Geological structure in the area of the upper reach of Hnilec Valley (Western Carpathians)

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Abstract: This paper investigates and refines the complicated Alpine geological structure and the division of lithostratigraphic sequences in the Vernár village locality. Herein we used field geological methods including geological mapping, structural observation and sample analysis. The study area is located in the Pusté Pole area (Vernár village) and at the upper reach of the Hnilecká dolina, and it contains several tectonic units formed during Alpine orogeny. These palaeo-Alpine tectonic units of the nappe stack differ by degree of metamorphism, deformation, age, and lithological composition. The lowermost structure is composed of the Veporic Unit consisting of metamorphosed Variscan crystalline basement and the Carboniferous to Triassic cover sequence. The Veporic Unit is overthrust by the newly separated Furmanec Sub-unit, which most likely has Gemeric affinity and these rocks were formerly considered a lower part of the Ipoltica Group (Hronic Unit). The Veporic Unit and Furmanec Sub-units underwent ductile deformation and metamorphosed under greenschist facies conditions. Finally, the uppermost nappe structure is formed by the un-metamorphosed Silicic Unit comprising the Vernár and Stratená nappes.

Key words: Western Carpathians, Vernár Nappe, Furmanec Subunit, Veporic Unit, nappe structure, lithostratigraphy

1. INTRODUCTION

The study area is located in the Vernár cadastre in the Poprad district and the Telgárt cadastre in the Brezno district in the upper reach of the Hnilec River. The investigated area orographically forms part of the sub-province of the Inner Western Carpathians (Kočický & Ivanič, 2011); the Spišsko-gemerský kras (Spiš-Gemer Karst), which is a part of the Slovenské Rudohorie Mts and part of the Tatra-Fatra Belt in the eastern part of the Nízke Tatry Mts. The mapped region extends to the boundary of Kráľova hoľa Mt. (1,946 m asl.) and Predná hoľa Mt. (1,546 m asl.), and the study area has an overall elongated shape in the NW–SE direction.

From a geological viewpoint, the investigated area is part of the Veporic Unit (Kráľová hoľa subzone) of the Central Western Carpathians (as in Plašienka et al., 1997; Froitzheim et al., 2008) or the Inner Western Carpathians – Middle and Upper groups of nappes (*sensu* Hók et al., 2014). Traditionally, the study area consists of the following three palaeo-Alpine tectonic units, from bottom to top: the Veporic Unit (the Variscan crystalline basement with the Foederata cover sequence), the Hronic Unit formed by the Ipoltica Group, and the Silicic Unit which has very complex structure and includes the Vernár and Stratená nappes (Fig. 1).

The entire geological structure, however, is very complex and still not well understood, and we can only state with certainty that the Veporic crystalline basement is confirmed in the study area. In addition, all known nappe structures lying on the Veporic Unit have been debated for at least fifty years, and the upper reach of the Hnilec Valley is almost on the periphery of all geological map sheets. Therefore, this requires precise geological investigation to understand the tectonic pattern of the Inner zones of the Western Carpathians. This inspired us to refine the complicated Alpine geological structure and the division of lithostratigraphic sequences into tectonic units based predominantly on the structural pattern, lithostratigraphy and metamorphic conditions. Our investigation was confined to the Vernár Nappe and the interconnection between the foot-wall and hanging-wall.

2. METHODS

The geological mapping was performed in basic steps, including field observation and measurement of geological phenomena, then taking samples and analysing them in the laboratory. Geological mapping is a multi-disciplinary approach combining lithostratigraphy, structural geology, geomorphology, sedimentology, and palaeontology. The mapping was performed on a basic 1:10,000 topographic map on map sheets 37–11–18, 37–11–19, 37–11–23, and 37–11–24 published by the Geodesy, Cartography, and Cadastre Authority of the Slovak Republic. The size of the studied area is approximately 8 km^2, and the geological and tectonic maps were based on both our new field work and a review and re-interpretation of archived and published materials (Kettner, 1937; Maheľ, 1956, 1957; Biely et al., 1992; Mello et al., 2000[a]).

3. RESULTS

3.1. Veporic Unit

The Veporic Unit is a thick-skinned thrust sheet formed by the pre-Alpine crystalline basement rocks and their sedimentary cover sequences. The crystalline basement mostly contains Lower Palaeozoic volcano-sedimentary rocks, which were later influenced by Variscan granitisation and Variscan to Alpine tectono-metamorphic processes. The Alpine metamorphism

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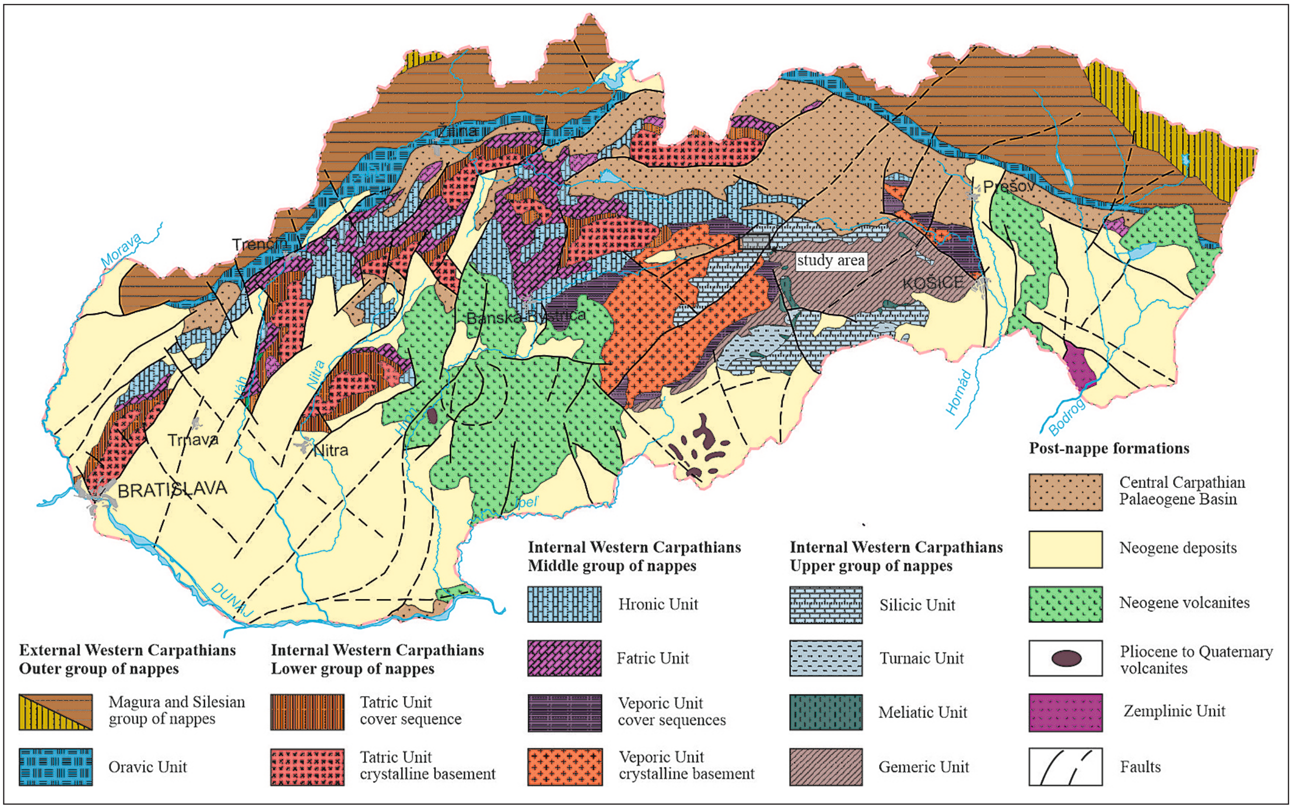

