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Pre-Cenozoic basement of the northeastern part of the Internal Western Carpathians from the perspective of the geological structure of the Tatry and Branisko mountains

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Abstract: The area between the Tatry and Branisko mountain ranges in northeastern Slovakia represents the most extensive territory covered by Paleogene sediments within the Internal Western Carpathians. In order to compile a tectonic map of the pre-Cenozoic basement, the locations at which the basement was present on the surface were analysed in detail to determine their tectonic affiliation. The Havran structure, previously classified as Fatricum, has been reclassified as Veporicum in the eastern part of the Tatry Mts. The rock complexes in the Branisko Mts. that were previously classified as part of the Tatric tectonic unit are now considered an integral part of the Veporicum. The pre-Cenozoic basement of the studied area comprises the Fatricum, Veporicum and Hronicum. The Mesozoic sediments of Fatric tectonic unit occur south of the surface outcrops of Oravic sediments. South of this, the pre-Cenozoic basement contains the Veporicum and Hronicum tectonic units.

Key words: tectonics, Tatricum, Veporicum, Fatricum, Hronicum

Introduction

Cenozoic sediments and volcanic rocks cover more than half of the territory of Slovakia. Together with locally preserved Upper Cretaceous rocks, they represent post-nappe sedimentary sequences within the Internal Western Carpathians (*sensu* Hók et al., 2019). Knowledge of the geological structure of the areas buried beneath the Cenozoic basins is essential not only for understanding the geometry and relationships of the Alpine tectonic units in their basement, but also for applied purposes, such as the exploration of geothermal water and energy.

The study area is situated in the northeastern part of the Internal Western Carpathians (IWECA) and represents the largest coherent region covered by Paleogene sediments (Fig. 1). The geological structure of the study area is depicted on several regional geological maps at a scale of 1:50,000 (Bajaník et al., 1984; Biely et al., 1992; Gross et al., 1999; Mello et al., 2000; Nemčok, 1990; Nemčok et al., 1994; Polák et al., 1996) or on the Geological Map of Slovak Republic (2013). The tectonic setting of the pre-Cenozoic basement was published by Fusán et al. (1987).

The surface geological structure is significantly dominated by Paleogene sediments of the Sub-Tatra Group (*sensu* Gross et al., 1984; Gross, 2008). Pre-Cenozoic rock complexes consist mainly of Mesozoic and locally Upper Paleozoic sedimentary cover of the Tatricum, Veporicum (Northern Veporicum) or Gemericum and allochthonous Fatric, Hronic, and Silicic cover nappes. Pre-Mesozoic crystalline basement complexes are represented by Paleozoic plutonic and metamorphic rocks of the Tatric, Veporic, and Gemeric thick-skinned tectonic units (Hók et al., 2019). Based on a detailed and critical analysis of the surface geological structure in the Tatry and Branisko Mts., supplemented borehole data and geophysical interpretations, this paper re-evaluates existing knowledge on the geological structure of the pre-Cenozoic basement, and provides new innovative view which differs from the previous interpretation (e.g., Fusán et al., 1987) mainly in terms of the tectonic categorization of the Tatric and Veporic rock complexes.

They also include information on structural geology concerning paleostress fields and significant faults.

The method employed involved mutual extrapolation and interpolation of surface data, borehole results, geophysical data and structural data. The principle of constructing a pre-Cenozoic basement map by extrapolation involves projecting surface data no more than halfway to different geological object (tectonic unit). In contrast, interpolation involves connecting identical surface geological objects or assuming their continuous extension into the basement beneath Cenozoic sediments or volcanic rocks. Continuous extension from the surface may be modified if limiting data from boreholes, geophysical surveys or structural data are available in the given area. Knowledge of the geological structure, especially the lithostratigraphic composition of individual tectonic units and their superposition, plays an important role here. Information obtained from boreholes represents the most important source, which largely com-

