Lithostratigraphy and tectonics of the eastern part of Veporské vrchy Mts. (Western Carpathians)

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Abstract

The study area is located in the eastern part of Veporské vrchy Mts. and is composed of several palaeo-Alpine tectonic units which are sealed by Cenozoic formations and volcanites. The palaeo-Alpine units differ by degree of metamorphism, deformation, age, and lithological composition. The Vepor Unit, which consists of metamorphosed Variscan crystalline basement and the Permian to Triassic Foederata Group, forms the lowermost structure of the palaeo-Alpine nappe stack in this area. The Vepor Unit is overthrust by (from the bottom to the top): (a) newly detected epimetamorphosed Carboniferous deposits of the Furmanec Unit which could by correlated with the Ochtiná Nappe of the Gemer Unit s.l. or with the Nižná Boca Formation of the Choč Nappe; (b) the unmetamorphosed "Lower" Muráň Nappe, newly described nappe unit within this area but with not well-known tectonic affinity; and (c) the unmetamorphosed Muráň Nappe s.s. of the Silica Unit which represents the uppermost portion of the palaeo-Alpine nappe pile. Post-nappe Upper Eocene to Oligocene remnants of sedimentary deposit together with remnants of the originally voluminous Neogene Vepor Stratovolcano are the youngest features of geological structure of the study area.

Key words: Western Carpathians, Veporské vrchy Mts., Vepor Unit, Foederata Group, tectonics, lithostratigraphy

1. INTRODUCTION

Orographically the study area belongs into the sub-province of Inner Western Carpathians (Mazúr & Lukniš, 1986). The territory is located in the western portion of Slovenské Rudohorie Mts. which is considered to be the largest mountain range in Slovakia. The mountains is spread in an area of over 4,000 km^2 large, about 140 km in length and 40 km in width. The study area is located ~1 km south-east of Pohronská Polhora village and ca. 8 km north-west of Tisovec town (Fig. 1).

From the regional geological point of view the investigated area belongs to the Vepor Unit (Kráľová hoľa subzone) of the Central Western Carpathians (Vass et al., 1988). The study area consists of the following palaeo-Alpine tectonic units (from bottom to the top): *(i)* the Vepor Unit (Variscan crystalline basement with the Foederata cover sequence), *(ii)* the Furmanec Unit, *(iii)* the Silica Unit; and post-nappe neo-Alpine *(i)* Horehronie sequence, *(ii)* Neogene Vepor Stratovolcano (Fig. 2).

This territory has never been geologically studied in detail and practically no relevant geological map of this area exists until today. The regional geological map at a scale of 1:50,000 published by Klinec (1976) did not solve the lithostratigraphy and tectonic position of palaeo-Alpine structure of the study area also known as the Kučelach tectonic outlier. The last published map did not cover the whole study area (Vojtko, 2000). Moreover, since the publication of regional geological map, the area became marginalized by geologists who deal with geology structure and tectonic evolution of the Western Carpathians.

The aim of this article was focused on interpretation of geological structure of the western part of the Kučelach tectonic outlier which is characterized by complicated Alpine tectonics. The investigation was mainly aimed at the Vepor cover sequence which was firstly lithostratigraphically subdivided into several formations.

2. METHODS

Geological mapping was carried out in basic topographic map at a scale of 1:10,000 in map sheets 36-24-13 and 36-24-18. The studied area is ~ 10 km^2 large. The geological and tectonic maps were drawn on the basis of new field work and a review and reinterpretation of archived and published materials (Bystrický, 1959; Klinec, 1976; Vojtko, 1999[a], 1999[b], 2000, 2003). Standard field research methods were used with the geological mapping. These methods include geological observations, structural measurements, documentation of outcrops, and sampling. Field work was supported by lithostratigraphical and structural analyses.

3. LITHOSTRATIGRAPHY AND MAGMATISM

The study area, despite its small size, is built by several tectonic units (Figs. 1, 2). The lowermost – Vepor Unit is formed by the pre-Alpine crystalline basement and its Permian–Triassic sedimentary cover a.k.a. Foederata Group (cf. Rozlozsnik, 1935; Schönnenberg, 1946; Klinec, 1976; Bajaník et al., 1983, 1984;

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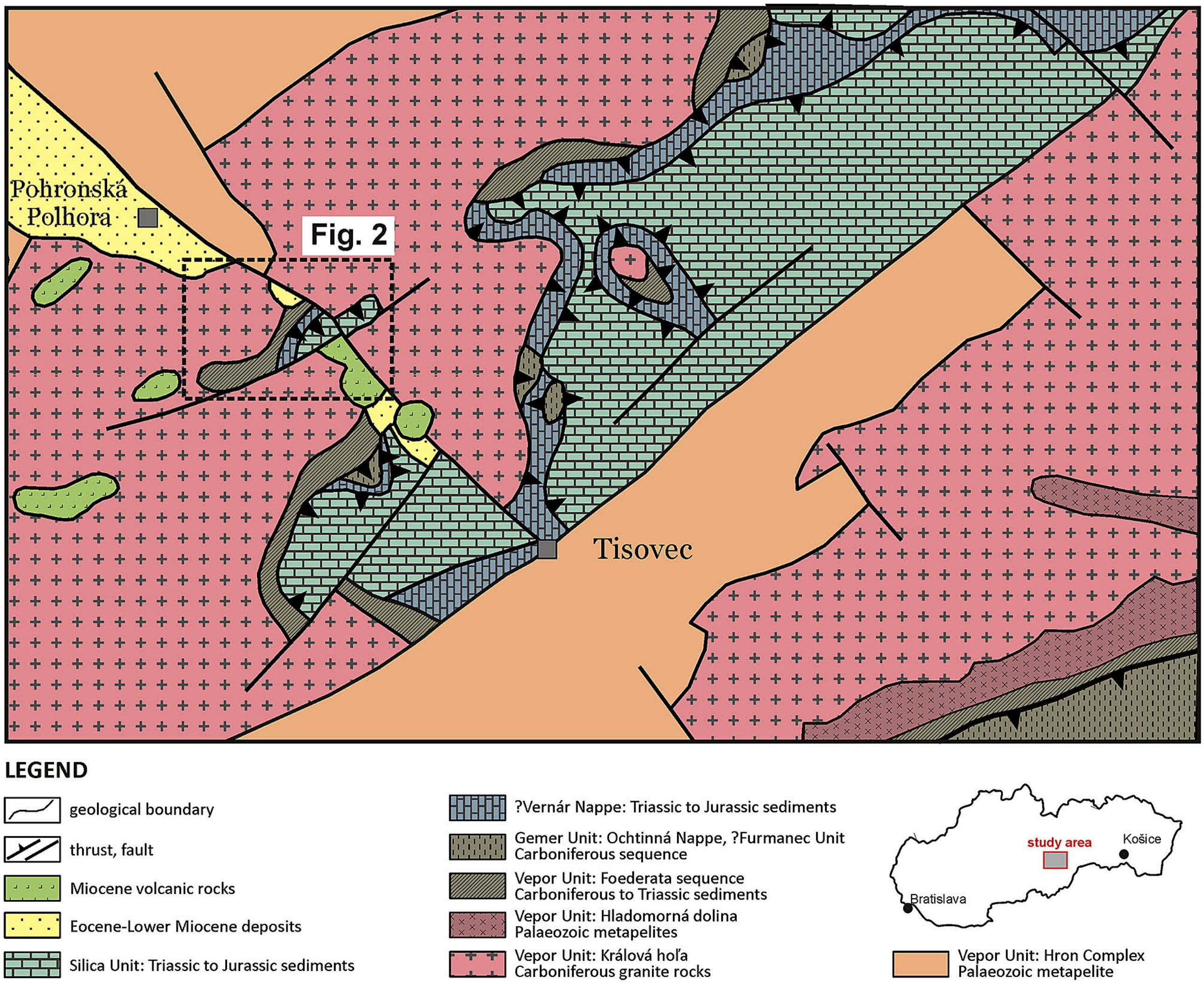

Fig. 1. Tectonic map of the Muránska Planina Mts. and surrounding area (according to Bezák et al., 2004; modified).

Plašienka, 1983, 1993). The Vepor Unit is overthrust by the only of the Carboniferous rock succession belonging to Furmanec Unit (cf. Plašienka & Soták, 2001). The uppermost nappe structure is formed by the unmetamorphosed Silica Unit, which is composed predominantly of Middle to Upper Triassic carbonate platforms (cf. Vojtko, 2000; Vojtko et al., 2000). The Palaeogene sediments sporadically occur in the north-eastern portion of this region and represent only erosive remnants of the Horehronie sequence (Vojtko, 2000; Soták et al., 2005). Besides this, a small andesite subvolcanic body of the Tisovec intrusive complex occurs in the south-eastern part of the investigated area and belongs to the Neogene Vepor Stratovolcano (*sensu* Konečný et al., 2015).

3.1. Vepor crystalline basement

The Vepor Unit represents the middle crustal-scale thick-skinned thrust sheets incorporated into the Alpine structure of the Central Western Carpathians (e.g., Andrusov et al., 1973). In newly proposed division of the Western Carpathians, this unit belongs to the Middle Group of nappes of the Internal Western Carpathians (cf. Hók et al., 2014). The unit overrides the Tatra-Fatra basement/cover sheet along the Čertovica line in the north-west. From the south-east it is overthrust along the Lubeník-Margecany line by the Gemer thick-skinned imbricated stack, overlain by the Meliatic oceanic accretionary-suture complexes and the Silica nappe (Reichwalder, 1982; Plašienka et al., 1997; Plašienka, 1999; Lačný et al., 2015). The Vepor Unit mainly comprises pre-Alpine crystalline basement and its Upper Palaeozoic–Mesozoic cover sequences are only locally preserved (Figs. 2 and 3).

Currently, the Vepor Unit can be subdivided into two tectonic units: the Northern Vepor Unit with its Veľký Bok cover sequence and Southern Vepor Unit with its Foederata cover sequence (Biely et al., 1992, 1997; Bezák et al., 1999[a], 1999[b]). Both units, divided by the Pohorelá Fault (e.g., Hók & Vojtko, 2011), have uniform crystalline rock complexes, but differ in lithostratigraphic evolution of cover sequences.