Fig. 1: Tectonic division of the Slovak part of Western Carpathians with location of study area (sensu Hók et al., 2014; base map according to Biely et al., 1996).

almost completely overprinted the original Variscan structures, especially in the southern part of the Veporic Unit (Plašienka, 1999; Jeřábek et al., 2008). The Veporic cover sequence consists of Upper Palaeozoic–Mesozoic complexes divided into two basic cover sequences; the Veľký Bok in the Northern Veporic Subunit and Foederata in the Southern Veporic Subunit. While the Veľký Bok sequence is well preserved and contains sedimentary strata from Permian to mid-Cretaceous, the Foederata is only rudimentarily preserved and ranges stratigraphically from Late Carboniferous to Late Triassic. These two subunits are divided by the Pohorelá Fault (cf. Hók & Vojtko, 2011) and only the Foederata cover sequence is present in the study area. Jurassic and younger sediments have not been confirmed.

The Southern Veporic Unit Variscan crystalline basement outcrops in the south-west of the study area, south of the Hnilec River (Figs. 2, 3). This basement consists of medium-grained, dark grey to dark green granodiorites and tonalities, which extend in the eastern part of Kráľová hoľa Mt. (1,946 m asl.). The dark green rock colour here is due to biotite disintegration to epidote-zoisite and chlorite group minerals, and a typical feature of these rocks is well-developed Alpine mylonitic foliation.

The lithostratigraphical succession of the Veporic cover comprises metamorphosed siliciclastic to carbonate rocks, and this entire succession was influenced by regional Alpine metamorphosis (Madarás & Ivanička, 2001; Lupták et al., 2003). The oldest known member of the strata is the Carboniferous volcano-sedimentary complex of the Revúca Group's Slatviná Formation, which formed the area from the Pod Zrázom saddle through the eastern slope of Košarisko hill (1,268 m asl.) and the western slopes of Tri kopce Mt. (1,507 m asl.) to the Hnilec River valley (Figs. 2, 3). The formation has quartz-sericite and chlorite-sericite phyllites with meta-sandstone and meta-arkose and mafic to felsic volcanic to volcaniclastic rocks (Fig.4). The phyllites have well-developed mylonitic foliation and younger cleavages and they are composed of quartz, sericite and chlorite. In some areas, they contain a higher content of the bituminous component, and very rarely, black shale intercalations. Frequent secondary silicification is also observed along the phyllite foliation planes and the alternating fine- to medium-grained meta-sandstones with phyllites are grey to dark-grey in colour. The thickness of the alternating layers is approximately 5–20 cm, and transitions between sandstone and coarser facies predominantly contain yellow-greyish to grey meta-arkoses (Fig. 4).

The composition also includes quartz keratophyre and meta-rhyolite tuffs and tuffites, which are fine- to medium-grained, grey and light-grey rocks. The volcanic rocks are also present as small lenticular bodies in the chlorite-sericite phyllites on the northwest slopes of Košarisko hill (1,268 m asl.). In contrast, the quartz keratophyre is fine-grained, light-yellow-white in colour and usually has well-developed pervasive foliation.

This formation also contains mafic volcanic rocks and mostly meta-basalt tuffs and tuffites with fine-grained light green, dark green and also olive colouring. This has typical planar fabric with dark grey or violet strips of hematite and specularite mineralization, especially in the Košarisko hill area. This mineralization has been investigated previously, and the flattening of the Alpine metamorphic foliation is very often overprinted by younger pervasive shear cleavage.