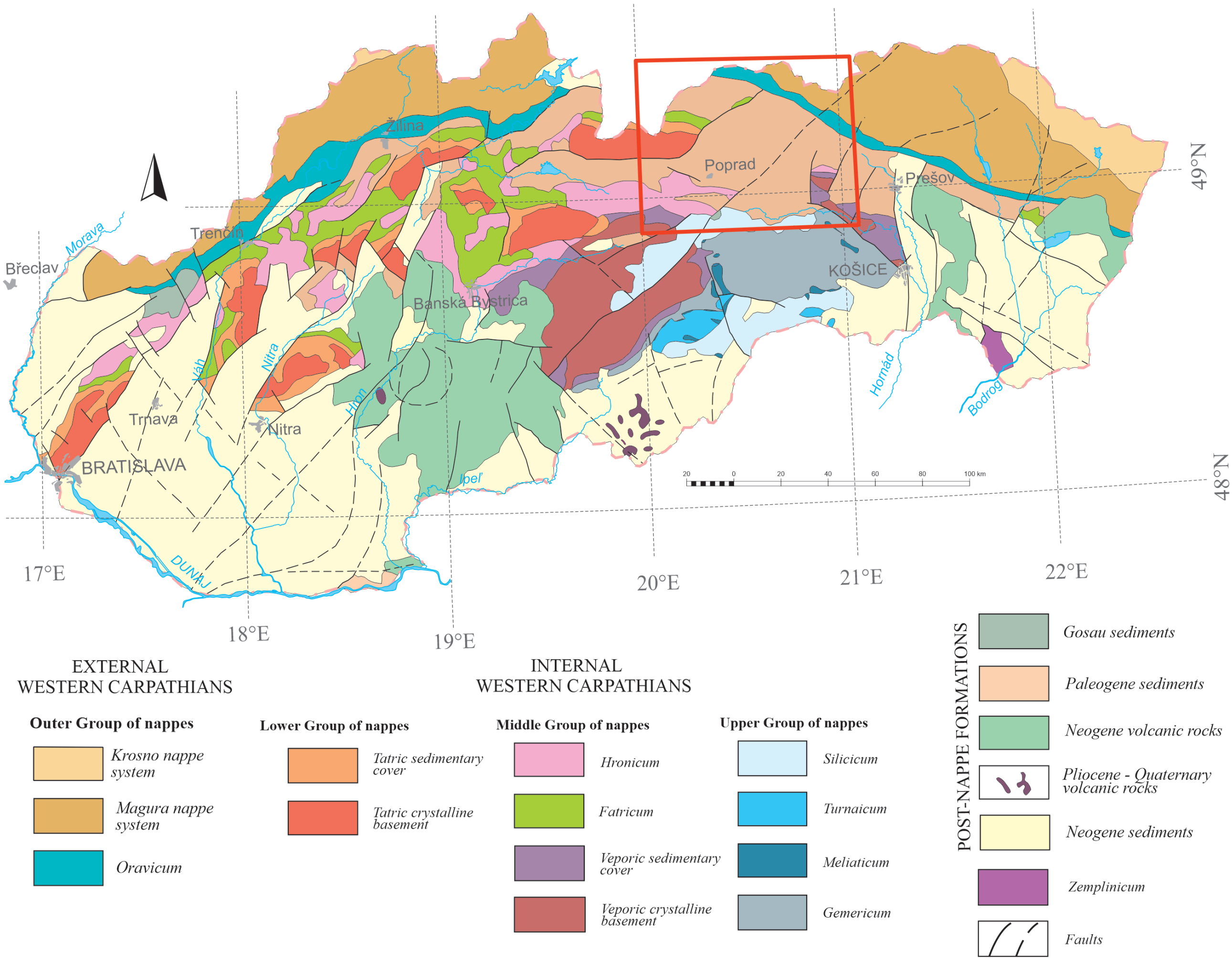

Fig. 1. Simplified tectonic map of Slovakia (Hók et al., 2019). The red rectangle represents the study area.

Methodology

The map of the pre-Cenozoic bedrock is based on a comprehensive review of published works and archived reports. The collected data have been categorized and expertly analysed. The input data primarily consists of the results of geological surveys (i.e. geological maps), boreholes (i.e. lithology and stratigraphy) and geophysical surveys (i.e. gravimetric, electric and seismic methods).

plements or expands upon the previous one. A borehole ultimately provides only point data. Therefore, the results obtained are always extrapolated or interpolated between individual boreholes or between a borehole and surface data.

When collecting data on the characteristics of pre-Cenozoic bedrock, especially from boreholes, the original description of the rock complexes encountered is important, as its quality can and often does vary. In this case, an expert decision must be made, either based on a direct inspection of the drill cores or based on a correlation with the geological conditions of the nearest surface or with other nearby boreholes, and finally based on a comparison with the latest generally accepted tectonic conditions.

The information obtained from the geophysical data was primarily derived from gravimetry (see Fig. 2), as these data are of supraregional significance and the results are consistently available across Slovakia (Kilényi & Šefara, 1989; Pašteka et al., 2017; Zahorec et al., 2021). To a lesser extent, results from seismic, magnetotelluric and electrical sounding, or electrical resistivity tomography have been used. These are mostly limited to individual areas and their correct interpretation often depends on correct correlation with surface or borehole data.

Structural and tectonic data are integral to correctly interpreting tectonic conditions in areas covered by Cenozoic sediments. Understanding these conditions and their proper extrapolation is of primary importance. The fundamental aspects of the Variscan orogeny must be considered, as well as the strict distinction of the structural character of Paleo-Alpine tectonic deformation (Jurassic–Cretaceous) from the consequences of Neo-Alpine tectonic processes (Cenozoic), and their mutual interaction, within the Alpine tectonic stage.