The studied area is located in the Southern Vepor Unit, which was considerably influenced by palaeo-Alpine tectono-metamorphic processes, especially by low- to medium-grade metamorphism and the development of a penetrative subhorizontal mylonitic structure that superimposed the Variscan metamorphic

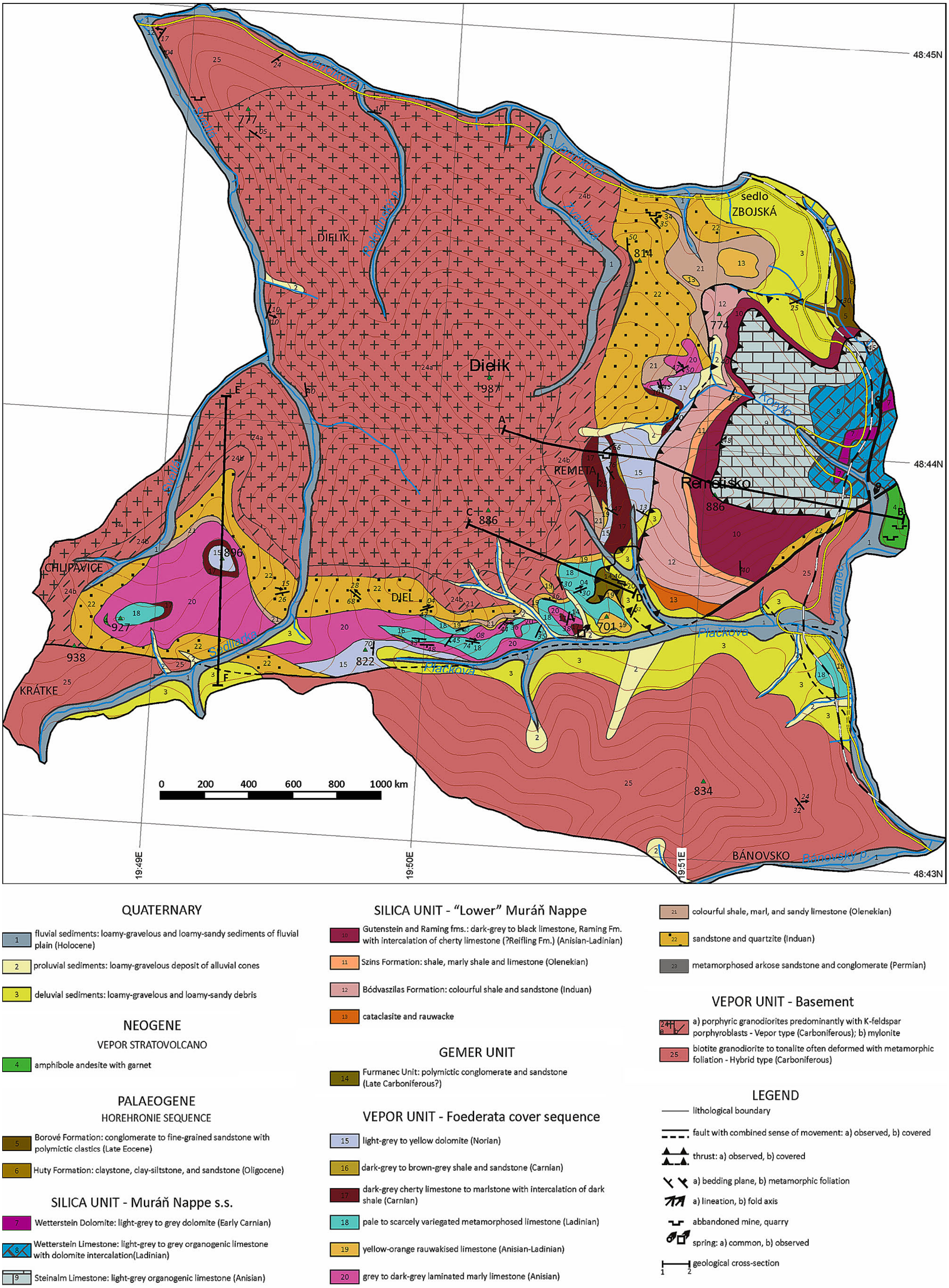

Fig. 2. Geological map of the Dielik (987 m asl.) and Remetisko (886 m asl.) hills surrounding area.

features and tectonic relationships of the pre-Alpine complexes (Hók et al., 1993; Plašienka, 1993; Jeřábek et al., 2008, 2012). In the north-west and south portion of the studied area, a porphyric varieties of granodiorites (Klinec, 1966, 1976; Bezák et al., 1999[b]; Vojtko, 1999[a], 2000) of the Vepor crystalline basement rocks occur locally (Kráľova hoľa Nappe; Putiš, 1989).

3.2. Vepor cover sequence (Foederata Group)

Lithostratigraphical succession of the Vepor cover is composed of metamorphosed siliciclastic to carbonate rocks which are rudimentary preserved beneath the Mesozoic accretionary wedge. This sedimentary sequence was firstly described by Rozlozsnik (1935) as "Föderata serie" and was considered to be the Palaeozoic in age. However, the Mesozoic age was not excluded and sedimentary succession was supposed as a part of the Vepor Nappe.

Later on, the Foederata series was considered to be only Mesozoic in age and a cover sequence of the Vepor Unit and most probably proximal part of the Choč Nappe (Schönnenberg, 1946; Kamenický, 1951). Unlike the previous works, Biely (1955) interpreted the Foederata cover as a fold structure and cover was considered to be a marginal part of the Northern Gemer Synclinorium (e.g., Maheľ, 1953, 1986). Likewise, Zoubek (1957) assumed that the Foederata series has the Gemer affinity. Moreover, Maheľ et al. (1968) gave all cover sequences lying on the Kráľova hoľa and Kohút crystalline basements (a.k.a. Southern Vepor basement) into one lithostratigraphic unit – the Struženík Unit. This unit was considered to be a transitional between the Krížna and the Choč sedimentation basins which was lying on the Variscan consolidated Southern Vepor crystalline basement (Maheľ et al., 1968).

Later, the Foederata series was codified as the Foederata Group (in Slovak transcription as Federátska skupina) by Vozár in Bajaník et al. (1983, 1984). In the area of the Muránska Planina Mts., the Foederata Group is similar to so-called Tuhár succession (Plašienka & Soták, 2001).

The Upper Palaeozoic–Mesozoic Foederata cover sequence represents the poorly preserved cover, which is composed of the Upper Carboniferous Slatviná Formation, Permian Rimava Formation, Lower Triassic clastics of Lúžna Formation, and a Middle to Upper Triassic carbonates (Fig. 2). Carbonate complex is locally regarded as the uppermost member in the stratigraphical succession of the Foederata cover sequence. This complex is strongly rauwackized, metamorphosed, and deformed and is located above the Permian to Lower Triassic siliciclastic succession (Figs. 3 and 4). The Triassic carbonate complex is composed mainly of the dark grey carbonate (Gutenstein Fm. – Early Anisian), light grey limestone (Wetterstein Fm. – Late Anisian to Early Carnian), cherty Limestones (Reifling/Raming limestone s.l. – Early Carnian), light grey-coloured limestones occasionally with cherts and shale intercalation (Partnach Member – Late Carnian), and grey-coloured dolomite (Haupt Dolomite – Norian). According to Vojtko (2000), carbonate complex can be correlated with rocks of the Dobšiná tectonic half-window located north-west of Dobšiná town in Rožňava district.

All the rocks of the Foederata Unit are metamorphosed under the greenschist facies condition and underwent ductile deformation. However, they remained in a parautochthonous position with respect to their basement (Hók et al., 1993; Plašienka, 1993; Vojtko, 2000, 2003; Ružička et al., 2011). Foederata Unit occurs in the central part of the study area and forms a NE–SW elongated structure (Fig. 2).

Rimava Formation (Permian)

The Rimava Fm. is composed of metamorphosed clastic sedimentary succession. The succession predominantly contains metapsamite and occasionally metapsefite and metapelite (Vozárová & Vozár, 1982, 1988). In the study area the Rimava Fm. is considered to be the lowermost portion of the Foederata cover sequence while the Slatviná Fm. is not preserved. In the northern part, mainly in the area of the Zbojská pass (721 m asl.), the Rimava Fm. is composed of arkose, arkose sandstone, and sandy conglomerate (Fig. 2). Southwards (Plačková Valley), the formation dying out and it is preserved only occasionally. The Rimava Fm. is considered to be Permian in age based on the lithostratigraphic similarity with the other tectonic unit in the Western Carpathians and biostratigraphic data (Planderová & Vozárová, 1978). However, the precise dating of the formation is still unknown.

Lúžna Formation (Induan - Olenekian)

From the lithostratigraphic point of view the rock composition corresponds to the Lúžna Fm., as was described by Fejdiová (1980). In the area of Dielik hill (987 m asl.), the lower part of the sedimentary formation is composed of middle- to coarse-grained quartzites, quartz and arkose sandstones, and graywackes (Figs. 2, 3, and 5A,B). Claystone intercalation, predominantly of green colour, begins to occur in the middle part of the strata. The upper part of the strata is characterized by fine- to middle-grained quartz sandstone and purple-coloured claystone. The total thickness of the strata is from few metres up to 100 m in the Diel hill area (903 m asl.).

The upper part of the formation is composed of dark grey-green clayey, silty, and sandy shale. In the lower part of the strata a well-bedded light-coloured quartz sandstone occurs (Figs. 2 and 3). Towards to the overlying strata, a calcareous beds, also referred to as „carbonate phylites", are preserved. These beds were first time described by Vrána (1966). This predominantly fine-grained strata of the Lúžna Formation is preserved only sporadically in the Diel hill (903 m asl.) and the Zbojská pass (721 m asl.). Its occurrence is mainly in the northern and south-eastern slope of Chlipavice Hill (896 m asl.).

Gutenstein Limestone type (Anisian)

The lowest portion of carbonate succession contains light grey to grey limestones, having a maximum thickness of up to 5 m, which pass into the dark grey often laminated limestones of the Gutenstein type (Fig. 3). Strata is strongly affected by deformation and metamorphism. Limestone is occasionally changed to dark grey to black calcareous shale with newly formed clastic white mica. The limestone of the Gutenstein type are cropped out in W–E trending narrow zone in the southern slope of Diel

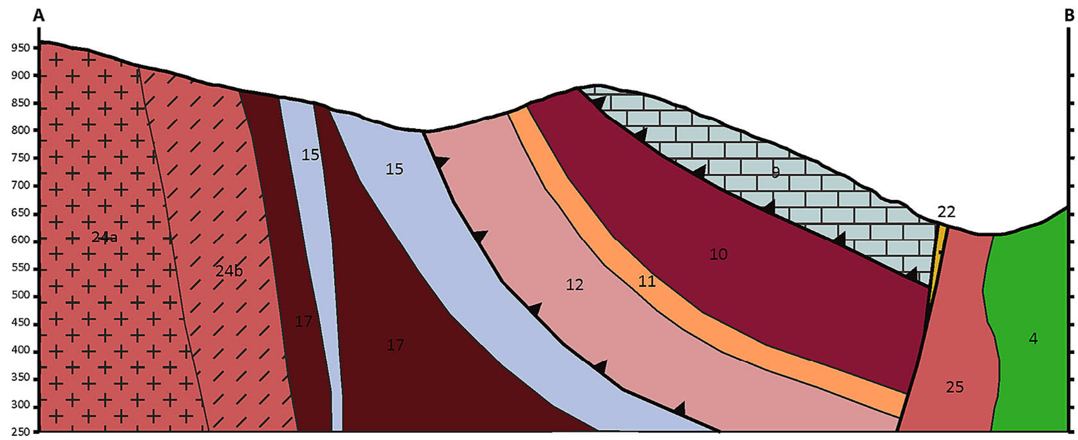

Fig. 3. Geological cross-sections of the study area.

