit (Fig. 2, 3). The "Rudy" locality is also a part of this site and probably represents a tectonically separated block of the Manín Unit, which had been transported southward by thrust faults over the sedimentary succession of the CCPB during the neo-Alpine (Miocene) period of the Western Carpathian tectonic evolution (cf. Sláviková, 2008).

4.3. Prostá site

An area built up by Prostá Mt. (1144 m a.s.l.) is located between Kúrska and Belianska dolina valleys (Fig. 2). Gently bended formations of the Tatric sedimentary cover are only internally deformed. More expressive deformations are noticeable in the Triassic complexes of the Fatric Unit. In the northern ridge of Prostá Mt. (1144 m a. s. l.), the map–scale duplex structure occurred within Middle Triassic carbonates representing competent layer and Upper Triassic variegated claystones and sandstones as an incompetent detachment layer (Fig. 3). Massive character of the carbonates and the disintegration of the Carpathian Keuper Fm. do not allow the direct observation on outcrops. This structure can be recognized only from the map pattern. From the tectonic point of view, the position of the structurally uppermost Hronic tectonic Unit, which directly overlies Jurassic limestone of the Tatric sedimentary cover without presence of the Fatric Unit in between is very interesting.

4.4. Príslopok site

Most deformed area is situated in the surrounding of Príslopok Mt. (1141 m a. s. l.). Unlike Haško & Polák (1978), as a Fatric Unit are considered only Jurassic limestone located at the top of Príslopok Mt. (1141 m a. s. l.) in the form of the tectonic outlier. The nappe sole is defined by tectonic contact with the Lučivná Fm. (uppermost member of the Tatric Unit) accompanied by cataclasites (rauhwackes). The rest of area is formed by the Tatric Unit. The most intense deformation similarly suffered the Triassic complexes as in the Prostá site. Several reverse faults and duplexes were observed along the contact between the Middle Triassic carbonates and the Carpathian Keuper shales (Fig. 3). The dipping of carbonate beds in a few outcrops is almost sub-vertical. Where the younger rocks occur, these faults intersect the whole sequence of the Tatric sedimentary cover. The most complex structure is exposed in the pass between Prostá Mt. and Príslopok Mt. The granites of the Tatric crystalline basement are located in the direct contact with the uppermost lithostratigraphic member of the Tatric Unit - the Lučivná Fm. This tectonic contact continues northeastward to the Belianska dolina Valley and southwestward to the Kúrska dolina Valley. Most likely, this structure can by interpreted as a northwest dipping reverse fault, although the granites are without visible structural features which could verify this assumption. However, within the Mesozoic complexes of the Príslopok site, the structures indicating intensive compression in the NW–SE direction are recorded. Continuation of mentioned structure can be found towards the southwest, between Kukurišova and Prostredná dolina valleys. Mutually folded Lower Triassic quartzite and crystalline basement of the Tatric Unit form a northeast plunging brachyanticline with the SW–NE oriented fold axis (Fig. 3). The basement/cover interaction is also recorded in the central part of the mountain range (Vrátna dolina Valley) and this structure is described as a south-vergent reverse fault (Barkáč, 1958).

5. DISCUSSION AND CONCLUSIONS

Revision of geological map in the western part of the Krivánska Fatra Mts. revealed a several structures important for tectonic reinterpretation of this area. According to Haško & Polák (1979), reduction or squeezing out of younger members of the Tatric Unit (Upper Jurassic and Cretaceous sediments) is a result of the palaeo-Alpine thrusting. It could be accepted, however upper members of the Tatric sedimentary cover including the Lučivná Fm., are situated directly beneath the Fatric Unit nappe sole in many places. The Upper Jurassic Ždiar Fm. is missing here probably primarily. Reduction of the Fatric Unit increase westward. It is most probably associated with the NW – SE oriented faults parallel with the main valleys (Kúrska and Belianska dolina valleys) and approximately perpendicular to general strike of structures. The various tectonic structures described previously are restricted/bounded by these faults and generally do not continue into the adjacent blocks, although the origin and age of their formation should be identical (Fig. 4). These faults can be interpreted as "compartmental faults" (*sensu* Brown, 1975 ex Davis & Reynolds, 1996), and have been later, and probably to present, active as a normal faults, as is apparent from the geological map and kinematic indicators recorded on slickenside surfaces in several outcrops.