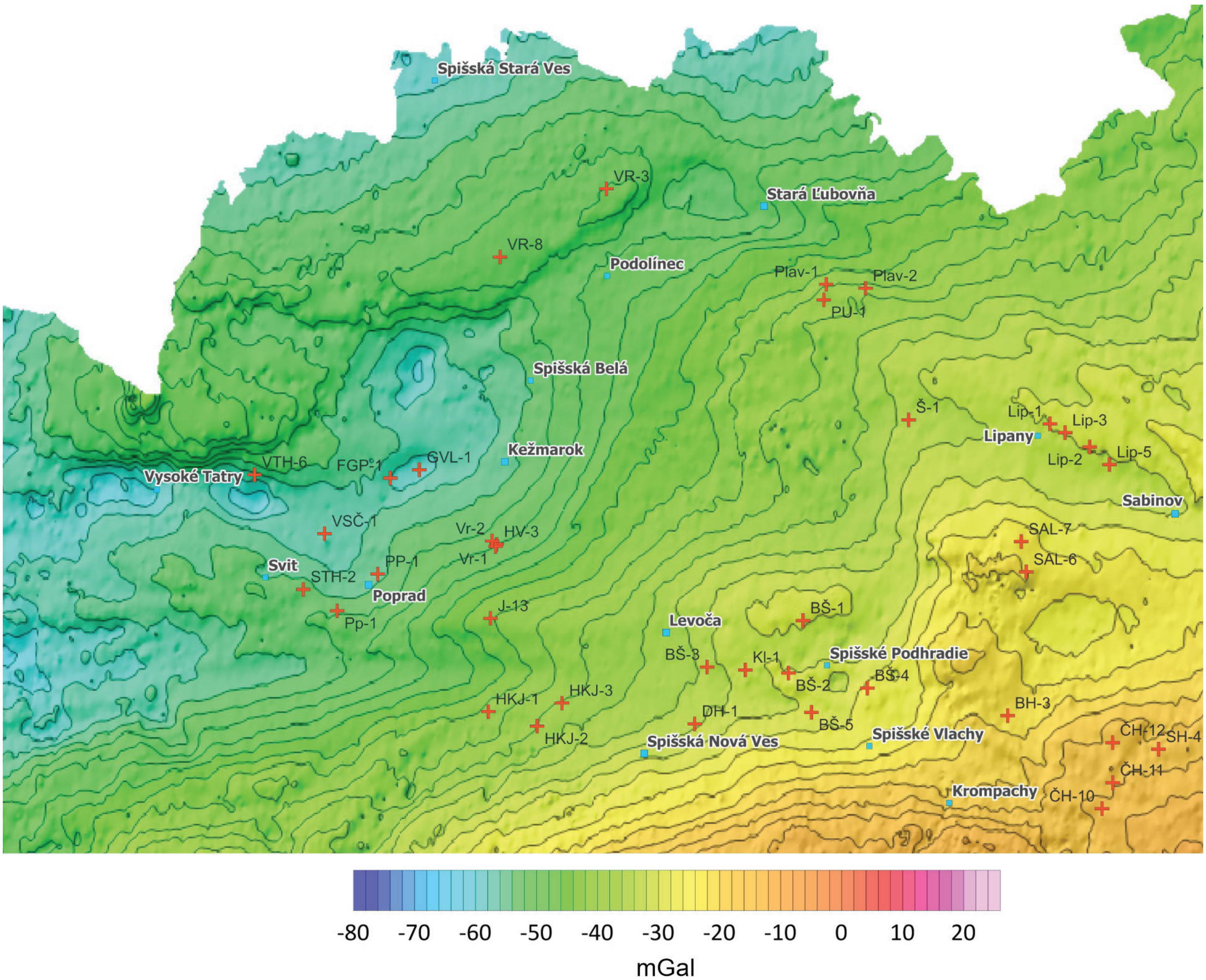

Fig. 2. Map of complete Bouguer anomalies in the study area showing the locations of boreholes that reached the pre-Cenozoic basement (Pašteka et al., 2017; Zahorec et al., 2021).

Surface occurrences of the pre-Cenozoic basement

Pre-Cenozoic basement in the area of interest (Fig. 3) is exposed at the surface in the Tatry Mts., the Vikartovský chrbát Ridge, Slovenský raj, Galmus, Spišsko-gemerské rudohorie Mts., Branisko, and Čierna Hora Mts., as well as in the Pieniny Klippen Belt. The Mesozoic formations of the Pieniny Klippen Belt have no significant impact on the structure of the pre-Cenozoic basement in the IWECA region.

The Tatry Mountains

The geological structure of the Tatry Mts. is depicted on the geological map and in the accompanying explanatory notes (Nemčok et al., 1993, 1994). In many aspects, the map is based on earlier publications by Uhlig (1900), Lugeon (1903), and especially Andrusov (1950). Notably, the geological map of the Vysoké Tatry area between the Bielovodská dolina and Javorová dolina Valleys has not been re-examined in detail since Andrusov's work in 1950. According to Nemčok et al. (1993, 1994), the Vysoké Tatry and Belianske Tatry regions comprise the Tatric and Fatric tectonic units. The crystalline basement rocks are represented by several types of granitoid and metamorphic rocks, which are generally considered to be part of the Tatricum. However, Andrusov (1950) states: *"... the origin of the crystalline cores of the recumbent folds of the Široká massif must be placed far to the south of their present location."*

The tectonic setting of the Vysoké Tatry (VT) and Belianske Tatry (BT) mountains differs markedly to the west, roughly along the north-south line connecting the Bielovodská dolina Valley, the Roztoky Valley and the Kôprová dolina Valley (the Kôprová dolina Valley Fault, as defined (the Kôprová dolina Valley fault, as defined by Bezák et al., 2004). The tectonic affiliation of parts of the Tatric and Fatric rock complexes is disputed. The Kôprová dolina Valley (also known as the Kôprová Fault Zone; Nemčok et al., 1993) runs through the Tatra Mountains, separating the elevated western part from the depressed eastern part.

To the west of the Kôprová dolina Valley Fault (KVF), the Mesozoic sedimentary rocks of the Tatricum are divided into an autochthonous part, represented by the Tomanová sequence, and cover-unit duplexes, namely Czerwone Wierchy, Giewont and Goryczkowa (Nemčok et al., 1993; Ostrowski et al., 2026). Granitoids are also present here, alongside cover Mesozoic sedimentary sequences in several duplexes (Bac-Moszaszwili et al., 1984). From a lithofacial and lithostratigraphic perspective, the Tatric cover has been divided and grouped into a number of different sequences (Kotański, 1961). However, defining the Tatricum in this area does not pose any significant problems. To the east of the KVF, duplexes of the cover sediments are absent, with only sediments of the cover units present in the Široká area (2,210 m a.s.l.). There, a rudimentary cover of crystalline basement rocks, in the form of the Lúžna Formation (Lower Triassic), is preserved. The Fatricum is present in two superimposed structures, the Havran and the Bujačí nappes (Nemčok et al., 1993, 1994).