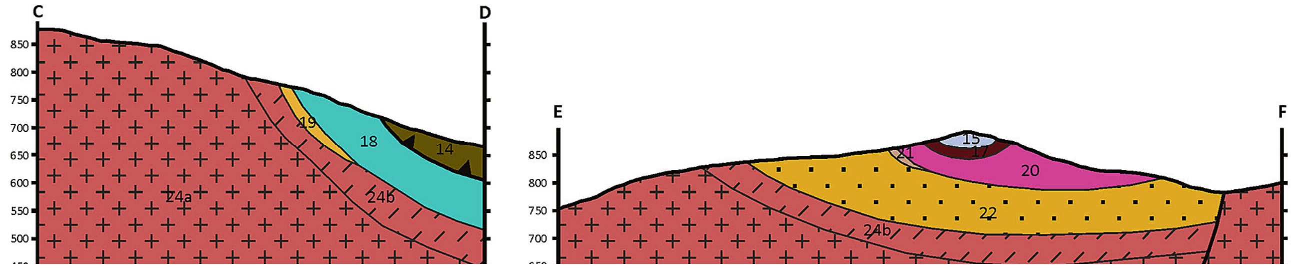

Fig. 3. Geological cross-sections of the study area.

hill (903 m asl.) and in the central part of Chlipavice hill (896 m asl.) in the west end of region (Fig. 2).

Wetterstein Limestone type (Ladinian)

The Wetterstein Limestone type is composed of light grey to grey limestone which occasionally alternate with pinkish limestone. This limestone often alternates with grey to dark grey limestone and sometimes it looks like grey flecked limestone (Fig. 3). They substitute not only vertically towards overlying strata but also laterally. Substitution of these layers is common and a thickness of alternating positions does not exceed 1–2 m. It is not possible to exclude that this alternation is most probably metamorphic origin. Macro- and microscopically they are identical with grey to flecked limestone in the area of Dobšinský potok stream. In the upper portion of the strata limestones are often affected by rauwackization and are substantially changed to rauwacke. These are, however, atectonic rauwacke which did not originate as a product of cataclasis. At present, the Wetterstein Limestone is considered to be massive limestone of the Ladinian age. In the field area these rocks appear mainly in the Plačková Valley, on the southern slope of Diel hill (903 m asl.) but they are also outcropped on Chlipavice hill (896 m asl.) territory (Fig. 2)

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Reifling/Raming limestones type (Early Carnian)

The formation is formed by thick-bedded up to laminated grey to dark grey limestone often with cherts (Figs. 3 and 5C). The cherts form irregular clumps shortened in direction perpendicular to cleavage or individual prolate bodies in the limestone with the size up to 8 cm. Black coloured conodont fauna was obtained from samples in the southern slope of Remeta hill (888 m asl.). The conodonts were strongly deformed so it was not possible to determine species (most probably belongs to Carnian in age). The lower portion of the formation is composed of rauwackes which gradually pass into the cherty limestone. The upper portion of the formation continuously passes into the overlying light grey limestone with shale's intercalation. Cherty limestone are located on the eastern slopes of Remeta hill and in the middle reach of the Plačková valley (Fig. 2).

Light grey limestone with shale and Haupt dolomite (Late Carnian–Norian)

The presence of light grey limestone with shale is quite unique in the study area. However, superposition of strata directly above the dark grey cherty limestone and beneath the grey dolomite refers to Carnian in age (Figs. 2 and 3). In the field area, there is just a small site with such type of sedimentary strata. These rocks are outcropped directly in the south-eastern slope of Diel hill (903 m asl.).

The Haupt Dolomite Fm. consists of massive thick-bedded light grey dolomite, including rauwacke layer which occur together with beds of yellow limestone. From the superposition point of view, the Haupt Dolomite Fm. represents the uppermost formation of the Foederata cover sequence (Vojtko, 2003). In the Foederata Unit, younger, Jurassic sedimentary formation is not known up to now. On the surface, the dolomites are located in broader area of the Diel pass (903 m asl.), the central part of Chlipavice hill (896 m asl.) and the eastern slope of the Remeta hill (888 m asl.).

3.3. Furmanec Unit

The Furmanec Unit (correlated with the Gemer Unit – Ochtiná Nappe; *sensu* Plašienka & Soták, 2001) is a term used for palaeo-Alpine unit which forms most internal part and structurally highest thick-skinned nappe of the Central Western Carpathians.

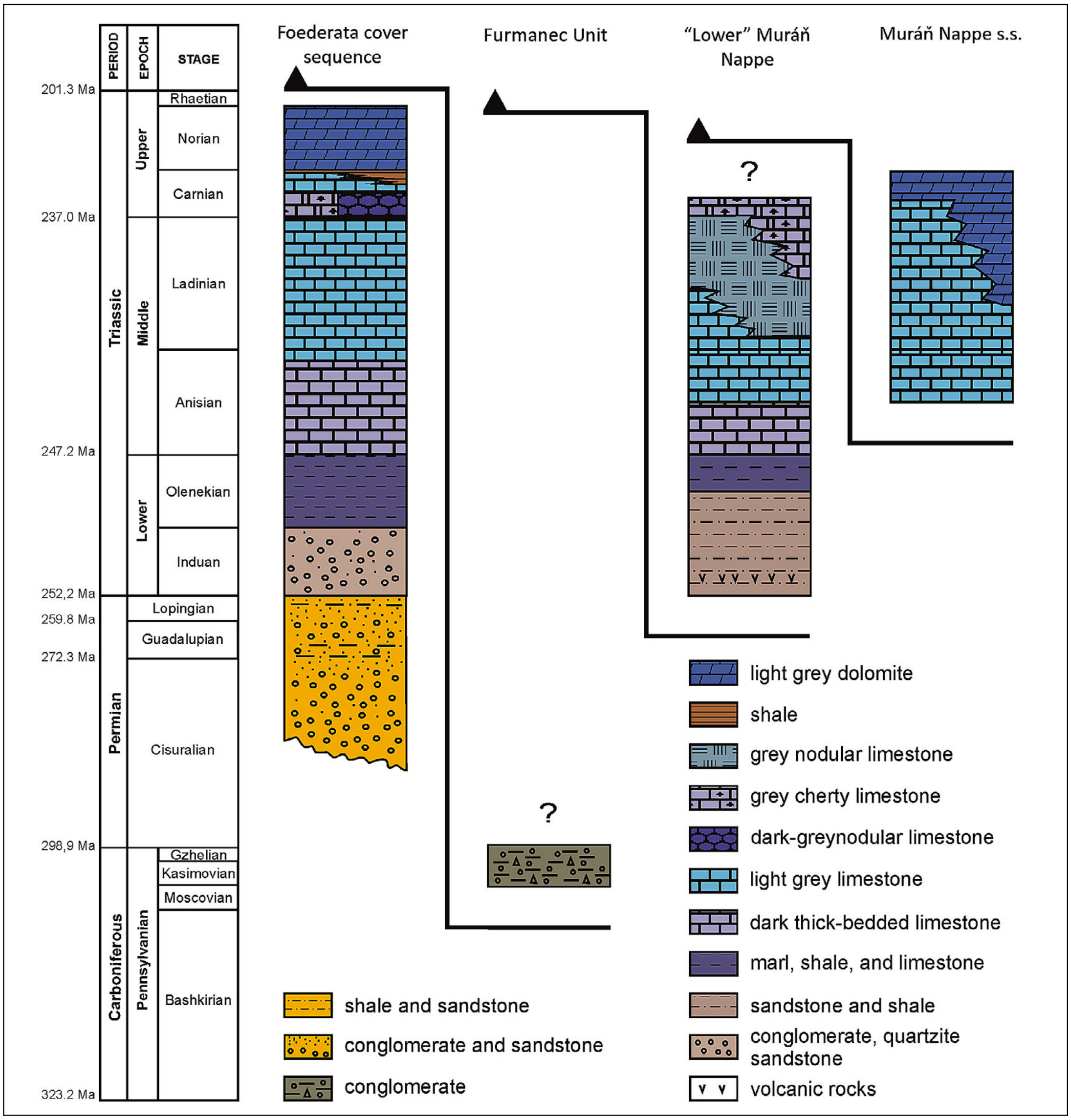

Fig. 4. Lithostratigraphic column of the Foederata cover sequence, Furmanec Unit, "Lower" Muráň Nappe, and Muráň Nappe s.s.

The Gemer Unit has fundamentally different rock composition, age and/or metamorphism than the other paleo-Alpine tectonic units. The unit mainly consists of epi-metamorphosed (lower green schist facies metamorphism) volcano-sedimentary succession predominantly of Early Palaeozoic age which is thrust on Carboniferous to Lower Triassic cover sequences. Unlike the Vepor Unit, the Variscan metamorphism did not reached such a significant temperature-pressure degree in the Gemer Unit (e.g., Plašienka et al., 1997).

The Gemer Unit is built by Early Palaeozoic rock complexes with their Upper Palaeozoic/Mesozoic cover sequences (Bajaník et al., 1983, 1984; Vozárová & Vozár, 1988; Rakús et al., 1998; Hók et al., 2001). The small tectonic slice of the Furmanec Unit, which occurs in the Plačková Valley (Figs. 2, 3, and 6), is predominantly composed of siliceous and sandy conglomerate with drowned clasts of quartz grains (Figs. 4 and 5D). The unit forms tectonic group which is underlying the "Lower" Muráň Nappe. In the Bánovo and Diel sites, a small occurrences of metamorphosed light grey to orange conglomerate with fragments of phyllite and quartz veins were observed. Unfortunately, a further detailed division was not possible due to rare occurrences of the tectonic unit in this area.

3.4. Silica Unit

The Silica Unit represents the higher-most and innermost unmetamorphosed nappe system in the Central Western Carpathians. The Silica Unit were rooted in either the southern or northern peripheries of the Meliatic Ocean. In spite of numerous recent studies, the precise palinspastic position of the Triassic carbonate platforms of the Silica Unit is uncertain (Hók et al., 1995; Rakús, 1996; Kozur & Mock, 1973, 1987, 1997; Kovács, 1997; Haas et al., 1995; Kovács et al. 2010). This unit forms internally weakly deformed thrust nappes, cropping out in the Slovenský kras, Slovenský raj, Galmus, Veporské vrchy, and Muránska planina Mts. The Silica Unit can be subdivided into the several partial nappes (e.g., Drienok, Muráň, Vernár, Stratená, and Silica nappes) and in the investigated area is represented by the Muráň Nappe which comprises unmetamorphosed sedimentary complexes of the Late Permian to Middle Jurassic. However, in the Muránska Planina Mts., studies over the last 20 years led to division of the Silica Unit into two subunits, namely the "Lower" Muráň Nappe and Muráň Nappe s.s.

3.4.1. "Lower" Muráň Nappe

The "Lower" Muráň Nappe represents unmetamorphosed up to anchimetamorphosed sedimentary succession which overlies the Furmanec Unit or directly the Vepor Unit and is covered by the Muráň Nappe s.s. (Figs. 4 and 6). Based on the previous works the nappe is interpreted as a part of the ?Turňa Unit (cf. Vojtko, 2000) or as a part of the Choč or Silica nappe system, respectively (cf. Havrila, 1997; Mello et al., 2000[a], 2000[b]).

In the study area, the bases of the "lower" Muráň Nappe is composed of Lower Triassic succession which consists of two lithologically different formations (Hips, 1996; Olšavský et al., 2010). The lower portion of the nappe represents Bódvaszilas Formation. This sedimentary strata consists of colourful sandstones and purple-coloured shales, occasionally with rhyolite intercalation (for further information see Uher et al., 2002; Ondrejka et al., 2007, 2015). However, new geochronological data refers also to Permian in age of this rhyolite (Ondrejka, 2004; Demko & Hraško, 2013). The upper portion of the lithological sequence is formed by the Szins Formation comprising thick beds of grey to greenish marl shales with conchodial appearance. These formations is mainly cropping out at the western slopes of Remetisko Mts. (886 m asl.) up to the Zbojská pass (721 m asl.).