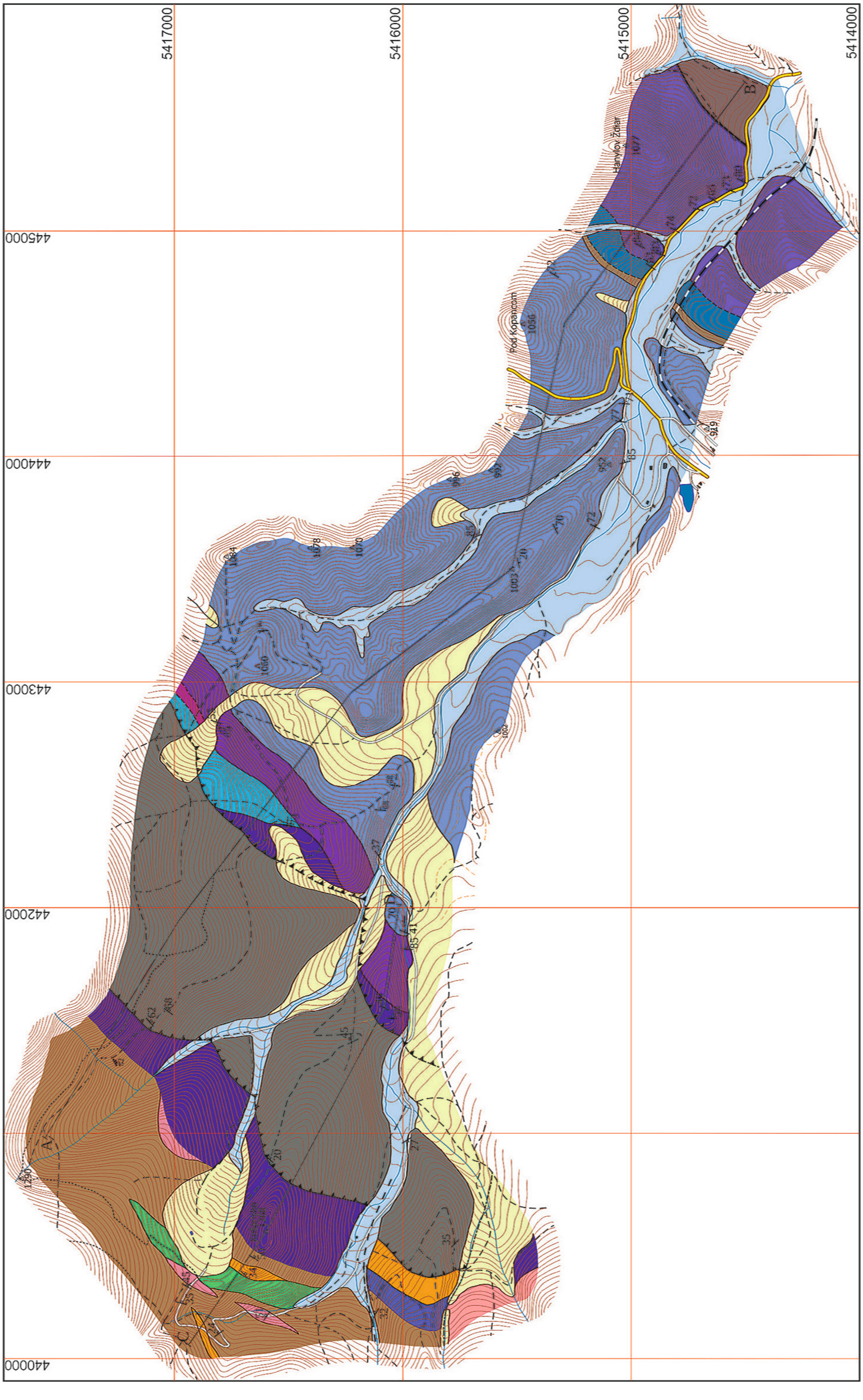

Fig. 2: Geological map of the upper reach of Hnilec Valley area. Note: for explanation see Fig. 3.

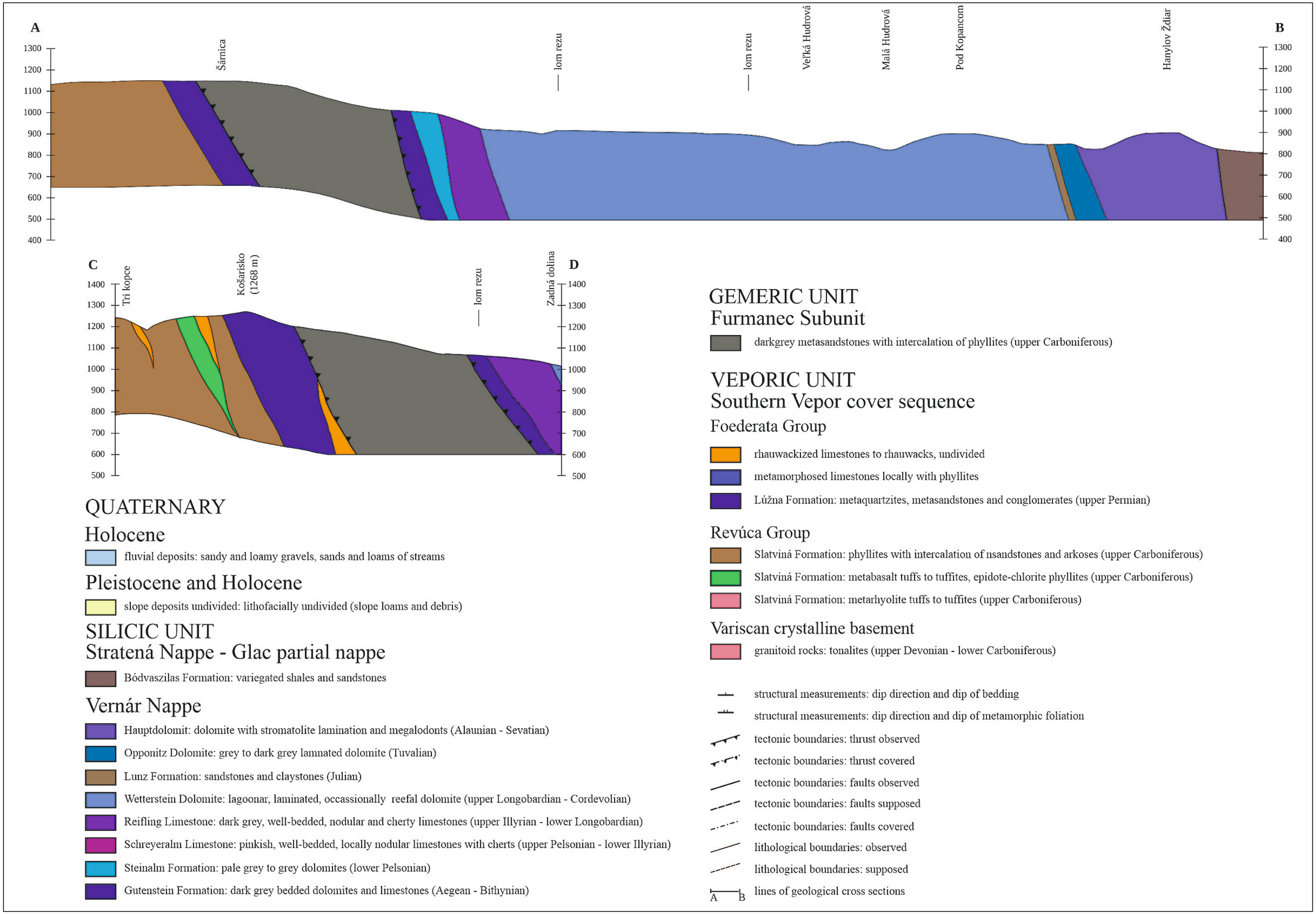

Fig. 3: Geological cross-sections of the upper reach of Hnilec Valley area.

A strip of metamorphosed quartzite of the Permian–Early Triassic Lužná Formation lies on sediments of the Slatviná Formation or directly on the tonalities, and this quartzite extends from the Zadná dolina valley to Košarisko hill (1,268m asl.) to southern slopes of Predná Hoľa Mt. (1,546m asl.) in the western part of the study area (Figs. 2, 3). The formation has fine-grained, light grey quartz sandstone with metamorphic pervasive foliation and stretching lineations with upward-fining towards the top.

The higher parts of the Foederata cover sequence are composed of carbonate rocks, including rauhwacke that forms small lenticular bodies in the Revúca Group and at the top of the Lúžna Formation. Above these are dark to black laminated crystalline limestone and dark-grey calcareous shales (Fig.4); and the entire area is significantly deformed and metamorphosed.