The folds and thrusts/faults style of structures, with the general SW–NE oriented fold axis and reverse fault strikes are typical phenomenon of this tectonic setting. The direction of tectonic displacement along these structures is generally top to the southeast. Except a duplex structure in the Prostá site, these structures are steeply dipping and their offsets are low. This geometric arrangement is in harmony with the accepted existence of positive flower structure in the Varín segment of the PKB (e.g. Potfaj et al., 1993; Král et al., 2007) and its influence to the geological setting of the Krivánska Fatra Mts. recorded as backthrusting (e.g. Haško & Polák, 1979; Marko et al., 2005). It is not entirely clear, whether such steep reverse faults could be formed primarily, or whether the movements took place over reactivated

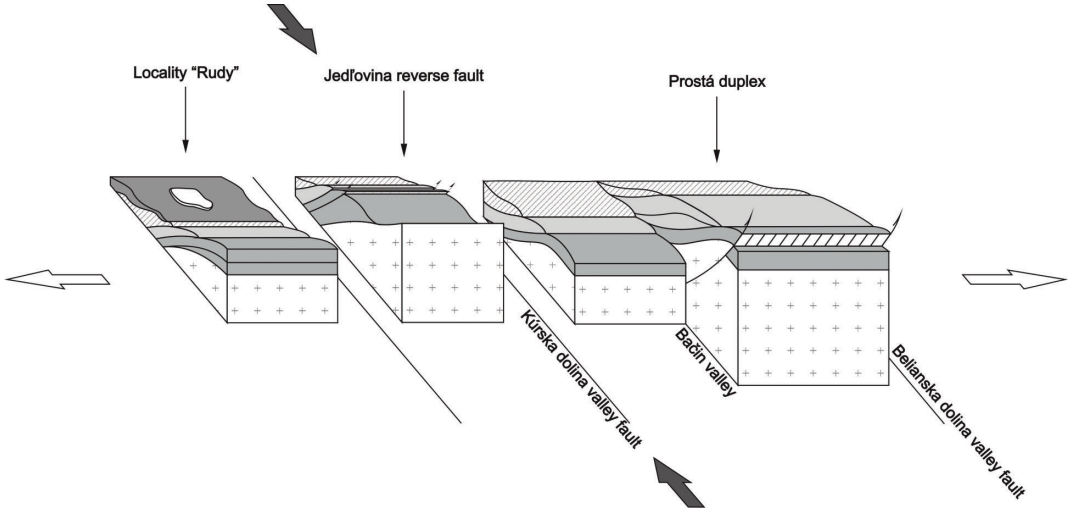

Fig. 4. Blockdiagram illustrating compartmental faulting in the western part of the Krivánska Fatra Mts. The various structures originated during compression regime (black arrows) are restricted by faults separating the area to individual segments, in which a deformation has been achieved in different ways. 1 – Tatric Unit crystalline basement, 2 – Tatric Unit sedimentary cover, 3 – Fatric Unit, 4 – Hronic Unit, 5 – Palaeogene sediments, 6 – Manín Unit