Towards the overlying strata a Middle to early Upper Triassic carbonate complex represented by dark to black-coloured limestones (Gutenstein Fm.) and grey to dark limestone (Steinalm and Raming/Reifling fms.) occurs. The carbonate sequence is preserved only in the eastern portion of the study area (Figs. 2 and 6).

3.4.2. Muráň Nappe s.s.

The Muráň Nappe s.s. is formed by the Middle to Upper Triassic carbonate platform complex which is preserved in the Kučelach tectonic outlier in the eastern end of the region (Figs. 2 and 6). The younger sedimentary strata of the Muráň nappe is not preserved in the mapped area.

The base of the Muráň Nappe s.s. consists of the Steinalm Limestone (Late Anisian) which is covered by the Wetterstein Limestone (Ladinian), and both represent identical facies. The

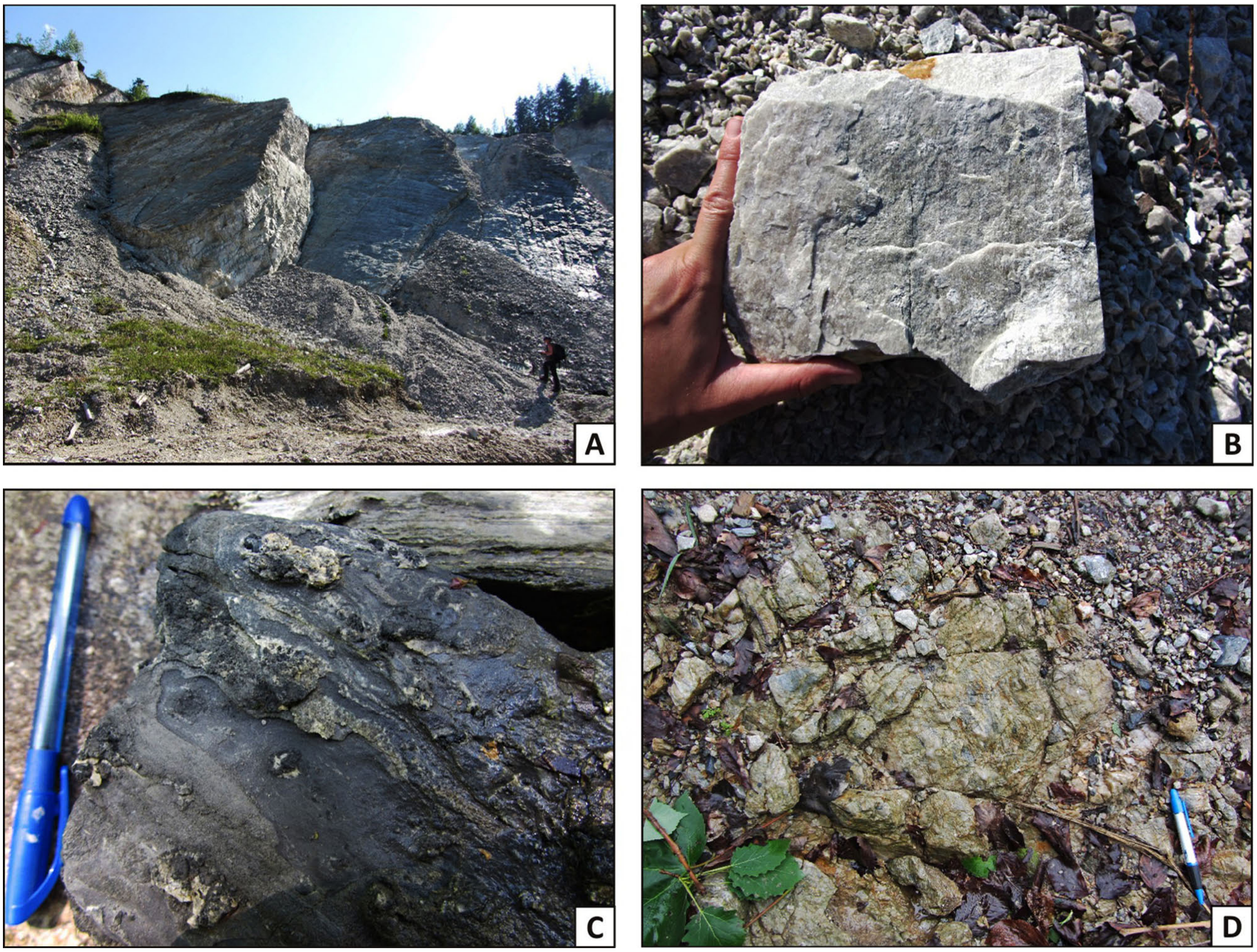

Fig. 5. The Foederata Group and Furmanec Unit field photos. A) the Zbojská abandoned quarry in the Lower Triassic Lúžna Formation of the Foederata cover sequence; B) macrophotograph of the Lúžna Formation; C) macrophotograph of the metamophosed cherty limestone – Reigling type from the Foederata cover sequence; D) macrophoto of metamorphosed polymictit conglomerate of the Furmanec Unit (? Carboniferous).

Steinalm Limestone are characterized by frequent crinoids and small breccia clasts with dasycladaceae of the genus *Physoporella*. In the study area, the Steinalm Limestone occur only at the western slopes of the Furmanec Valley and at the eastern slope of Remetisko hill (886 m asl.).

The Wetterstein Fm. forms main part of the Kučelach tectonic outlier. The light grey coloured formation is characterized by relative common presence of *Diplopora anulata* and *Teutloporella herculea* dasycladaceae. The limestone is often dolomitized and dolomite forms lithostratigraphic lenses. Towards the overlying strata, the Wetterstein Limestone is gradually changing to Wetterstein Dolomite, cropping out at the Furmanec Valley. This dolomite is characterized by light grey to grey colour, rarely dark colour, and massive or cucrozic texture. Bedding is well-developed and it is emphasized by alternation of dark and light lamination (Fig. 4).

3.5. Horehronie sequence

In the study area Palaeogene sediments are extended only sporadically and represent erosive remnants of transitive sedimentary succession (Horehronie sequence) between the Central Carpathian Palaeogene Basin located in the north and the Buda Basin located in the south. These sediments crop out

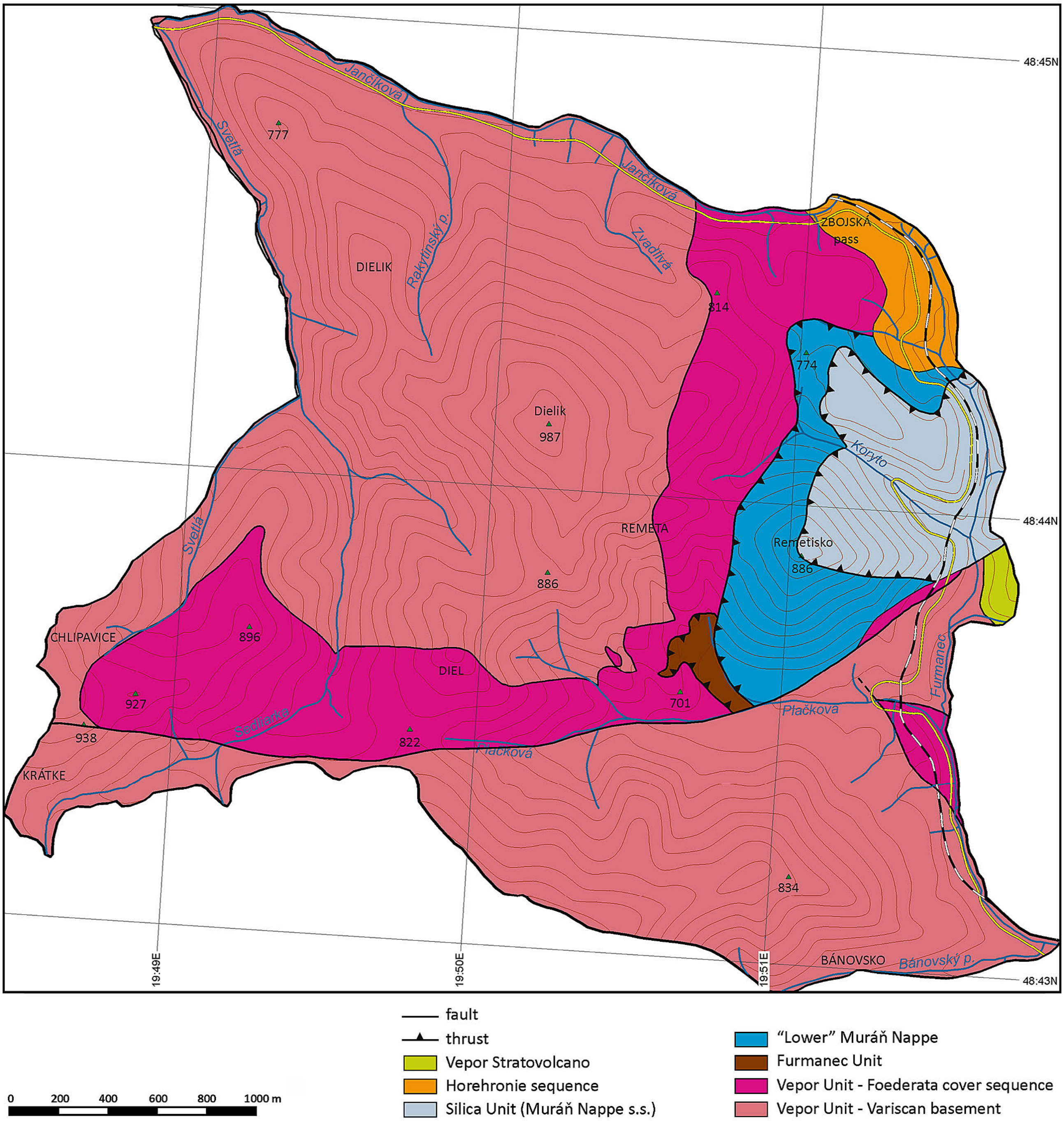

Fig. 6. Tectonic map of the Dielik (987 m asl.) and Remetisko (886 m asl.) hills and surrounding area.