3.2. Gemeric Unit – Furmanec Subunit

The Furmanec Subunit represents newly defined tectonic unit in the study area. The lithological sequence was included in the Ipoltica Group of the Hronic Unit in the past. Unfortunately, there are not stratigraphical data to prove the Carboniferous age of these sequence. The Furmanec Subunit is comprises by metamorphosed siliciclastic deposits, which were supposedly included into the Ochtiná Group in the study area (*sensu* Plašienka & Soták, 2001). This metamorphosed succession is outcropped between the Vernár Nappe and the Foederata cover sequence as a thick strip extending across the entire studied area in the NE–SW direction (Figs. 2, 3). The formation comprises of grey- to dark-grey fine-grained meta-arkose, meta-sandstone

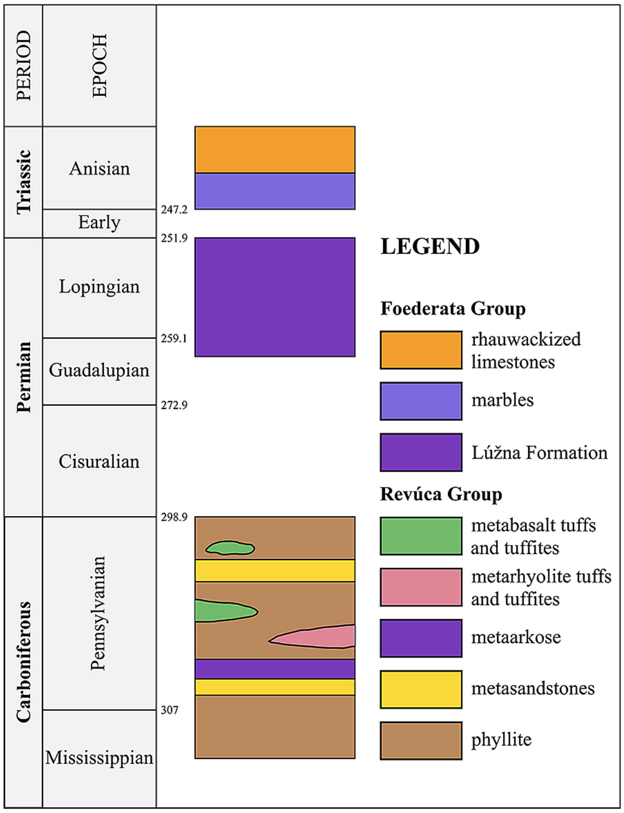

Fig. 4: Lithostratigraphic column of the Foederata cover sequence of the Southern Veporic Unit.

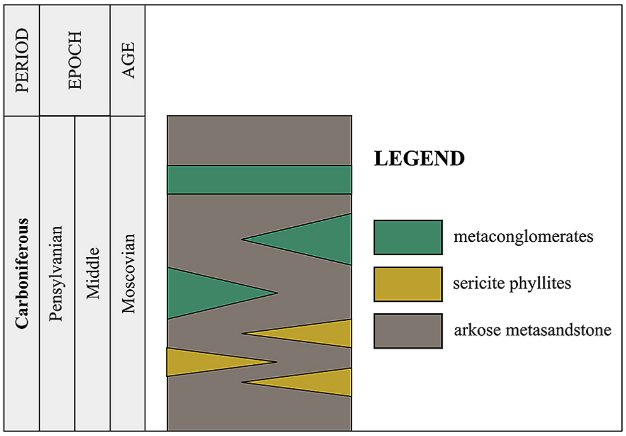

Fig. 5: Lithostratigraphic column of the Furmanec Subunit.

with numerous inter-layers of sericitic and dark grey phyllites (Fig. 5).

Pervasive tectonic foliation and stretching lineation are well developed in the fine-grained rocks, and two different aged lineations can be identified in some areas. The younger is most likely stretching lineation, and although the older one is rarely preserved it is genetically associated with mineral lineation. Finally, there is also intersection lineation in some places caused by penetration of metamorphic foliation (S_1) with younger cleavage (S_2)

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3.3. Silicic Unit – Vernár Nappe

The Silicic Unit is the uppermost unit in the Western Carpathians. Although its original sedimentation area of the Silicic Unit is unknown it originated from either the southern or northern shelf of the Meliatic Ocean. The Silicic Unit forms internally

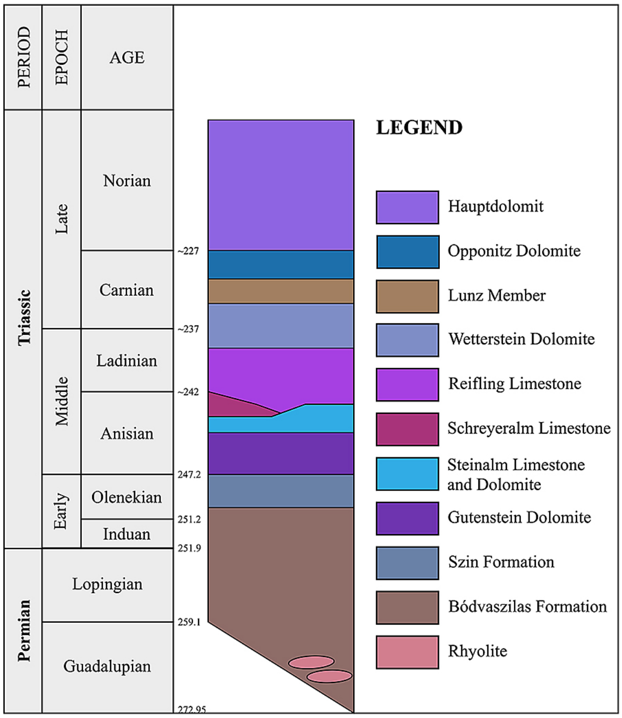

Fig. 6: Lithostratigraphic column of the Vernár Nappe (Silicic Unit).

weakly deformed thrust nappes, cropping out predominantly in the Slovenský kras, Slovenský raj, Galmus, and Muránska planina Mts (Figs. 2, 3). The Silicic Unit can be subdivided into the following partial nappes dependent on its position – the Drienok, Muráň, Vernár, Stratená, and Silicic nappes. In the study area, the un-metamorphosed Vernár Nappe (Maheľ, 1986) outcrops on the surface. Although the tectonic affiliation of the Vernár Nappe to a higher tectonic unit is unclear, some authors consider the nappe part of the Hronic Unit (Kettner 1937; Maheľ, 1956, 1957), and others as a part of the Silicic Unit (Biely et al., 1992; Mello et al., 2000[a,b]) or else they included it in the Gemeric Unit (Andrusov, 1968). The Vernár Nappe stratigraphic range is from Upper Permian to Upper Triassic.