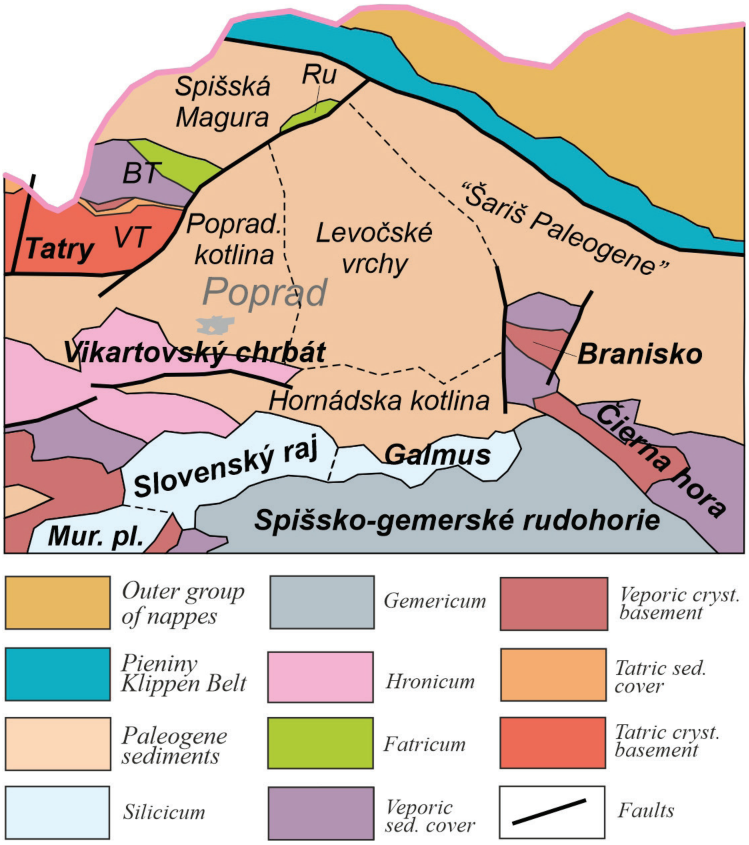

Fig. 3. Simplified tectonic map and regional geological division (Vass et al., 1988) of the study area. VT – Vysoké Tatry subunit, BT – Belianske Tatry subunit, Ru – ružbašský ostrov.

Fig. 4. A section from the geological map of the Tatry Mountains (Nemčok et al., 1994) with explanations and markings of the presumed Veporicum structures. The inverted stratigraphic sequence of a recumbent fold, whose core consists of crystalline rock and which today represents the Veporic outlier, is illustrated in Fig. 5.


geological section
Havran structure (Veporicum)
Bujačí structure (Fatricum)
Tatricum
Veporicum outlier
FATRIKUM – Krížňanský príkrov FATRICUM – Krížna nappe
Krieda Cretaceous
50 muránske vápence; vrchný hoteriv – spodný apt
Muráň Limestones; Upper Hauterivian – Lower Aptian
Jura – krieda Jurassic – Cretaceous
51 svetlé pelitické vápence (biancone, majolika) a škvrnité sliene; titón – cenoman
light-coloured pelitic limestones (Biancone, Maiolika).and spotted marls; Tithonian – Cenomanian
Jura Jurassic
52 červené doskovité až lavicovité hľuznaté rohovcové vápence; kimeridz – spodný titón
red bedded to thick-bedded nodular limestones; Kimmeridgian – Lower Tithonian
53 radiolarity, radioláriové vápence,hľuznaté vápence a bridlice; bajok – kimeridž
radiolarites, radiolarian limestones, nodular limestones and shales; Bajocian – Kimmeridgian
54 hierlatzské a adnetské vápence: červené, ružové, sivé hľuznaté vápence, čierne ílovce, krinoidové vápence; pliensbach ? – toark
Hierlatz and Adnetz Limestones: red, pink, gray nodular limestones, black claystones, crinoidal limestones; Pliensbachian ? – Toarcian
55 rohovcové vápence; pliensbach
nodular limestones; Pliensbachian
56 allgäuské vrstvy: kremité škvrnité vápence, sivé škvrnité slienité vápence, sliene a bridlice so spongolitmi „fleckenmergel"; sinemúr – spodný bajok
Allgäu Member: siliceous spotted limestones, gray spotted marly limestones, marls and shales with spongolites "Fleckenmergel"; Sinemurian – Lower Bajocian
57 babošské (pisanské) kremence: kremité pieskovce, kremence, piesčité vápence, piesčité ílovité bridlice; sinemúr
Baboš (Pisany) Quartzites: quartzose sandstones, quartzites, sandy limestones, sandy shales; Sinemurian
58 kopienecké vrstvy: sivé organodetritické vápence, tmavosivé slienité bridlice, vápnité pieskovce, piesčité-krinoidové a oolitické vápence; vrchný rét – sinemúr
Kopienec Member: gray organodetrital limestones, dark-gray marly shales, calcareous sandstones, sandy-crinoidal and oolitic limestones; Upper Rhetian – Sinemurian
Trias Triassic
59 fatranské súvrstvie: tmavosivé až čierne vápence, sivé až čierne lumachelové vápence, tmavé bridlice, krinoidové a oolitické vápence; rét
Fatra Formation: dark-gray to black limestones, gray to black lumachelle limestones, dark shales, crinoidal and oolitic limestones; Rhetian
60 lavicovité a sivomodré dolomity v karpatskom keuperi; norik
bedded and gray-blue dolomites in Carpathian Keuper; Norian
61 karpatský keuper: pestré ílovito-piesčité bridlice, pieskovce, kremence, drobnozrnné zlepence, žltkavé dolomity, karbonátové zlepence; norik – ? spodný rét
Carpathian Keuper: variegated shales and sandy shales, sandstones, quartzites, fine conglomerates, yellowish dolomites, carbonate conglomerates; Norian – ? Lower Rhetian
62 ramsauské dolomity: masívne aj hrubolavicovité, svetlé až tmavosivé dolomity, miestami s polohami brekcií; ladin – karn
Ramsau Dolomites: massive or thick-bedded, light to dark-gray dolomites, locally with breccia layers; Ladinian – Carnian
63 nerozdelené vápence a dolomity; anis – ladin
limestones and dolomites, undifferentiated; Anissian – Ladinian
64 gutesteinské vrstvy: tmavosivé lavicovité vápence, dolomity, bazálne brekcie s vložkami červíkovitých vápencov; anis
Gutenstein Member: dark-gray thick-bedded limestones, dolomites, basal breccias intercalated with wormy limestones; Anissian
65 verfénske súvrstvie: kremité pieskovce, pestré a čierne bridlice, bunkové dolomity, vápence; vyšší skýt
Werfenian Formation: quartzose sandstones, variegated and black shales, rauwackes, limestones; upper Scythian
66 kremence a kremenné pieskovce; spodnejší skýt
quartzites and quartzose sandstones; lower Scythian
TATRIKUM TATRICUM
MEZOZOIKUM MESOZOIC
Krieda Cretaceous
67 porubské súvrstvie: sivé bridlice, piesčité vápence, pieskovce; alb – spodný turón ?
Porúbka Formation: gray shales, sandy limestones, sandstones; Albian – Lower Turonian ?
68 svetlé rífové vápence a rífové brekcie (urgónska litofácia); barém – apt
light-coloured reef limestones and reef breccias (Urgonian lithofacies); Barremian – Aptian
69 sivé oolitické a pelitické rohovcové vápence; valangin – hoteriv
light-coloured oolitic and pelitic nodular limestones; Valanginian – Hauterivian
70 limburgity a ich vulkanoklastiká
limburgites and related volcanoclastics
Jura – Krieda Jurassic – Cretaceous
71 masívne organogénne vápence; doger – malm
massive organogene limestones; Dogger – Malm
72 hľuznaté ružové, sivé vápence a tmavé lavicovité vápence; kelovej, oxford, kimeridž, titón, berias, valangin, hoteriv
pink, gray nodular limestones and dark bedded limestones; Callovian, Oxfordian, Kimmeridgian, Tithonian, Berriasian, Valanginian, Hauterivian
Jura Jurassic
73 krinoidové a červené vápence so stromatolitami; bajok – bat
crinoidal and red limestones with stromatolites; Bajocian – Bathonian
74 pieskovce a piesčito-krinoidové vápence; hetanž – bajok
sandstones and sandy-crinoidal limestones; Hettangian – Bajocian
Trias Triassic
75 tomanovské súvrstvie: tmavé ílovito-piesčité až grafitické, vápnité pieskovce, piesčité vápence s vložkami oolitických a lumachelových vápencov; rét
Tomanová Formation: dark sandy to graphite shales, calcareous sandstones, sandy limestones intercalated with oolitic and lumachelle limestones; Rhetian
76 karpatský keuper: kremence, pieskovce, dolomity; vrchný karn – norik
Carpathian Keuper: quartzites, sandstones, dolomites; Upper Carnian – Norian
77 gutensteinské vrstvy: tmavé vápence s dolomitizačnými prejavmi, červíkovité vápence; anis – ladin
Gutenstein Member: dark partly dolomitized limestones, wormy limestones; Anissian – Ladinian
78 gutensteinské vrstvy: svetlé dolomity, dolomitické vápence a brekciovité dolomity; anis – ladin
Gutenstein Member: light-coloured dolomites, dolomitic limestones and brecciated dolomites; Anissian – Ladinian
79 pestré ílovité bridlice, pieskovce, slienité bridlice, vápence; skýt (verfén)
variegated shales, sandstones, marly shales, limestones; Scythian (Werfenian)
80 lúžňanské súvrstvie: zlepence, kremité pieskovce, kremence; skýt
Lúžna Formation: conglomerates, quartzose sandstones, quartzites; Scythian
PALEOZOIKUM PALEOZOIC
Perm Permian
81 koperšadské (meďodolské) zlepence
Koperšady (Meďodoly) conglomerates
KRYŠTALINIKUM CRYSTALLINE COMPLEX
MAGMATITY (PALEOZOIKUM) IGNEOUS ROCKS (PALEOZOIC)
82 leukokratné granitoidy
leucocratic granitoids
83 porfýrické granitoidy s výrastlicami ružovočervených K-živcov (typ Goričkovej)
porphyritic granitoids with pink-red K-feldspar phenocrysts (Goričková – type)