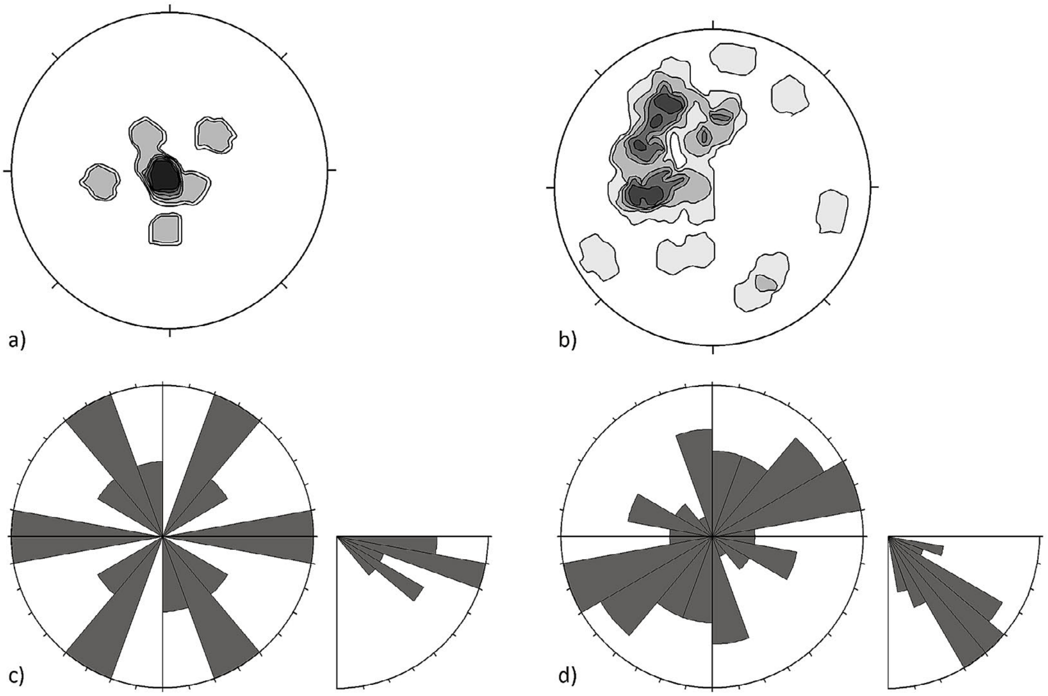

Fig. 7. Tectonograms of metamorphic foliation measured in the Vepor crystalline basement and Foederata cover sequence: a) contour plot of metamorphic foliation in the basement (9 data); b) contour plot of metamorphic foliation in the Foederata cover sequence (35 data); c) rose diagram of strikes and dips of metamorphic foliation in the basement (9 data); d) rose diagram of strikes and dips of metamorphic foliation in the Foederata cover sequence (35 data).

at the Zbojská pass (721 m asl.) and in the bedrock of upper reach of Furmanec stream. In the bedrock of Furmanec stream, coarse-grained transgressive conglomerate with intercalation of fine-grained claystons were documented. The conglomerate consists mainly of the Vepor crystalline and Foederata cover sequence pebbles (predominantly metamorphosed quartzite with well-developed Alpine metamorphic foliation of the Lúžna Fm.). The size of pebbles reached from a few centimetres up to 50 cm.

The lowermost sedimentary succession of the Horehronie sequence is represented by shallow-marine deposits of the Borové Fm. (Figs. 2 and 6). This deposit is formed by coarse-grained conglomerate and sandstone reaching thickness of a few meters up to 25 m. Stratigraphically the formation is considered to be the Late Eocene in age (Priabonian) which is indirectly derived from the known stratigraphic age of overlying claystone strata (Soták et al., 2005).

The Oligocene Huty Fm. represents the uppermost sedimentary succession of the Horehronie sequence (Figs. 2 and 4). The formation comprises mostly fine-grained deep water deposit which is formed by intercalation of thick-bedded calcareous claystone with thin-bedded conglomerate, sandstone, and siltstone. In the study area, a total thickness of deposit is reaching tens of meters. Towards the north-west the total thickness of preserved sedimentary strata reached more than 350 m which was proved by borehole exploration (e.g., Pulec, 1966).

3.6. Neogene Vepor Stratovolcano

Neogene Vepor Stratovolcano of Sarmatian age (Konečný et al., 2011, 2015) was observed in the broader area between Tisovec and Brezno towns. The area of the central volcanic zone, the so-called Tisovec intrusive complex, consists of various types of andesite necks and dykes from acid to mafic composition and diorite stocks and necks (Bacsó, 1964; Konečný et al., 2015).

The subvolcanic levels expected in the Neogene Vepor Stratovolcano were eroded due to the Late Miocene to Quaternary exhumation in the Veporské vrchy Mts. Therefore, characteristic morphological features of the stratovolcano has been removed by erosion. These processes created unique conditions for study of volcanic and geological relations of the deposits and the deeper levels of the volcano-plutonic complex at the surface which are described in detail in the work of Konečný et al. (2015). In the eastern part of the field area extrusive body of amphibole andesite with garnet (Fig. 2), so-called Pálenica extrusive complex (cf. Konečný et al., 2015) occurs.

3.7. Quaternary deposits

Quaternary sediments are represented by Holocene alluvial to fluvial deposits which are located in the valleys of Svetlá, Furmanec, and Plačková streams (Fig. 2). They are composed of coarse-grained gravels with intercalation of sand and clay. Other observed Quaternary sediments are proluvial to debris (slope) sediments, occasionally also alluvial fans with gravels, sands, and clays of Pleistocene in age.

4. TECTONIC INTERPRETATION AND DISCUSSION

Geological structure and tectonic evolution was interpreted on the basis of field work – geological mapping, structural research, and sampling. The investigated area has a complex geological structure. The area is built up by several tectonic units which are different from each other in certain aspects, such as lithological composition, metamorphic, and tectonic overprint as well as their geological evolution. In terms of tectonics these units can be divided into two main groups. The first group covers the palaeo-Alpine nappe pile with metamorphic overprint recorded on the development of penetrative foliation and lineation (the Vepor and Furmanec units; Fig. 7) and superficial nappe stack („Lower" Muráň Nappe and Muráň Nappe s.s.) without any metamorphic overprint. The second group is characterized by post-nappe deposition of Upper Palaeogene to Lower Neogene sedimentary succession belonging to the Horehronie sequence and by Middle Miocene volcanism (Fig. 6).

Based on the obtained results from the field area, the basement is formed by Vepor granite rocks represented by the Kráľova hoľa Nappe. The crystalline basement is directly covered by the Foederata cover sequence with a stratigraphic range from the Permian to Late Triassic, determined by a lithostratigraphic comparison with similar strata of other palaeo-Alpine unmetamorphosed tectonic units of the Western Carpathians. Moreover, biostratigraphic data are not informative about the lithostratigraphic age of the Foederata sedimentary strata. Stratigraphically, only cherty limestone of the cover sequence from the Dobšiná and Tuhár regions were confirmed by conodonta fauna (Straka, 1981). Presence of Jurassic members is not known from the Foederata cover sequence in the whole Vepor Unit.

The principal benefit of this research was not only detailed division of the Foederata sedimentary strata but also earmarking of sedimentary deposits (?Carboniferous) which most probably belong to the Furmanec Unit. Occurrences of polymictic conglomerates with intercalation of black slate may be seen only in an outcrops along the forest road going from the forester's lodge Pod Dielom towards the Diel pass, directly under remote high voltage power lines. Based on lithostratigraphic composition and tectonic position (over the Foederata cover sequence and beneath the "Lower" Muráň Nappe), these deposits were included into the Furmanec Unit which is correlated with the Gemer Unit – Ochtiná Nappe (sensu Plašienka & Soták, 2001). However, there is no stratigraphic control of this Carboniferous sedimentary sequence. For this reason, another tectonic interpretation cannot be excluded and this problem still remains an open question. Currently, it is the most north-western (most external) occurrence of rocks with the Gemer affinity in the Central Western Carpathians.

The "Lower" Muráň Nappe is thrust on metamorphosed and strongly deformed ductile tectonic units such as the Vepor and Furmanec units with considerable structural and metamorphic gap (Fig. 6). Stratigraphic range of the nappe is Early to Late Triassic but its tectonic affiliation still remain considerably problematic. From geological point of view the nappe might be included into: *i)* Hron Unit (e.g., Vozárová & Vozár, 1988); *ii)* Turňa Unit (cf. Vojtko, 1999[a], 2000); *iii)* Silica Unit (Havrila, 1997) and *iv)* Vernár Unit (Hók et al., 2004). At present, it is not possible to clearly include the nappe in one of these tectonic units.

Structurally, the Silica Unit (Muráň Nappe s.s.) represents the highest tectonic unit in the study area (Fig. 6). The Muráň Nappe s.s. is outcropped in the eastern part of the mapped area with confirmed stratigraphic range from Anisian to Carnian (Klinec, 1976; Vojtko, 1999[a], 2000). Current knowledge of this Triassic strata clearly refers to its Silica origin.

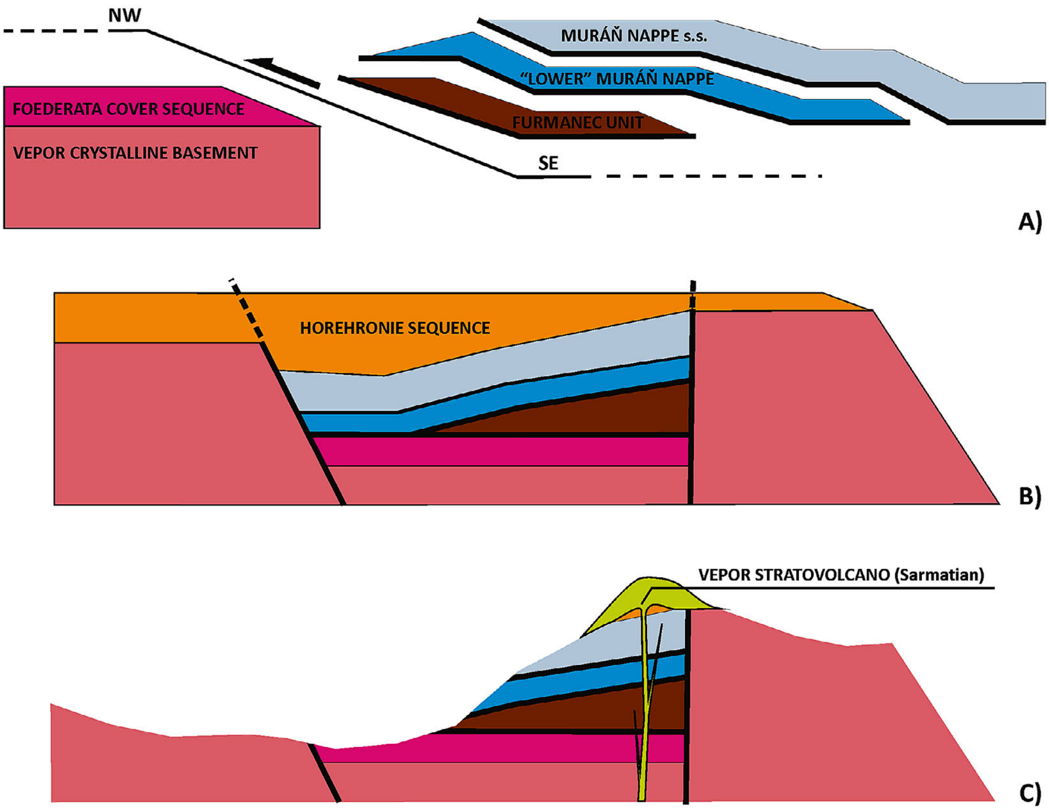

Fig. 8. General model of tectonic evolution since Late Jurassic. Explanations: A) Late Jurassic to Early Cretaceous tectonic scenario – evolution of Mesozoic accretionary wedge with nappe stacking which is thrust on the Vepor Unit northwestward; B) Early Miocene tectonic scenario with sealed palaeo-Alpine nappe stack by the Late Eocene to Late Oligocene strata; C) Pliocene to Quaternary tectonic scenario represented by erosional base level with preserved palaeo-Alpine nappe stack and the Horehronie sequences which are cut by Sarmatian subvolcanic andesite bodies.