3.3.1. Bódvaszilas and Szin formations

The Vernár nappe sedimentation began with siliciclastic sedimentation divisible into two members: the *Bódvaszilas Formation* (Late Permian–Early Triassic), formed by reddish-violet or grey-green claystones, sandstones and also occasionally by fine-grained conglomerates. The Formation contains brownish and grey-green mica sandstones (Fig. 6), and quartz-schist and quartzite can be found in some places. The upper parts of the formation also has carbonate interlayers. In addition, drilling in the southern Zadná dolina part of the formation uncovered evaporite-gypsum and anhydrite (Zelman et al., 1969). Permian sediments were previously conditionally included in this formation despite the term Bodvaszilas Formation being reserved only for the Lower Triassic sedimentary deposits.

The formation is accompanied by felsic volcanism with its pink, green, and rarely brownish porphyric quartz rhyolite, whose stratigraphic position was uncertain for a long time. While some authors considered them Permian (Biely et al., 1992), others consigned them to Lower Triassic by basing the estimation of their age on stratigraphic contact with the Bódvaszilas Formation which is Lower Triassic (Zorkovský, 1959). The first geochronologic data was supplied by Demko and Hraško (2013) with the rhyolite age determined at 263 ± 3.5 Ma (CHIME – EMP monazite dating), thus clearly demonstrating their Permian age. A similar result (263.3 ± 1.9 Ma) was achieved with more accurate SIMS U-Pb zircon isotope dating (Ondrejka et al., 2018). According to this geochronological data, the siliciclastic deposits can be dated back to Upper Permian to earliest Lower Triassic.

The overlying sediments are in the upper Lower Triassic *Szin Formation* lying on top of the Bódvaszilas Formation (Fig. 6). This has plate-like or slaty limestone with grey-green to yellow marlstones and grey-green clayey marlstones. Small reddish-violet marlstone intercalations can be observed in some places. The lower parts of the formation are more detritic, and carbonatic material increases in the upward direction (Maheľ, 1956). Although these formations do not reach the mapped area, it is important to include their characterization in this chapter.

3.3.2. Gutenstein Formation

Massive deposition of carbonates began after sedimentation of the predominantly siliciclastic formations. Grey, dark-grey to black, fine-grained, bituminous Gutenstein Dolomite (Aegean–Bithynian) is present at the base (Fig. 6). This has the typical rhomboidal dolomite weathering and it forms 5–10 cm thin beds, occasionally up to 50 cm. The dolomites are poor in fossil residues, but there were often pseudomorphs from evaporite minerals and some rare laminated and stromatolite-like structures.

The formation also contains a small amount of dark grey to black bituminous limestones with micritic structure in layers varying from 10 to 100 cm in thickness. The limestones do not contain organic residues but often have calcite veins. There are also numerous worm-like structures in the lower part of this section, and geological map herein shows Gutenstein dolomites and limestones unified in one field due to the small areal extent (Fig. 2).

3.3.3. Steinalm Formation (Early Pelsonian)

A sequence pass into massive light-grey cryptocrystalline dolomites with medium-grained grey-yellow dolomites and overlies the Gutenstein Fm. The dolomites nearest the overlying strata pass into the light-coloured massive "Wetterstein-like" limestone (Fig. 6). Unfortunately, there were no visible macrofossils in this dolomitic formation. Although geologists recognised this formation long ago, it was often incorrectly assigned to the Gutenstein or Wetterstein formations. The Steinalm Limestone and dolomite can be distinguished from the Wetterstein Formation by fossil record and by their position in the stratigraphic sequence because they are separated from the Upper Ladinian to Lower Carnian Wetterstein Limestone by Schreyeralm, Reifling and Raming limestone strata.

3.3.4. Schreyeralm, Reifling, and Raming formations (Late Pelsonian–Longobardian)

There are a few metres of grey-brown, pink to pink-violet packed biomicrite limestone in the overburden of the Steinalm Formation in the northern part of the studied area. These have layered-to-nodular form with organic detritus freely dispersed in the rock, and laminar embankments which are most likely organodetritic limestone are visible in them. The Schreyeralm, Reifling and Gutenstein formations were originally mapped as one formation and labelled "dark limestone" (Mahel, 1957). For the first time, this type of limestone was cartographically differentiated from other types in the geological mapping of the Slovenský Raj, Galmus and Hornádska kotlina (Mello et al., 2000[a], 2000[b]).

A new member of the Reifling Limestone sequence was mapped above the Guteinstein Dolomite, Steinalm and Schreyeralm limestones (Fig.6). The formation extends NE–SW along the entire area of the Vernár Nappe, and has a light to dark grey colour with micritic texture and it is well layered with average 5 to 15 cm thickness. This limestone contain honey-like or black chert nodules mixed with unevenly dispersed organo-detritus and clay. The largest organo-detritus proportion is in the lower part of the formation and this is reflected in the darker limestone colours. The rich fauna includes re-deposited crinoid parts, echinoid spines, foraminifers, radiolarites, gastropods and juvenile ammonites (see also Maheľ, 1957).

The Longobardian Raming Limestone resembles the allodapic layers in the Reifling Limestone. It is light grey or light grey-brown limestone with crinoid detritus and 1–5 cm layer thickness. This was not separated in the geological map because of its limited occurrence, and it is mainly included in the Reifling Limestone.

3.3.5. Wetterstein Formation (Longobardian–Cordevolian)

The Wetterstein Dolomite form a substantial part of the Vernár Nappe (Fig. 6). It is off-white, light grey, dark grey to dark brown-grey or blackish in colour. Dark varieties contain many bituminous components. The dolomite is layered to massive, which is probably due to the occurrence of reef's facies that were lately almost completely dolomitized. Often fragments of Dasycladaceae *Teutloporella herculea* (STOPP) and *Teutloporella aequalis* GÜMBEL were observed.

Irregularly dispersed small lenticular bodies of a limestone, which probably form so called „patch" reef are also presented. These small patch reef bodies did not pass the complete dolomitization, as the surrounding lagoonal parts of the Wetterstein Formation. The limestone is a white-grey, grey to brown-grey colour. It is markedly recrystallized, layered (20–50 cm) to massive. Lagoonal facies contains bituminous dark brown, layered limestone. Graded bedding of bioclasts and the occurrence of algae is typical.

3.3.6. Lunz Formation (Julian)

Massive carbonate sedimentation was interrupted by a pluvial event and this produced a few metre thick layer of clastic sediments, which are reflected in the field by depression-shaped landforms. On the surface, they present only debris outcrops on the left side of the Hnilecká dolina valley. The Lunz Formation has dark grey to black siltstone fine-grained brownish and brown-grey sandstone to quartzite (Fig. 6). Several metres of the layers were previously mapped on two occasions, but neither was confirmed because of the poor quality of the outcrops.

3.3.7. Opponitz Dolomite (Tuvalian) and Hauptdolomit (Norian–Rhaetian)

A few metres-wide strip of light-grey and dark-grey dolomite lies above the siliciclastic sediments, and this is considered the Opponitz Dolomite (Fig. 6). It has stromatolite texture at a higher level and is mostly poor in organic residues. However, the boundary between the Opponitz and Hauptdolomit formations was not accurately detected during field mapping. The formation gradually passes into the Norian Hauptdolomit Formation, and no fossil residues were found in this area.