At the mouth of the Kežmarská Biela voda Valley, above the Lúžna Formation, the Gutenstein Limestones (Middle Triassic) appear in their normal stratigraphic position. However, the Gutenstein Limestones are tectonically separated from the Lúžna Formation sediments by a nappe contact (Nemčok et al., 1994). This contact can be traced westward to the area east of Veľké Biele pleso and to the west of the Napájadlový potok Valley (near the Kežmarská chata hut), where the Gutenstein Limestones are again separated from the Lúžna Formation by a nappe contact. The same situation occurs far as the upper part of of the Meďodolský potok Valley, where a fold structure is present. In its synform parts, the Gutenstein limestones or the shales of the Lúžna Formation are found in their normal stratigraphic position, above the Lower Triassic and Permian sediments (Meďodoly conglomerates), with fragments of the Goryczkowa-type granite in their footwall (Gorek, 1954). The Gutenstein Limestones bordering the north-eastern edge of the aforementioned fold structure occupy a normal position as the upper fold limb and passes upwards into higher members of the lithostratigraphic sequence. Despite these apparently normal stratigraphic relationships is tectonically assigned to the Fatricum on the geological map (Nemčok et al., 1994).

To the west, the Gutenstein Limestones lie above massive organodetritic limestones (Middle to Upper Jurassic), and both formations belong to the Tatricum tectonic unit. On the left bank of the Javorová dolina Valley, on the northeastern slopes of Svišťovka (2,070 m a.s.l.), crinoidal and red limestones with stromatolites (Bajocian–Bathonian) and Carpathian Keuper Formation are found overlying leucocratic granitoids. The entire rock complex, apparently in an inverted stratigraphic position, is assigned to the Tatric tectonic unit (Nemčok et al., 1994). In the hanging wall of the Tatric cover sequence, a crystalline basement thrust slice is present, represented by porphyritic granites (Goryczkowa-type, e.g. Kohút et al., 2019) and sediments of the Lúžna Formation (Fig. 5). The aforementioned rock complex is tectonically separated from the Tatric crystalline basement. In Zadná kopa (1,674 m a.s.l.) and Holica (1,628 m a.s.l.), the same granites, together with the Lúžna Formation and Mesozoic sediments ranging in age from the Middle Triassic to Cenomanian form a continuous lithostratigraphic sequence that connects seamlessly to the Havran nappe. The presence of a crystalline basement as an integral part of the Havran structure above the Tatric sedimentary cover indicates its tectonic affinity with the Veporicum.