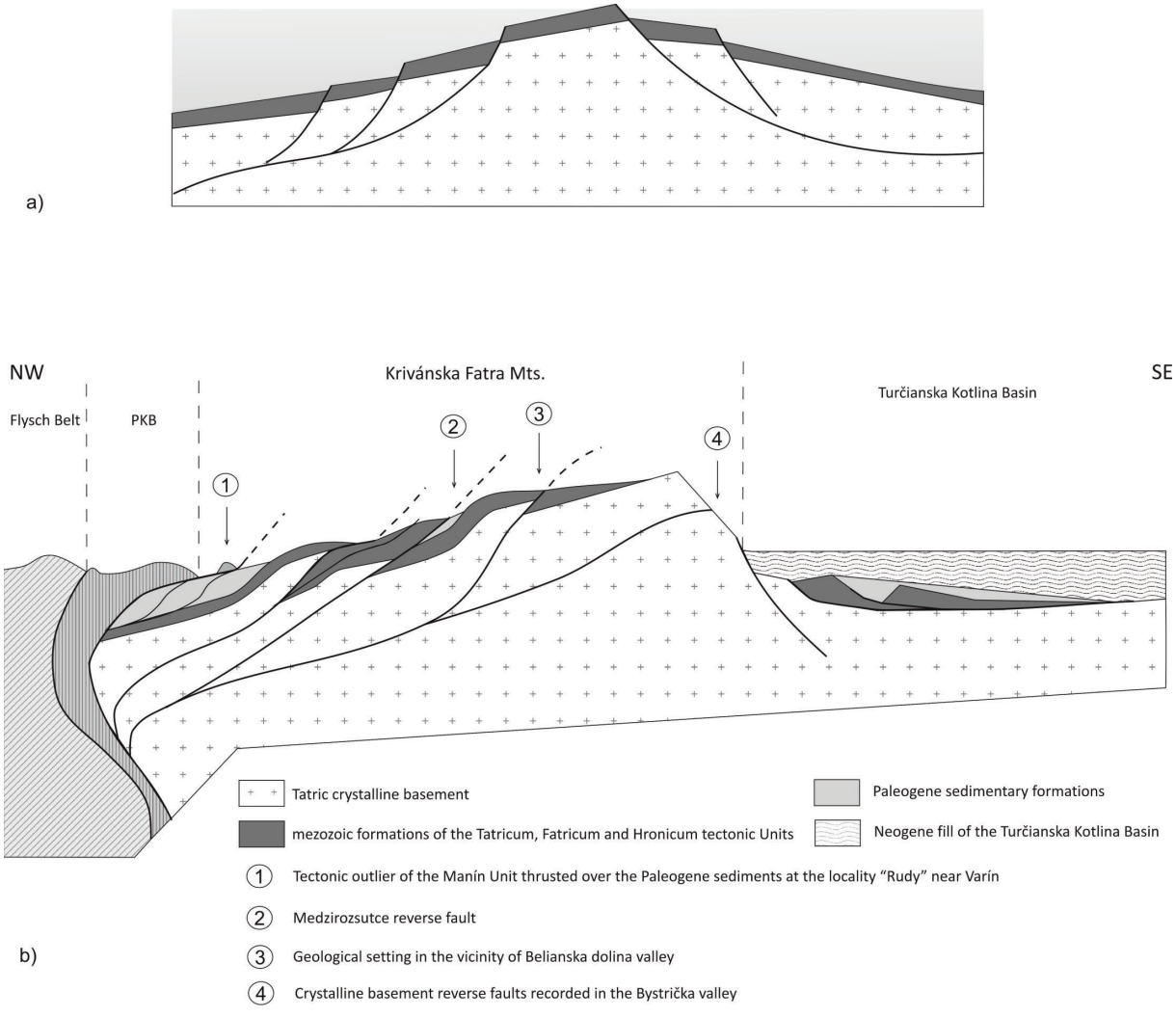

Fig. 5. Tectonic model of the Krivánska Fatra Mts. showing the palaeotectonic situation during Palaeogene extension regime (a) and the major Cenozoic reverse structures originated on the inverted normal faults (b).

older normal faults (cf. Williams et al., 1989; Kelly et al., 1999). If so, predisposed normal faults were most probably active during the extensional regime (?Eocene – Oligocene), which is connected with transgression of the Palaeogene strata over the palaeo-Alpine structure (cf. Kázmér et al., 2003) (Fig. 5).

The geological setting in the vicinity of the "Rudy" locality documents post-Palaeogene age of southward displacement. Following this fact, as well as knowledge from surrounding areas (e.g. Marko et al., 2005; Pešková et al., 2009), the processes and events responsible for the rebuilding/overprinting of the palaeo-Alpine nappe structure of the Krivánska Fatra Mts. probably started during the Early Miocene.

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