4.1. Palaeo-Alpine tectonic evolution

The Alpine compressional evolution and burial of the Vepor Unit started in the Late Jurrasic/Early Cretaceous after the closure of the Jurassic Meliata Ocean (Kozur & Mock, 1973; Dallmeyer et al., 1993; Maluski et al., 1993; Faryad & Henjes-Kunst, 1997; Árkai et al., 2003; Putiš et al., 2014, 2015). Closure of the Meliata Ocean is documented by radiometric dating of glaucophane in the Bôrka Nappe (Faryad, 1995[a], 1995[b]) and by the youngest known sedimentary strata from the Silica and Meliatic units (cf. Mello et al., 1997, 2000[a],2000[b]; Bezák et al., 1999[a],1999[b]). The Eo-Alpine Cretaceous convergence in the Western Carpathians documents northward (in present coordinates) propagating nappe stacking of the major crustal-scale units, Gemer, Vepor, and Tatra-Fatra (e.g., Tomek, 1993; Plašienka et al., 1997; Froitzheim et al., 2008; Putiš et al., 2009, 2014; Hók et al., 2013). This process caused individualization of palaeo-Alpine tectonic units (nappe bodies) which form the main structure of the study area (Fig. 8A).

Compression stage related to maximal burial in the Vepor Unit culminated in time span of ~ 110–95 Ma ($_{40}$Ar/$_{39}$Ar and K-Ar ages) under green-schist to amphibolite facies metamorphic conditions (Maluski et al., 1993; Kováčik et al., 1996, 1997; Janák et al., 2001; Lupták et al., 2003; Jeřábek et al., 2008). The lateral orogen-parallel extension of the Vepor Unit finished at the latest by 97 Ma, which is suggested by the post-kinematic growth of monazite in the southern Foederata cover sequences dated by the laser ablation ICP-MS method (cf. Bukovská et al., 2013).

Exhumation of the Vepor Unit from beneath the Gemer, Meliatic, and Silica nappe systems most likely reflects an underthrusting of the Tatra-Fatra basement southward. The exhumation of the Vepor dome led to unroofing and eastwards movement of the overlying rock sequences (Fig. 7). Extensional movement of the individual segments was realized on low-angle normal listric fault shear zones (Hók et al., 1993; Plašienka, 1993; Madarás et al., 1996; Jeřábek et al., 2012).

Exhumation of the Vepor Unit is documented by zircon fission-track ages of 75–65 Ma and apatite fission-track ages of 63–55 Ma indicating rapid to moderate cooling phase during the Late Cretaceous to Early Palaeocene followed by moderate to slow cooling phase from the Late Palaeocene to Eocene (cf. Kráľ, 1977; Kováč et al., 1994; Plašienka et al., 2007; Vojtko et al., 2013, 2015 in press). On the basis of the Late Eocene (Priabonian) onset of the new sedimentary cycle, the exhumation process terminated during the Bartonian.

4.2. Neo-Alpine tectonic evolution

The neo-Alpine tectonic stage covers the period from the Late Palaeocene to Quaternary immediately after exhumation of the Vepor metamorphic dome. During the Late Cretaceous to Early Palaeocene the study area was exhumed up to the present day form (for further information see Vojtko et al., 2013, 2015 in press). In the Late Eocene to Early Miocene the Vepor exhumation was replaced by new sedimentary cycle of the Central Carpathian Palaeogene Basin and/or the Buda Basin system. Palaeo-Alpine nappe stack was covered with tenuously defined sedimentary sequences named as the Horehronie sequence (Fig. 8B). This sedimentary sequence can be proved by preserved Late Eocene (Priabonian) to Late Oligocene sedimentary sequence on the palaeo-Alpine nappe stack in the broader area of the Zbojská pass (721 m asl.). In addition, given sediments are preserved in the Brezno and Horehronie depressions (Pulec, 1966; Klinec, 1976), at the top of Magnet hill (964 m asl.;Vojtko, 2000; Plašienka & Soták, 2001; Soták et al., 2005). In the area of Zbojská pass (721 m asl.), the identified sedimentary strata was considered to be a part of the Central Carpathian Palaeogene Basin (e.g., Maheľ et al., 1964, 1968; Pulec, 1966), but connection with the Buda Basin was not eliminated (Soták et al., 2005). In the Zbojská pass (721 m asl.), the sedimentary strata comprises mostly conglomerates and breccia and represent transgressive deposits of the Borové Fm. Pebbles consist mainly of quartzites, arkose, different kind of metamorphosed and unmetamorphosed dolomite and limestone, fewer shale and extremely rare of crystalline rocks (granite rocks). The pebble material of quartzite and arkose has very well-developed planar anisotropy (cleavage) and some stretching lineations are strikingly similar to the quartzite and arkose of the Foederata cover sequence. It means that the exhumation of the Vepor Unit caused exposing of the Foederata cover sequence and most probably also crystalline basement on the surface. The Borové Fm. continuously passes to the claystone and siltstone, probably belonging to the Huty Fm. After sedimentation of the Upper Eocene to Lower Miocene deposit, erosion took place resulting to almost complete denudation of this sedimentary strata. In present, Upper Eocene to earliest Upper Oligocene are preserved only in the area of the Zbojská pass (721 m asl.). It is expected that younger sedimentary sequence has been removed by erosion.

Early to Middle Miocene erosion exposed again the palaeo-Alpine nappe pile which was subsequently buried under andesite volcanic products of the Neogene Vepor Stratovolcano during the Sarmatian in age (cf. Konečný et al., 2011, 2015). In the study area, the products of Sarmatian volcanism (andesite) were mapped in the Furmanec valley where andesite were mined in a quarry (Fig. 8C).

After the volcanic activity, a significant erosion started again and led to removing of almost all Sarmatian rocks of volcanic conus, with a few exceptions preserved outside the study area (for further information see Konečný et al., 2015).

The palaeo-Alpine nappe stack in the investigated area is the result of the relative downward movement of the northwestern hanging wall along the fault that surrounds the geological structure from the southern side. Therefore, the Kučelach tectonic outlier can be interpreted as the NE–SW oriented asymmetric half-graben developed along the transtensive strike-slip fault zone where the nappe stack of the palaeo-Alpine tectonic units (Vepor, Furmanec (Gemer), Silica units) and Cenozoic post-nappe sedimentary formation (Horehronie sequence) were preserved. All of the above mentioned structural elements are located in the northwestern drooping block of the asymmetric graben. The only exceptions are preserved deposits of the Foederata cover sequence on the southern block at the Tisovec–Brezno railway cutting (note: occurrence not recorded in any previous geological works). Their tectonic position is exceptional and hardly interpretable, also because of the significant covering by Quaternary deposits. Probably it is a small buried block in-between crystalline basement. However this question remained unanswered.

5. CONCLUSION

The study area includes the western part of the Kučelach tectonic outlier located 8 km north-west of Tisovec town, where several units/subunits were identified. There are: (a) Variscan crystalline basement of the Vepor Unit; (b) the Foederata cover sequence of the Vepor Unit; (c) the Furmanec Unit with tectonic affinity to the Gemer Unit; (d) the "Lower" Muráň Nappe with tectonic affinity to the Silica Unit (e) the Muráň Nappe s.s. of the Silica Unit; (f) the Horehronie sequence with transitional sedimentary succession between the Central Carpathian Palaeogene Basin and the Buda Basin; and (g) the Neogene Vepor Stratovolcano of Sarmatian in age.

By complex geological research (geological mapping, structural analysis) a detailed characteristic of the Palaeo-Alpine nappe stack was distinguished. Observed degree of metamorphosis led to different reheating and deformation of individual tectonic units. The first group of tectonic units can be characterised by Alpine metamorphic overprint and significant ductile deformation of the Vepor Unit and newly determined the Furmanec Unit. This division of the Furmanec Unit was carried out by its tectonic position and lithological correlation with a Carboniferous sedimentary sequence. Therefore, this unit is considered to be the Gemer affinity. However, the exact integration of the Furmanec Unit to the known Palaeo-Alpine units was not possible due to absence of biostratigraphic data but the Hronic closeness cannot be excluded. Based on the lithological observation, the Foederata cover sequence has stratigraphic range of Permian to Late Triassic with preserved whole known sedimentary succession.

The palaeo-Alpine nappe stack of the investigated area is also formed by unmetamorphosed nappe pile formerly belonging to the Silica Unit – Muráň Nappe. However, based on the field research. the division of the Muráň Nappe into the two individual nappes (the "Lower" Muráň Nappe and Muráň Nappe s.s.) can be assumed. Consideration of the "Lower" Muráň Nappe as an independent nappe structure was based on lithostratigraphic criteria. Unfortunately, the lack of geological data does not allow to incorporate the unit to any known Palaeo-Alpine tectonic units of the Western Carpathians. Conditionally, this nappe is suggested to be a part of the Silica Unit.

The aforementioned palaeo-Alpine nappe structure is sealed by the Upper Eocene to Oligocene deposits which are preserved only as an erosive remnants of the Horehronie sequence. From lithostratigraphical and biostratigraphical point of view, the sedimentary sequence is interpreted as a transitive sedimentary succession between the Central Carpathian Palaeogene Basin located in the north and the Buda Basin located in the south.

In addition, presented detailed field research provides basis for further geological study in the Kučelach tectonic outlier. Therefore, a new research which will be supplemented by biostratigraphical evaluation of the strata and detailed structural study is required to solve unanswered questions.

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References

Andrusov D., Bystrický J. & Fusán O., 1973: Outline of the structure of the West Carpathians. Guide book, X. Congress CBGA, GÚDŠ, Bratislava, 44 p.

Árkai P., Faryad S.W., Vidal O. & Balogh K., 2003: Very low-grade metamorphism of sedimentary rocks of the Meliata unit, Western Carpathians, Slovakia: implications of phyllosilicate characteristics. *Internal Journal of Earth Sciences*, 92, 1, 68–85.

Bajaník Š., Hanzel V., Ivanička J., Mello J., Pristaš J., Reichwalder P., Snopko L., Vozár J. & Vozárová A., 1983: Vysvetlivky ku geologickej mape Slovenského rudohoria - východná časť. 1: 50 000, GÚDŠ, Bratislava, 223 p.

Bajaník Š., Ivanička J., Mello J., Reichwalder P., Pristaš J., Snopko L., Vozár J. & Vozárová A., 1984: Geologická mapa Slovenského Rudohoria-východná časť 1: 50000. ŠGÚDŠ Bratislava.

Bacsó Z., 1964: Protriasové skarnové ložiská pri Tisovci. Geol. Práce, Zprávy, 31, GÚDŠ, Bratislava, 13–45.

Bezák V., Dublan L., Hraško Ľ., Konečný V., Kováčik M., Madarás J., Plašienka D. & Pristaš J., 1999[a]: Geologická mapa Slovenského rudohoria – Západná časť (M 1: 50 000), GÚDŠ, Bratislava.

Bezák V., Hraško L., Kováčik M., Madarás J., Siman P., Pristaš J., Dublan L., Konečný V., Plašienka D., Vozárová A., Kubeš P., Švasta J., Slavkay M. & Liščák P. 1999[b]: Vysvetlivky ku geologickej mape Slovenského rudohoria – západná časť (M 1:50 000). GÚDŠ, Bratislava, 178 p.