It is reasonable to consider the Havran structure to be part of the Veporicum, in a similarly to the Nízke Tatry Mountains (Biely et al., 1992), the Staré Hory Mountains (Polák et al., 2003) and the Tribeč Mountains (Ivanička et al., 1988), as well as in the context of the Šariš-1 borehole results (Š-1, Koráb et al., 1986).

Meanwhile, the Fatricum sensu stricto could be represented by the Bujačí nappe/structure (cf. Nemčok et al., 1994; Geological Map of Slovak Republic, 2013).

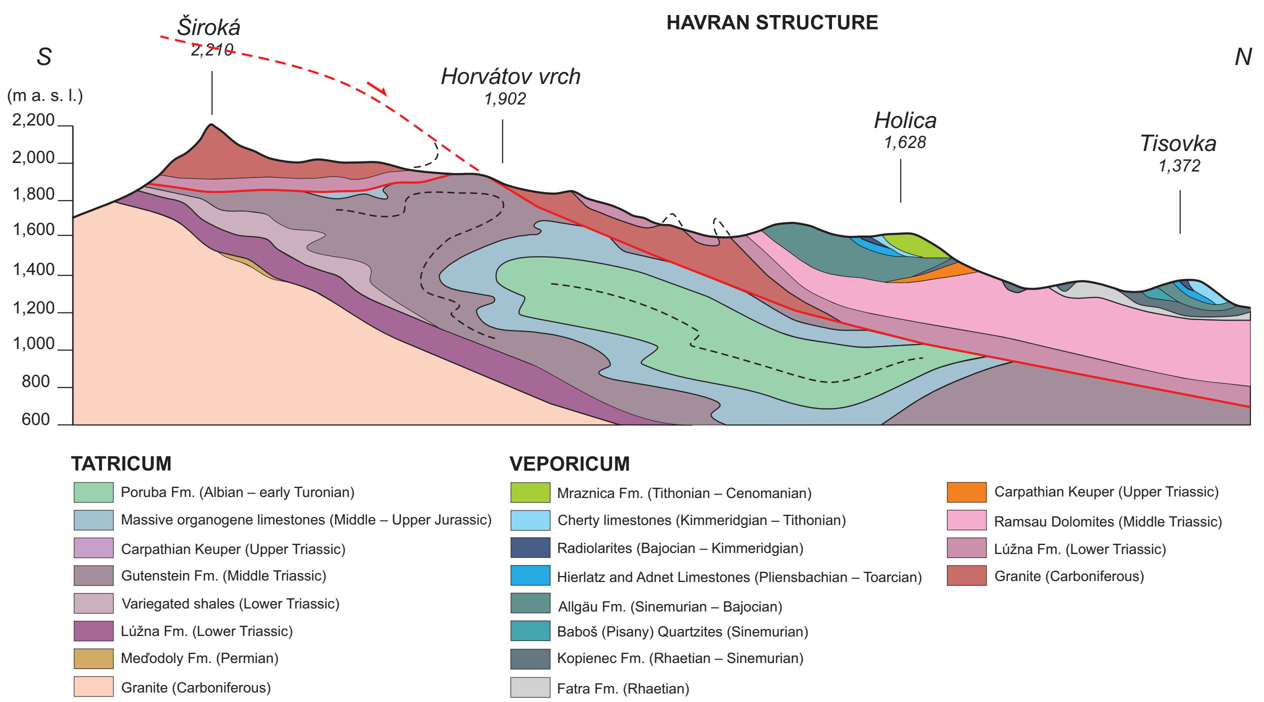

Fig. 5. Geological section between Široká (2,210 m a.s.l.) and Tisovka (1,372 m a.s.l.) documenting the allochthonous position of the Veporic tectonic unit (Havran structure) on the Tatricum (for the location of the section, see Fig. 3).

The Bujačí structure may also represent a continuous, folded structure of the Havran nappe, with Middle Triassic dolomites forming its core. In that case, it would require a southward displacement of the dolomites and the associated lithostratigraphic units in the upper limb of the fold. There is no evidence of south-vergent displacements in the Tatra Mts. Furthermore, the high rheological resistance of dolomites to folding suggests that their presence in the core of a recumbent fold is less likely. It is simpler and more energetically plausible to assume that this is a separate duplex structure. However, this assumption requires further research. On the southeastern edge, the pre-Cenozoic rock sequences of the Tatry Mountains are separated from the Paleogene sedimentary sequences by the Ružbachy Fault (RuF). The RuF was tectonically active throughout the Cenozoic (Jacko, 2000).

Vikartovský chrbát Ridge

The Vikartovský chrbát Ridge is largely composed of the Hronic tectonic unit. The rock complexes of the Lower Paleozoic Ipoltica Group form the prevailing portion of the area (Vozárová & Vozár, 1979). Mesozoic rocks of the Hronicum are present in the stratigraphic range from the Lower Triassic to the Lower Jurassic. Lithofacially, imbricated Hronic sedimentary rocks of both the Čierny Váh and Biely Váh facial type are present here (Havrila, 2011). The rocks formations are monoclinally inclined to the north (c.f. Biely et al., 1992; Geological Map of Slovak Republic, 2013) and the basement of the Hronicum consists of rocks of the Northern Veporicum.

Slovenský raj Mountains

In the Slovenský raj region, the geological structure is characterised by the Stratená Group of the Silicic tectonic unit (Mello et al., 2000). The stratigraphic range extends from the Lower to the Middle Triassic, with the Wetterstein Limestones making up most of the surface (see Mello et al., 2000; Geological Map of Slovak Republic, 2013).