The Hauptdolomit Formation is regarded as the uppermost member in the stratigraphical succession of the Vernár Nappe in the study area (Fig. 6). The bedding is often very well developed and this formation has cyclically alternating 10–50 cm layers and massive fine-grained dolomites with grey, light brown-grey and dark brown-grey colour. The dark varieties have a large proportion of bituminous component, and contain stromatolites and occasionally Megalodon bivalves.

3.4. Silicic Unit – Stratená Nappe

The Lower Triassic Bódvaszilas Fm. of the Glac Partial Nappe of Stratená Nappe was mapped at the eastern end of the study area (Figs. 2, 3). These rocks are separated by the Muráň Fault from the Upper Triassic Hauptdolomite of the Vernár Nappe on the western side. Their lithological content is almost the same as the Vernár Nappe's except for the absence of products from rhyolite volcanic activity.

3.5. Quaternary deposits

Quaternary superficial deposits extend across the study area along the Hnilec River and adjacent streams (Fig. 2). The Pleistocene sediments are coarse- to fine-grained slope debris. These sediments range from proluvial to slope debris sediments, and there are also occasional Pleistocene alluvial fans with gravels, sands and clays. The Holocene alluvial to fluvial deposits are mainly clayey and sandy clays, and sands with large pebbles are predominantly found along the active fluvial systems.

4. TECTONICS AND INTERPRETATION

The study area located in the Pusté Pole area and at the upper reach of the Hnilecká dolina Valley has complex geological structure. This is depicted in geological mapping, field sampling, and structural measurements. From a structural point view, the investigated area is composed of the palaeo-Alpine nappe stack. The tectonic units differ in lithostratigraphic composition, metamorphic, and tectonic overprint and also in their geological evolution. From the bottom to the top there are: *(i)* Southern Veporic crystalline basement; *(ii)* Foederata cover sequence of the Southern Veporic basement; *(iii)* Furmanec Subunit, this is most likely part of the Gemeric Unit. These tectonic units with metamorphic overprint contain penetrative foliation and lineation; *(iv)* Silicic Unit – Vernár Nappe and *(v)* Silicic Unit– Glac Partial Nappe, which is part of the Stratená Nappe and lacks metamorphic overprint (Fig. 7).

Metamorphosed volcano-sedimentary succession was included in the Foederata cover sequence of the Veporic Unit; based on lithostratigraphic composition and the tectonic position over the Veporic crystalline basement and beneath the metamorphosed and ductile deformed rocks of the Furmanec Subunit, (cf. Madarás & Ivanička, 2001). While the Foederata cover sequence is metamorphosed under greenschist facies condition (Lupták et al., 2003) and underwent ductile deformation (cf. Plašienka, 1993), it remained in a para-autochthonous position to the basement (Hók et al., 1993; Plašienka, 1993; Vojtko, 2000; Vojtko et al., 2015). These rock sequences were previously included in the Predná hoľa Complex that was considered an integral part of the Devonian aged Veporic crystalline basement (cf. Zoubek, 1935; Bajaník et al., 1979). However, there is no stratigraphic or geochronologic confirmation of this metamorphosed and intensively folded sedimentary sequence with bimodal volcanic products (cf. Kubíny, 1959; Biely, 1961; Madarás & Ivanička, 2001). While other tectonic interpretations cannot be excluded and this currently remains unresolved, we interpret the complex as part of the Foederata cover sequence due to the presence of limestones, which are most likely Triassic together with the rauhwackes folded in the sequence (see also Madarás & Ivanička, 2001).

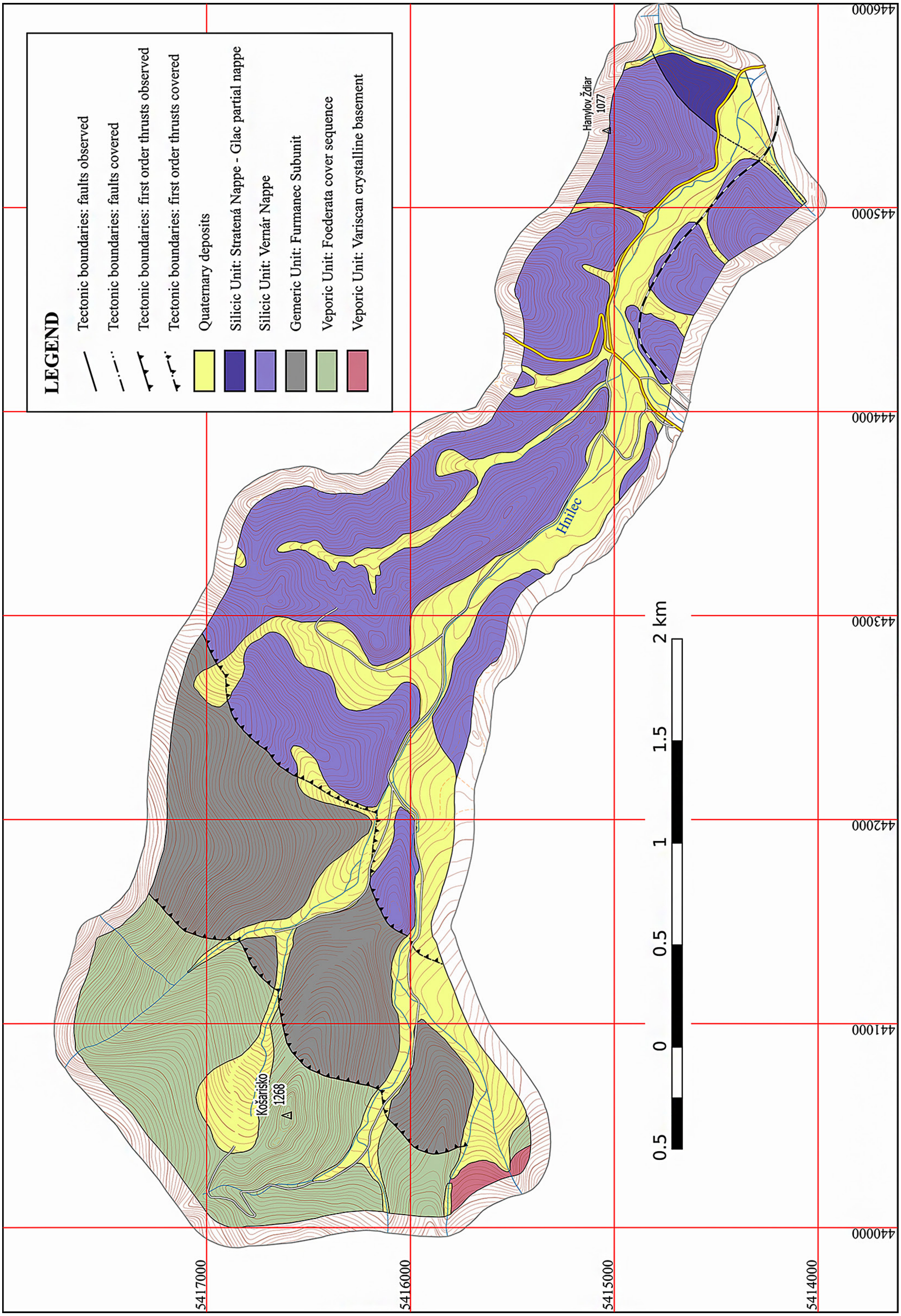

Fig. 7: Tectonic map of the upper reach of Hnilec Valley area.