Bezák, V., Broska, I., Ivanička, J., Reichwalder, P., Vozár, J., Polák, M., Havrila, M., Mello, J., Biely, A., Plašienka, D., Potfaj, M., Konečný, V., Lexa, J., Kaličiak, M., Žec, B., Vass, D., Elečko, M., Janočko, J., Pereszlényi, M., Marko, F., Maglay, J., Pristaš, J., 2004. Tectonic map of Slovak Republic. MŽP SR – ŠGÚDŠ, Bratislava.

Biely A. 1955: Geologické pomery v okolí Lovinobane. Geologické Práce, Zprávy, 2, 125–131.

Biely A., Beňuška P., Bezák V., Bujnovský A., Halouzka R., Ivanička J., Kohút M., Klinec A., Lukáčik E., Maglay J., Miko O., Pulec M., Putiš M. & Vozár J., 1992: Geologická mapa Nízkych Tatier (M 1:50 000). Štátny geologický ústav Dionýza Štúra, Bratislava.

Biely A., Bujnovský A., Vozárová A., Klinec A., Miko O., Halouzka R., Vozár J., Beňuška P., Bezák V., Hanzel V., Kubeš P., Lukáčik E., Maglay J., Molák B., Pulec M., Putiš M. & Slavkay M. 1997: Vysvetlivky ku geologickej mape Nizkych Tatier. (M 1:50 000). Štátny geologický ústav Dionýza Štúra, Bratislava, 232 p.

Bukovská Z., Jeřábek P., Lexa O., Konopásek J., Janák M. & Košler J., 2013: Kinematically unrelated C–S fabrics: an example of extensional shear band cleavage from the Veporic Unit (Western Carpathians). *Geologica Carpathica*, 64, 103–116.

Bystrický J., 1959: Príspevok ku stratigrafii Muránskeho mezozoika (Muránska plošina). Geologické Práce, Zošit, 56, 1–53.

Dallmeyer R.D., Neubauer F. & Putiš M., 1993: $^{40}Ar/^{39}Ar$ mineral age controls for the Pre-Alpine and Alpine tectonic evolution of nappe complexes in the Western Carpathians. *In:* Spišiak J. and Pitoňák P. (Eds.): PAEWCR conference, Stará Lesná, Excursion Guide, 13–20.

Demko R. & Hraško Ľ., 2013: Ryolitové teleso Gregová pri Telgárte. *Mineralia Slovaca*, 45, 4, 161–174.

Faryad S.W., 1995[a]: Petrology and phase relations of low-grade high-pressure metasediments from the Meliata unit, Western Carpathians, Slovakia. *European Journal of Mineralogy,* 7, 71–87.

Faryad S.W., 1995[b]: Phase petrology and P-T conditionsof mafic blueschists from the Meliata unit, Western Carpathians, Slovakia. *Journal of Metamorphic Geology*, 13, 701–714.

Faryad S.W. & Henjes-Kunst F., 1997: K-Ar and Ar-Ar age constraints of the Meliata blueschist facies rocks, the Western Carpathians (Slovakia). *Tectonophysics*, 280, 141–156.

Fejdiová O., 1980: Lužňanské súvrstvie – formálna spodnotriasová litostratigrafická jednotka. Geologické Práce, Správy. Geologický ústav Dionýza Štúra, Bratislava, 74, 95–101.

Froitzheim N., Plašienka D. & Schuster R., 2008. Alpine tectonics of the Alps and Western Carpathians. *In:* McCann T. (Ed.): The geology of Central Europe. Geological Society (London), 1141–1232 (Abb. 2–8).

Haas J., Kovács S., Krystyn L. & Lein R., 1995: Significance of Late Permian-Triassic facies zones in terrane reconstruction in the Alpine-Nord Pannonian domain. *Tectonophysics,* 242, 19–40.

Havrila M., 1997: Vzťah hronika a silicika. Manuscript, Geological Survey of the Slovak Republic, Bratislava, 31 p.

Hips K., 1996: Stratigraphic and facies evaluation of the Lower Triassic formations in the Aggtelek-Rudabánya Mountains, NE Hungary. *Acta Geologica Hungarica*, 39, 4, 369–411.

Hók J. & Vojtko R., 2011: Interpretácia pohorelskej línie v podloží stredoslovenských neovulkanitov (Západné Karpaty). *Acta Geologica Slovaca*, 3, 1, 13–19.

Hók J., Kováč P. & Madarás J., 1993: Extenzná tektonika západného úseku styčnej zóny gemerika a veporika. *Mineralia Slovaca*, 25, 3, 172–176.

Hók J., Kahan Š. & Aubrecht R., 2001: Geológia Slovenska. Univerzita Komenského v Bratislave, 47 p. (ISBN 80-223-1592-3).

Hók J., Kováč P. & Rakús M., 1995: Výsledky štruktúrneho výskumu Vnútorných Karpát a ich interpretácia. *Mineralia Slovaca*, 23, 231–235.

Hók J., Havrila M., Rakús M., Vojtko R. & Kráľ J., 2004: Nappe contact as a tool of paleotectonic reconstruction (Inner Western Carpathians a case of study). *Geolines* 17, 39–40.

Hók J., Pelech O. & Slobodová Z., 2013: Kinematická analýza horninových komplexov veporika a hronika v oblasti sklenoteplického ostrova (Stredoslovenské novulkanity). *Acta Geologica Slovaca*, 5, 2, 129–134.

Hók J., Šujan M. & Šipka F., 2014: Tektonické členenie Západných Karpát - prehľad názorov a nový prístup. *Acta Geologica Slovaca*, 6, 2, 135–143.

Janák M., Plašienka D., Frey M., Cosca M., Schmidt S., Lupták B. & Méres Š., 2001: Cretaceous evolution of a metamorphic core complex, the Veporic unit, Western Carpathians (Slovakia): P-T conditions and in situ $^{40}Ar/^{39}Ar$ UV laser probe dating of metapelites. *Journal of Metamorphic Geology*, 19, 197–216.

Jeřábek P., Faryad W.S., Schulmann K., Lexa O. & Tajčmanová L., 2008: Alpine burial and heterogeneous exhumation of Variscan crust in the West Carpathians: insight from termodynamic and argon diffusion modelling. *Journal of the Geological Society,* 165, 479–498.

Jeřábek P., Lexa O., Schulmann K. & Plašienka D., 2012: Inverse ductile thinning via lower crustal flow and fold-induced doming in the West Carpathian Eo-Alpine collisional wedge. *Tectonics,* 31, TC5002, doi:10.1029/2012TC003097.

Kamenický J. 1951: O hadci pri Dankovej. Geologický Sborník Slovenskej akadémie vied, 2, Bratislava, 3–30.

Klinec A., 1966: K problémom stavby a vzniku veporského kryštalinika. Sborník geologických vied, rad Západné Karpaty, 6, 7–28.

Klinec A., 1976: Geologická mapa Slovenského rudohoria a Nízkych Tatier (1: 50 000). GÚDŠ, Bratislava.

Konečný V., Konečný P. & Pécskay Z., 2011: The Vepor stratovolcano: a new paleovolcanological reconstruction (Central Slovakia). 2. otevřený kongres České geologické společnosti a Slovenskej geologickej spoločnosti, 21.–25.09 2011, Monínec, 50 p.

Konečný V., Konečný P., Kubeš P. & Pécskay Z., 2015: Paleovolcanic reconstruction of the Neogene Vepor stratovolcano (Central Slovakia), part I. *Mineralia Slovaca,* 47, 1, 1–76.

Kovács S., 1997: Middle Triassic rifting and facies differentiation in northeast Hungary. In Sinha A.K., Sassi F.P. & Papanikolau D. (Eds): Geodynamic domains in the Alpine-Himalayan Tethys. Oxford & IBH Publ., New Delhi, 375–397.

Kovács S., Sudar M., Karamata S., Haas J., Péró Cs., Grădinaru E., Gawlik H.-J., Gaetani M., Mello J., Polák M., Aljinović D., Ogorelec B., Kolar-Jurkovšek T., Jurkovšek B. & Buser S., 2010: Triassic environments in the Circum-Pannonian Region related to the initial Neotethyan rifting stage. In: Vozár J., Ebner F., Vozárová A., Haas J. Kovács J., Sudar M., Bielik M. & Péró Cs.: Variscan and Alpine terranes of the Circum-Pannonian Region. Geological Institute, Slovak Academy of Sciences, Bratislava, 84–156.

Kováč M., Kráľ J., Márton E., Plašienka D. & Uher P., 1994: Alpine uplift history of the Central Western Carpathians: Geochronological, paleomagnetic, sedimentary and structural data. *Geologica Carpathica*, 45, 83–96.

Kováčik M., Kráľ J. & Maluski H., 1996: Metamorphic rocks in the Southern Veporicum basement: their Alpine metamorphism and thermochronologic evolution. *Mineralia Slovaca*, 28, 185–202.

Kováčik M., Kráľ J. & Maluski H., 1997: Alpine reactivation of the southern Veporicum basement: metamorphism, $^{40}Ar/^{39}Ar$ dating, geodynamic model and correlation aspects with the Eastern Alps. *In:* Grecula P., Hovorka D. & Putiš M. (Eds): Geological Evolution of the Western Carpathians. Mineralia Slovaca - Monograph, 163–174.

Kozur H. & Mock R., 1973: Zum Alter und zur tektonischen Stellung der Meliata-Serie des Slowakischen Karstes. Geologický Zborník Geologica Carpathica, 24, 365–374.

Kozur H. & Mock R., 1987: Deckenstrukturen im südlichen Randbereich der Westkarpaten (Vorläufige Mitteilung). *Geologische und Paläontologische Mitteilungen*, 14, 6, 131–155.

Kozur H. & Mock R., 1997: New paleographic and tectonic inter-pretations in the Slovakian Carpathians and their implications for correlations with the Eastern Alps. Pat II: Inner Western Carpathians. *Mineralia Slovaca,* 29, 164–209.

Kráľ J., 1977: Fission track ages from some granitoid rocks in the West Carpathians. *Geologický zborník Geologica Carpathica*, 28, 2, 269–276.

Lačný A., Sýkora M. & Plašienka D., 2015: Reinterpretácia výskytov meliatika v oblasti Brádna a Rákoša (Revúcka vrchovina, Západné Karpaty). *Acta Geologica Slovaca*, 7, 1, 85–92.

Lupták B., Janák M., Plašienka D. & Schmidt S.T., 2003: Alpine low-grade metamorphism of the Permian-Triassic sedimentary rocks from the Vepor Superunit, western Carpathians: phyllosilicate composition and "crystallinity" data. *Geologica Carpathica*, 54, 367–375.

Madarás J., Hók J., Siman P., Bezák V. & Ledru P., 1996: Extension tectonics and exhumation of crystalline basement of the Veporicum unit (Central Western Carpathians). *Slovak Geological Magazine*, 3–4, 179–183.

Maheľ M. 1953: Niektoré problémy severogemerídnej synklinály. Geologický Sborník, 4, Bratislava, 221–254.

Maheľ M., Andrusov D., Buday T., Franko O., Ilavský J., Kullman E., Kuthan M., Matějka A., Mazúr E., Roth Z., Seneš J., Scheibner E. & Zoubek V., 1964:

Vysvetlivky k prehľadnej geologickej mape ČSSR 1: 200 000, M-34XXVI, Banská Bystrica. Ústredný ústav geologický, Bratislava, 270 p.