Galmus Mountains

The Galmus area in the study region borders the northern edge of the Gemeric belt (Vass et al., 1988). Its rock composition consists of Middle Triassic carbonates of the Silicicum, Paleozoic rocks of the northern Gemeric cover sequences, and Paleozoic sedimentary sequences and volcanic rocks of the Rakovec Group of the Gemericum (Mello et al., 2000; Polák et al., 1996; Bajaník et al., 1984; Geological Map of Slovak Republic, 2013).

Branisko Mountains

The Branisko Mts. (Fig. 6) is a horst structure, with the Poľanovce Fault (PF) to the west and the Šindliar Fault (ŠF) to the east. Both faults are normal faults, with a displacement of more than 500 metres on the fault surface. The ŠF has shown evidence of recent instrumental movement (Stercz et al., 2025).

Along the southern edge of the Branisko Mts., there are sequences of Paleozoic crystalline basement rocks (granites, migmatites and gneisses), which are part of the Miklušovce Complex within the Veporicum (Polák et al., 1996). Further north, the crystalline basement rocks belong to the Patria Complex (amphibolites, migmatites and granites), and are alternatively classified as part of the Tatricum or the Veporicum. Paleozoic sedimentary rocks (arkoses, breccias and conglomerates) have likewise been assigned to both the Veporicum and the Tatricum (the Brusno and Korytné formations).

Other Carboniferous and Permian sedimentary and volcanic rocks form part of the Ipoltica Group and are classified as belonging to the Hronicum. Mesozoic sedimentary sequences are tectonically classified as either Veporicum or Tatricum, although an alternative interpretation is sometimes presented (Polák et al., 1996). In contrast, the Middle to Upper Triassic dolomites and the rare occurrences of the Gutenstein Limestone along the northern margin of the Branisko Mountains have consistently been assigned to the Hronicum (Polák et al., 1996; Geological Map of Slovak Republic, 2013). The overview of the geological structure indicates that the tectonic affiliation of some rock complexes remains uncertain, with alternative assignments to either the Tatricum or the Veporicum. Moreover, these interpretations do not fully correspond to the generally accepted tectonic superposition of the Alpine tectonic units. The tectonic attribution of the rock complexes assigned to the Hronicum is likewise opened to question.

The rock complexes in the Branisko Mountains are generally dipping northwards (Polák et al., 1996). In this configuration, the Miklušovce Complex (classified as Veporicum) would dip beneath the Patria Complex (classified as either Tatricum or Veporicum). This would imply that the Tatricum is in tectonic superposition above the Veporicum. In this configuration, neither the Paleozoic-Mesozoic sedimentary rocks nor the rocks of the Patria Complex can be considered part of the Tatricum.

A similar situation occurs west of the village of Šindliar, where the Hronic sedimentary rocks (Gutenstein limestone) occur in a tectonic position above the Tatric and Veporic sedimentary complexes (Lúžna Formation). The occurrence of the Hronicum directly above the Tatricum, in the absence of the Veporicum and/or Fatricum, would constitute an exceptional tectonic configuration within the IWECA region. Therefore, both the Miklušovce and Patria complexes, together with their Paleozoic and Mesozoic sedimentary cover, more likely belong to the Veporicum. However, a more detailed analysis of the geological map raises fundamental questions regarding the tectonic affiliation of several Mesozoic rock formations assigned to the Hronicum. In the northern part of the Branisko Mountains, there is a significant volume of Triassic dolomites generally interpreted as the Middle Triassic Hronic dolomites. However, their description on the geological map is inconsistent. In the western part of the area, they are identified as the Ramsau Dolomite (Upper Anisian–Ladinian), whereas in the eastern part, they are described simply as grey massive dolomites (Middle–Upper Triassic). Regarding the grey massive dolomites of the Middle–Upper Triassic, which occur northwest of the Šindliar village above the Gutenstein Limestone (Anisian), the Lúžna Formation (Lower Triassic) and the Patria Crystalline Complex, there is reasonable doubt about their tectonic affiliation with the Hronicum. Their lithostratigraphy suggests a single uninterrupted sequence belonging to the Veporicum. The presence of a thrust contact between the Gutenstein Limestone and the grey dolomites, which normally form part of a continuous lithostratigraphic succession, appears highly improbable. This interpretation is further challenged by the situation along the southwestern margin of the Branisko Mts., east of the village of Dúbrava, where an analogous stratigraphic succession is exposed without a nappe boundary between the dolomites and the Gutenstein Limestones.

Additional support is provided by the SAL-7 borehole, located approximately 5 km northeast of the village of Šindliar in the valley of the Renčišovský potok creek (Haluška et al., 1995; Geological Map of Slovak Republic, 2013). The borehole penetrated the Carpathian Keuper Formation beneath the Paleogene sedimentary sequences, at depth interval between 362 and 742 m (Polák et al., 1992). The presence of the Carpathian Keuper Formation definitively excludes the occurrence of the Hronicum in the wider surroundings of the SAL-7 borehole. Therefore, if the grey dolomites dip northwards, they would have been found below the sediments of the Carpathian Keuper Formation in the SAL-7 borehole. If we consider their tectonic affiliation with the Hronicum, however, such a position is almost impossible. However, if the dolomites are part of the Veporicum, the Carpathian Keuper rocks represent a nor-