The Furmanec Subunit (*sensu* Plašienka & Soták, 2001) correlates with the Ochtiná Nappe of the Gemeric Unit and directly overlies the metamorphosed Foederata volcano-sedimentary sequence (Fig. 7). The geological structure is almost identical to the Muránska Planina Mts, but there is no stratigraphic proof. In addition, the subunit is metamorphosed under greenschist facies conditions with well-developed metamorphic foliation and stretching lineation. While the precise integration of the Furmanec Subunit with known palaeo-Alpine units is impossible due to the absence of biostratigraphic data, the Hronic closeness cannot be excluded (cf. Demko & Olšavský, 2005) – although it currently appears improbable. Moreover, these rocks possess some structures, which can be related to the Foederata Unit – Markuška partial nappe (cf. Plašienka, 1986), and this adds to the difficulty of precise differentiation.

The Vernár Nappe is thrust onto the Alpine metamorphosed and ductile deformed Veporic Unit and Furmanec Subunit with a considerable structural and metamorphic gap. Structurally, the Vernár Nappe of Silicic Unit located in the western part of the area in the Permian to Norian stratigraphic range is the highest structure in the study area (Fig. 7). Although younger sediments have not been proven, it is most likely that the Jurassic rocks were removed by erosion. While we consider that the Vernár Nappe rocks form part of the Silicic Unit, the Upper Triassic strata of the Vernár Nappe also have similar sedimentary evolution to the Hronic Unit. Finally, lithostratigraphy indicates that the Vernár Nappe is most similar to the Muráň Nappe.

The tectonic evolution of the studied units begins immediately after the demise of the Variscan orogeny, followed by denudation predominantly during the Late Carboniferous and Permian periods. Each of the assigned tectonic units had different evolution from this period until the thrusting and final emplacement to its current position. Sedimentation in the Southern Veporic domain began by lacustrine sediments in the Late Carboniferous (Slatviná Fm.) with continuous transition to the Permian siliciclastic terrestrial deposits (Rimava Fm.; as in Vozárová & Vozár, 1982, 1988). Numerous products from bimodal volcanism interrupted sedimentary succession during the Late Palaeozoic. A new sedimentary cycle then began in the semi-arid continental conditions at the Permian/Triassic boundary (Lúžna Fm.) with gradual transgression of the sea and subsequent evolution of the carbonate platform from the Anisian Gutenstein and Steinalm formations to the Carnian-Norian. This comprised layered limestone, shale fragments and dolomites, and younger sediments than the Norian sequence are unknown in the Foederata cover (cf. Plašienka, 1993; Vojtko et al., 2015).

The onset of sedimentation in the future Vernár Nappe area is characterized by transitional sediments from continental shores to Middle Permian marine deposits. In all likelihood, the Upper Permian paralic to Lower Triassic deposits with rhyolite volcanism (Bódvaszilas Fm.) were deposited with gradual increase carbonate component in the Szin Fm. Siliciclastic sedimentation in the Early Anisian was relatively quickly replaced by carbonate production; initially under limited marine conditions as in the Gutenstein strata and later under the more open conditions of the Steinalm carbonate ramp of the lower Pelsonian. Late Anisian Meliata Ocean break-up led to the drowning of the shallow-water ramp deposits from the late Pelsonian, and open marine deposits such as those in the Schreyeralm, Reifling, and Raming Lts. were formed. There was no carbonate platform in this area during the late Pelsonian to early Longobardian stages, most likely because of the strong acidification of the Meliata marine environment from extensive volcanic activity in the southern regions. Shallow-water carbonates then began to reform the carbonate platform in the Late Ladinian also known as the Wetterstein Carbonate Platform. However, this carbonate production was disrupted by the Middle Carnian pluvial event with siliciclastic sediments deposition during the Late Carnian and predominantly Norian. Finally, shallow-water carbonate production began during the Late Carnian, especially in the Norian, and this resulted in formation of the Hauptdolomit/Dachstein Limestone Upper Triassic Carbonate Platform.

Demise of the Upper Triassic Carbonate Platform occurred at the Rhaetian and Hetangian boundary. During this period, the partly weathered Hauptdolomit emerged and the Neptunian dykes in these dolomites were most likely filled with the light grey limestone of Early Jurassic epoch. While higher formations in the Vernár Nappe remain unknown, it can be assumed from analogy with the Stratená and Muráň nappes that the sedimentation in the Jurassic period experienced gradual drowning until the Callovian stage (cf. Rakús & Sýkora, 2001).

During closure of the Meliata Ocean, the tectonic units were subsequently individualised into the nappe system from the Upper Jurassic and Lower Cretaceous. This was caused by subduction of the oceanic crust to the south, and the units were consequently pushed northward onto the Gemeric Unit. Thereafter, the Gemeric Unit began to thrust onto the Southern Veporic Unit due to less available space, and this was evidently buried, deformed, and underwent Alpine metamorphosis (cf. Árkai et al., 2003; Dallmeyer et al., 1993; Faryad & Henjes-Kunst, 1997; Lexa et al., 2003; Vojtko et al., 2016, 2017).

Metamorphism in the tectonic units gradually upwardly due to vertical thinning and isograd telescoping. This is ascribed to extensional thinning within and above a low angle normal fault (detachment) which exhumed the Veporic metamorphic core complex (as in Plašienka, 1999; Plašienka et al., 1999; Jeřábek et al. 2012; Bukovská et al., 2013). The highest degree of metamorphosis is in the Southern Veporic crystalline basement, lower in the Foederata cover sequence and lowest in the Furmanec Subunit (Plašienka et al., 2016). Synkinematic paleo-Alpine (Late Cretaceous) metamorphism reached upper greenschists facies conditions in both units. The Vernár Nappe and the Glac Partial Nappe were not affected by metamorphism and this is indicated by the CAI index on the conodonts (1.5–2.0 – diagenesis, temperature interval approximately 100–200°C). Similar results from the Vernár Nappe were also published by Havrila (2011).