Maheľ M., Buday T., Cicha I., Fusán O., Hanzlíková E., Chmelík F., Kamenický J., Koráb T., Kuthan M., Matějka A., Nemčok J., Pícha F., Roth Z., Seneš J., Scheibner E., Stráník Z., Vaškovský I. & Žebera K., 1968: Regional geology of Czechoslovakia. Part II: The West Carpathians. Geological Survey of Czechoslovakia, Academia, Praha, 723 p.

Maheľ M., 1986: Geologická stavba Československých Karpát 1, Bratislava, Veda, 503 p.

Maluski H., Rajlich P. & Matte P., 1993: 40Ar – 3Ar dating of the Inner Carpathians Variscan basement and Alpine mylonitic overprinting. *Tectonophysics,* 223, 313–337.

Mazúr E. & Lukniš, M., 1986: Geomorfologické členenie SSR a ČSSR (mapa). Slovenská kartografia (Bratislava).

Mello J., Elečko M., Pristaš J., Reichwalder P., Snopko L., Vass D., Vozárová A., Gál Ľ., Hanzel V., Hók, J., Kováč P., Slavkay M. & Steiner A., 1997: Vysvetlivky ku geologickej mape Slovenského krasu (1:50000). Geologická služba Slovenskej republiky, Bratislava, 255 p.

Mello J., Filo I., Havrila M., Ivanička J., Madarás J., Németh Z., Polák M., Pristaš J., Vozár J., Koša E. & Jacko S. jun., 2000[a]: Geologická mapa Slovenského raja, Galmusu a Hornádskej kotliny (M 1:50 000). Geologický ústav Dionýza Štúra, Bratislava.

Mello J., Filo I., Havrila M., Ivan P., Ivanička J., Madarás J., Németh Z., Polák M., Pristaš J., Vozár J., Vozárová A., Liščák P., Kubeš P., Scherer S., Siráňová Z., Szalaiová V. & Žáková E., 2000[b]: Vysvetlivky ku geologickej mape Slovenského raja, Galmusu a Hornádskej kotliny (M 1:50 000). Geologický ústav Dionýza Štúra, Bratislava, 303 p.

Ondrejka M., 2004: Ryolity A-typu silicika v prostredí permsko-triasového kontinentálneho riftingu Západných Karpát: geochémia, mineralógia, petrológia. PhD. thesis, Comenius University in Bratislava, Faculty of Natural Sciences, 129 p.

Ondrejka M., Uher P., Pršek J. & Ozdín D., 2007: Arsenian monazite-(Ce) and xenotime-(Y), REE arsenates and carbonates from the Tisovec--Rejkovo rhyolite, Western Carpathians, Slovakia: Composition and substitutions in the (REE,Y)XO4 system (X = P, As, Si, Nb, S). *Lithos*, 95, 1–2, 116–129.

Ondrejka M., Broska I. & Uher P. , 2015: The late magmatic to subsolidus T-fO2 evolution of the Lower Triassic A-type rhyolites (Silicic Superunit, Western Carpathians, Slovakia): Fe-Ti oxythermometry and petrological implications. *Acta Geologica Slovaca*, 7, 1, 51–61.

Olšavský M., Šimo V. & Golej M., 2010: Hronsecké vrstvy: korelačný člen medzi silicikom s.l. (drienocký príkrov) a hronikom (frankovský príkrov; Západné Karpaty). *Mineralia Slovaca*, 42, 3, 407–418.

Planderová E. & Vozárová A., 1978: Vrchný karbón v južnej časti veporíd. Geologické Práce, Správy, 70, GÚDŠ, Bratislava, 129–141.

Plašienka D., 1983: Geologická stavba tuhárskeho mezozoika. *Mineralia Slovaca*, 15, 1, 49–58.

Plašienka D., 1993: Structural pattern and partitioning of deformation in the Veporic Federata cover unit (Central Western Carpathians). *In:* Rakús M. & Vozár J. (Eds): Geodynamický model a hlbinná stavba Západných Karpát. Konferencie, Sympóziá, Semináre, GÚDŠ, Bratislava, 269–277.

Plašienka D., 1999: Tektochronológia a paleotektonický model jursko-kriedového vývoja Centrálnych Západných Karpát. Veda, Slovenská Akadémia Vied, Bratislava, 125 p.

Plašienka D. & Soták J., 2001: Stratigrafické a tektonické postavenie karbónskych sedimentov v doline Furmanca (Muránska planina). *Mineralia Slovaca*, 33, 1, 29–44.

Plašienka D., Grecula P., Putiš M., Kováč M. & Hovorka D., 1997: Evolution and structure of the Western Carpathians: an overview. *In:* Grecula P., Hovorka D. & Putiš M. (Eds.): Geological evolution of the Western Carpathians. Mineralia Slovaca - Monograph, Bratislava, 1–24.

Plašienka D., Broska I., Kissová D. & Dunkl I., 2007: Zircon fission-track dating of granites from the Vepor - Gemer Belt (Western Capathians): constraints for the Early Alpine exhumation history. *Journal of Geosciences*, 52, 113–123.

Pulec M., 1966: Geologický výskum terciéru vnútorných kotlín centrálnych Západných Karpát. Záver. správa, Manuscript, archive GSSR, Bratislava, 185 p.

Putiš M., 1989: Štruktúrny a metamorfný vývoj kryštalinika východnej časti Nízkych Tatier. *Mineralia Slovaca*, 21, 217–224.

Putiš M., Frank W., Plašienka D., Siman P., Sulák M. & Biroň A., 2009: Progradation of the Alpidic Central Western Carpathians orogenic wedge related to two subductions: constrained by $^{40}Ar/^{39}Ar$ ages of white micas. *Geodinamica Acta*, 22, 1, 31–56.

Putiš M., Danišík M., Ružička P. & Schmiedt I., 2014: Constraining exhumation pathway in an accretionary wedge by (U-Th)/He thermochronology – Case study on Meliatic nappes in the Western Carpathians. *Journal of Geodynamics*, 81, 80–90.

Putiš M., Yang Y.-H., Koppa M., Dyda M. & Šmál P., 2015: U/Pb LA–ICP–MS age of metamorphic–metasomatic perovskite from serpentinized harzburgite in the Meliata Unit at Dobšiná, Slovakia: Time constraint of fluid-rock interaction in an accretionary wedge. *Acta Geologica Slovaca*, 7, 1, 63–71.

Rakús M., 1996: Jurassic of the innermost Western Carpathians zones – its importance and influence on the geodynamic evolution of the area. *Slovak Geological Magazine*, 3-4/96, Bratislava, 311–317.

Rakús M., Potfaj, M. & Vozárová A., 1998: Basic paleographic and paleotectonic units of the Western Carpathians. *In:* Rakús M. (Eds.): Geodynamic development of the Western Carpathians. Geology Survey of Slovak Republic, Bratislava, 15–26.

Reichwalder P., 1982: Structural characteristics of root zones of some nappes in innermost parts of West Carpathians Alpine strctural elements: Carpathian - Balcan - Pamir orogene zone. VEDA, Slovak Academy of Sciences, Bratislava, 43–56.

Rozlosznik P., 1935: Die geologischen Verhältnisse der Gegend von Dobsina. Geol. Hung., Ser. Geol., 5, 1–118.

Ružička P., Vozárová A., Michálek M. & Dyda M., 2011: Alpine regional metamorphism of Föderata Group metacarbonates (southern Veporicum, Western Carpathians, Slovakia): P–T conditions of recrystallization. *Geological Quarterly*, 55, 1, 9–26.

Schönnenberg R., 1946: Geologische Untersuchungen an nord-westerland des Zips-Gomorer Erzgebirges (Karpaten). Z. Dtsch. geol. Gesell., 98, 70–120.

Soták J., Plašienka D. & Vojtko R., 2005: Paleogénne sedimenty veporského pásma – biostratigrafické údaje z nových výskytov na SSZ od Tisovca. *Mineralia Slovaca, Geovestník,* 37, 13–14.

Straka P., 1981: O veku série foederata. Geologické Práce, Správy, 75, 57–62.

Tomek Č., 1993: Deep crustal structure beneath central and inner West Carpathians. *Tectonophysics,* 226, 417–431.

Uher P., Ondrejka M., Spišiak J., Broska I. & Putiš M., 2002: Lower Triassic potasium-rich rhyolites of the Silicic Unit, Western Carpathians, Slovakia: geochemistry, mineralogy and genetic aspects. *Geologica Carpathica*, 53, 1, 27–36.

Vass D., Began A., Gross P., Kahan Š., Köhler E., Lexa J. & Nemčok J., 1988: Regionálne geologické členenie Západných Karpát a výbežkov Panónskej panvy na území ČSSR. M 1: 500 000, SGÚ-GÚDŠ-Geofond, Bratislava.

Vojtko R., 1999[a]: Geológia a tektonika Tisovského krasu a okolia, Diplomová práca, Katedra geológie a paleontológie, Prírodovedecká fakulta, Univerzita Komenského v Bratislave, Bratislava, 77 p.

Vojtko R., 1999[b]: Litostratigrafia Tisovského krasu a masívu Kučelachu. In: Uhrin M. (ed.): Výskum a ochrana prírody Muránskej planiny 2, Revúca, 7–17.

Vojtko R., 2000: Are there tectonic units derived from the Meliata-Hallstatt trough incorporated into the tectonic structure of the Tisovec Karst? (Muráň karstic plateau, Slovakia), *Slovak Geological Magazine*, 6, 4, 335–346.

Vojtko R., 2003: Štruktúrna analýza zlomov a geodynamický vývoj strednej časti Slovenského rudohoria. Katedra geológie a paleontológie, Prírodovedecká fakulta, Univerzita Komenského v Bratislave, Bratislava, 91 p.

Vojtko R., Hók J., Kováč P., Madarás J. & Filová I., 2000: Geological structure and tectonic evolution of the Southern Veporicum. *Slovak Geological Magazine,* 2–3, 6, 287–292.

Vojtko R., Králiková S., Minár J. & Fügenschuh B., 2013: Low thermal evolution of the Southern Veporic Unit crystalline basement (Central Western Carpathians) constrained by new fission track data. *In:* 11[th] Workshop on Alpine Geological Studies and 7[th] IFAA. Berichte Geol. B.-A. 99, pp. 96–97.

Vojtko R., Králiková S., Jeřábek P., Schuster R., Danišík M., Fügenschuh B., Minár J. & Madarás J., 2015: Geochronological evidence for the Alpine tectono-thermal evolution of the Veporic Unit (Western Carpathians, Slovakia). *Tectonophysics*, in press.

Vozárová A. & Vozár J., 1982: Nové litostratigrafické členenie bazálnej časti obalu južného veporika. Geologické Práce, Správy, 78, 169–195.

Vozárová A. & Vozár J., 1988: Late Paleozoic in West Carpathians. Monografia, GÚDŠ, Bratislava, 314 p.

Vrána S., 1966: Alpidische Metamorphose der Granitoide und der Foederata – serie im Mittelteil der Veporiden. Sborník geologických vied, rad Západné Karpaty, 6, 29–84.

Zoubek V. 1957: Zpráva o geologických výzkumech pohoří Veporu v okolí Tisovce. Zprávy o geologických výzkumech v r. 1956, ÚÚG, Praha, 201–203.