The unmetamorphosed Vernár Nappe lies on the Veporic and Gemeric metamorphic complexes with pronounced structural and metamorphic disconformity, and its emplacement is the latest deformational stage. Reconstruction of the structural evolution and metamorphic conditions enable us to suggest that the slice of Carboniferous sediments cannot be incorporated in the higher cover nappe units. Moreover, the internal structure of the Carboniferous sediments closely resembles the structure of the Gemeric Unit–Ochtiná Group.

Exhumation of the Vepor-Gemer metamorphic core began during the Late Cretaceous to Eocene (as in Vojtko et al., 2016) through unroofing, when the overlying nappes were moved to the southeast with the Silicic nappe system along the detached low angle shear zone (Hók et al. 1993; Plašienka 1993; Madarás et al. 1996; Jeřábek et al. 2012; Bukovská et al., 2013; Novotná et al., 2015). Erosion/denudation of the Vepor area continued until the Late Eocene and resulted in formation of a planation surface prior to the Central Carpathian Palaeogene Basin transgression. The secondary burial of the Veporic Unit under the Silicic nappe system occurred after the final stages of exhumation, and certainly before the sedimentation of the Central Carpathian Palaeogene Basin (Králiková et al., 2016; Vojtko et al., 2016, 2017).

Following sedimentation of the Central Carpathian Palaeogene Basin at the boundary of the Oligocene and the Early Miocene, the activity of the Muráň Fault and its structures rapidly decreased. This assumption is confirmed by Palaeogene sediments being only minimally shifted by this significant fault structure (Marko, 1993; Mello et al., 2000[a], 2000[b]; Sůkalova et al., 2012). However, there is gradual surface uplift of this area and subsequent erosion of the Palaeogene sediments until the full exposition of the palaeo-Alpine nappe structure. Central Carpathian Palaeogene Basin sediments were preserved only in the Hornád Basin (north of the study area) and in the Horehronské Podolie Depression (southwest of the study area). These formed as 'synform' structures during the Neogene period.

The Vernár Nappe has almost homoclinal structure with the NE–SW striking and inclination steeply dipping 60–80° south-eastwards. While very similar structure is observed in the Veporic and Furmanec units, this is more complex because the unit underwent polyphase Alpine deformation (Fig. 8).

5. CONCLUSIONS

Herein, the geological structure and lithostratigraphy were refined and reclassified through geological mapping of the Hnilec Valley in the Pusté Pole locality. The following litostratigraphic members were conditionally reclassified in other tectonic units; from the bottom to the top *(i)* the Variscan crystalline basement of the Veporic Unit; *(ii)* the Foederata cover sequence of the Veporic Unit; *(iii)* the Furmanec Subunit with tectonic relationship to the Gemeric Unit; *(iv)* the Vernár Nappe and *(v)* the Glac partial nappe of the Stratená Nappe of the Silicic Unit.

The observed nappe stack can be divided into two groups according to Alpine metamorphic overprint; and the degree of metamorphosis led to different heating and deformation of individual tectonic units. The first and structurally lower group of tectonic units was metamorphosed with characteristic metamorphic overprint and significant ductile deformation. Both the Veporic Unit and the newly determined Furmanec Subunit, which most likely has Gemer affinity, were included in this nappe stack. The second nappe group has unmetamorphosed nappe pile and contains the Vernár and Stratená nappes.

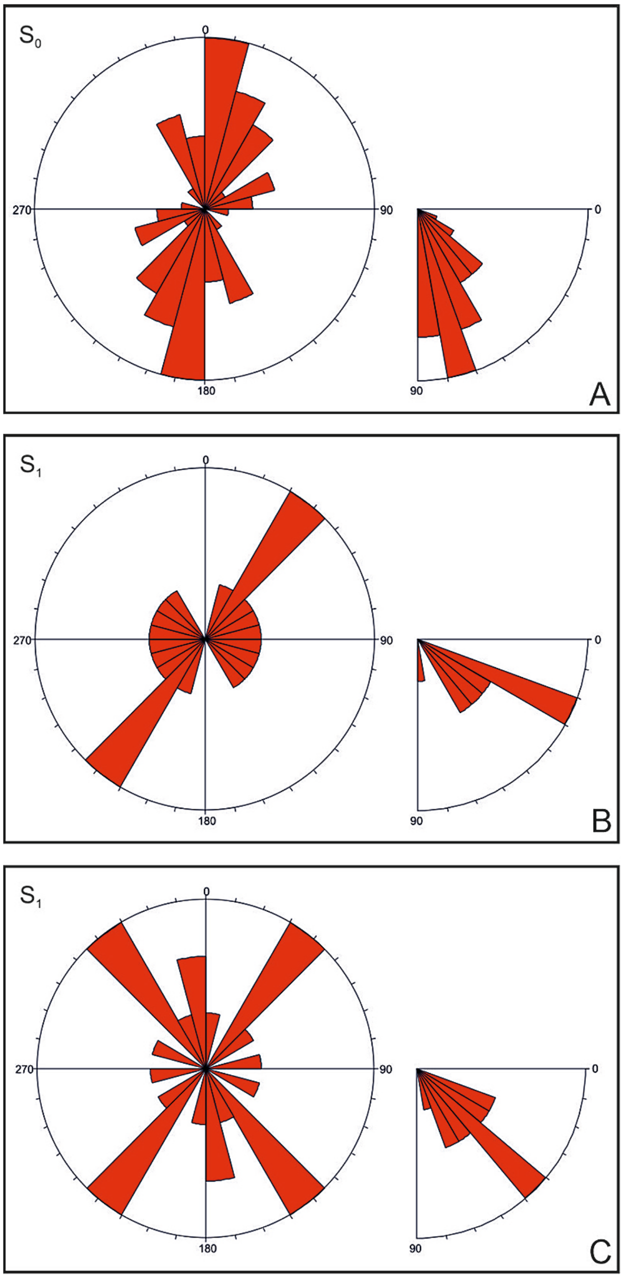

Fig. 8: Tectonograms: A) bedding planes in the Vernár Nappe with the NNE – SSW striking and inclination approximately 60–70° towards ESE; B) metamorphic foliation in the Veporic Unit with the NE–SW striking and the gently dips approximately 20–30° towards SE; C) metamorphic foliation in the Furmanec Subunit with the NE–SW striking with the dip of 50°.

In conclusion, the division of the Vernár Nappe as an independent nappe structure is based on lithostratigraphic and structural criteria. However, the lack of additional data precludes incorporating the unit in any known palaeo-Alpine tectonic units of the Western Carpathians. Finally, our results suggest that the Vernár Nappe is part of the Silicic Unit.

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