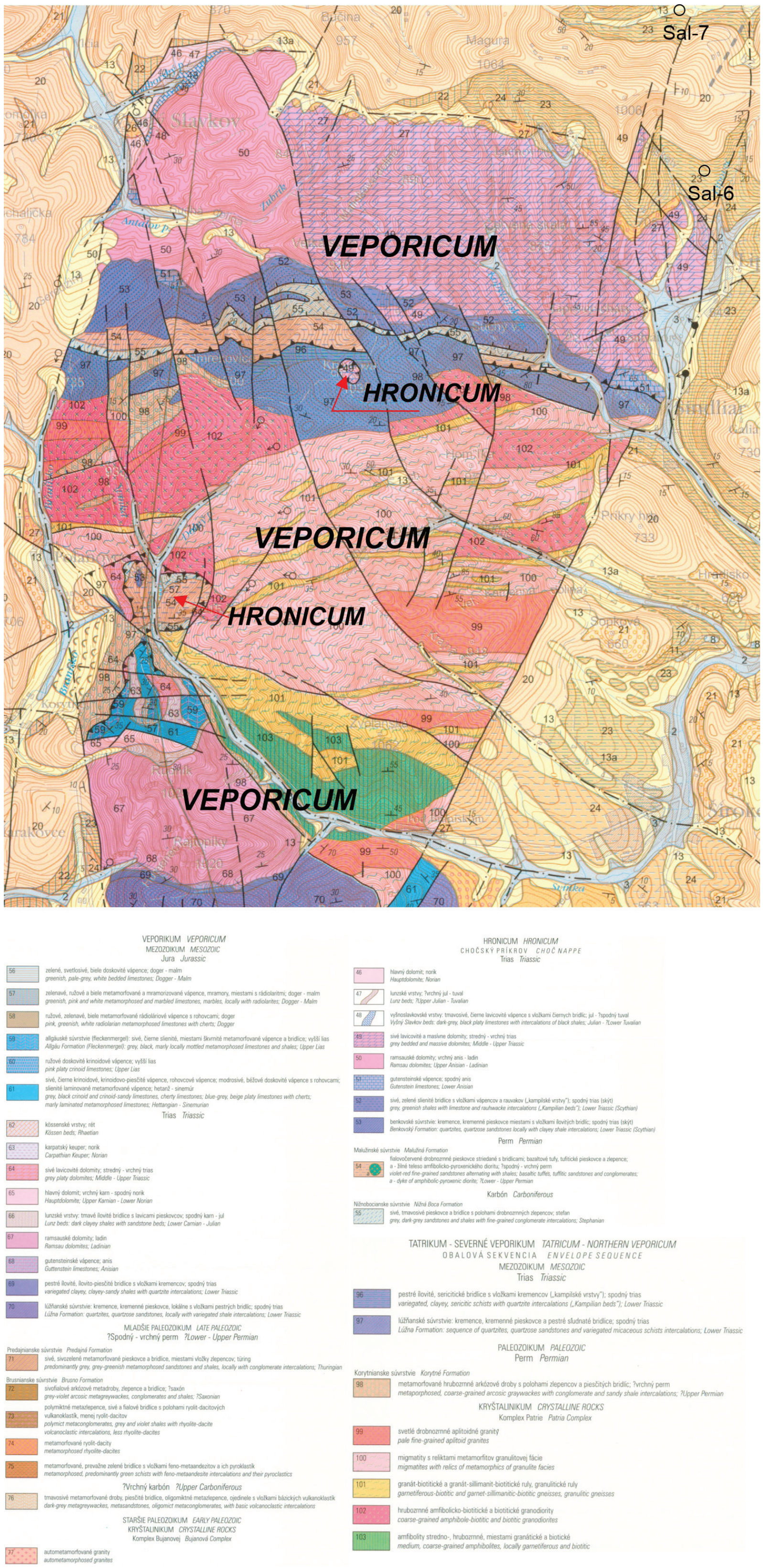

Fig. 6. A section from the geological map of Branisko and Čierna hora (Polák et al., 1996) with explanations and marking of the presumed Veporic structures.

mal continuation of the stratigraphic sequence and can be correlated with the Veporicum (Fig. 6).

Based on the analysis of the geological map and field observations, it can be assumed that north and northeast of the Branisko Mts., a tectonic unit of the Veporicum (Northern Veporicum) occurs beneath the Paleogene sedimentary sequence. Data from boreholes also support this assumption, as explained below.

Interpretation of the tectonic affiliation of pre-Cenozoic basement rocks

The Šariš-1 (Š-1) borehole (Figs. 7, 8), located approximately 10 km north of the village of Vyšný Slavkov, plays a crucial role in compiling a tectonic map of the pre-Cenozoic basement north and northeast of Branisko Mts.

The Š-1 borehole penetrated a Mesozoic stratigraphic sequence ranging from the Lower Triassic (Induan) to the Lower Cretaceous (Albian). The Lower Triassic sedimentary sequences overlie directly the crystalline basement composed of granitic rocks in the upper part and gneiss in the lowermost part of the borehole. The Mesozoic rocks were originally tectonically classified as part of the Fatricum, and the crystalline complex was considered part of the Tatricum (Koráb et al., 1986). However, upon critical review of this configuration, there is no convincing evidence to place a nappe boundary between the crystalline basement rocks and the Mesozoic sedimentary sequences, which form the autochthonous Mesozoic cover of the crystalline basement complex. Therefore, the entire pre-Cenozoic section of the borehole, including the crystalline basement complex, can be correlated with the Northern Veporicum. It should also be noted that the Mesozoic sedimentary sequences of Northern Veporicum and Fatricum are largely identical in terms of lithostratigraphy. Their tectonic affiliation is often determined by the presence of crystalline basement rocks at the base of the complex or by the arrangement of clearly defined tectonic units with their characteristic features, particularly their typical lithostratigraphic members on a broader regional scale.

Mesozoic rocks of the Veporic cover sequence also occur on the northeastern margin of the Čierna hora Mts. and have been documented in borehole SH-1, Bzenov (Cibuľka et al., 1993), SH-4, Kvačany (Cibuľka et al., 1993), BH-3, Víťaz (Frankovič et al., 1974) and boreholes ČH-10, 11, 12 of the Čierna hora series (Frankovič et al., 1981). Middle Triassic dolomites were observed beneath the Paleogene sediments, representing a continuation of the surface

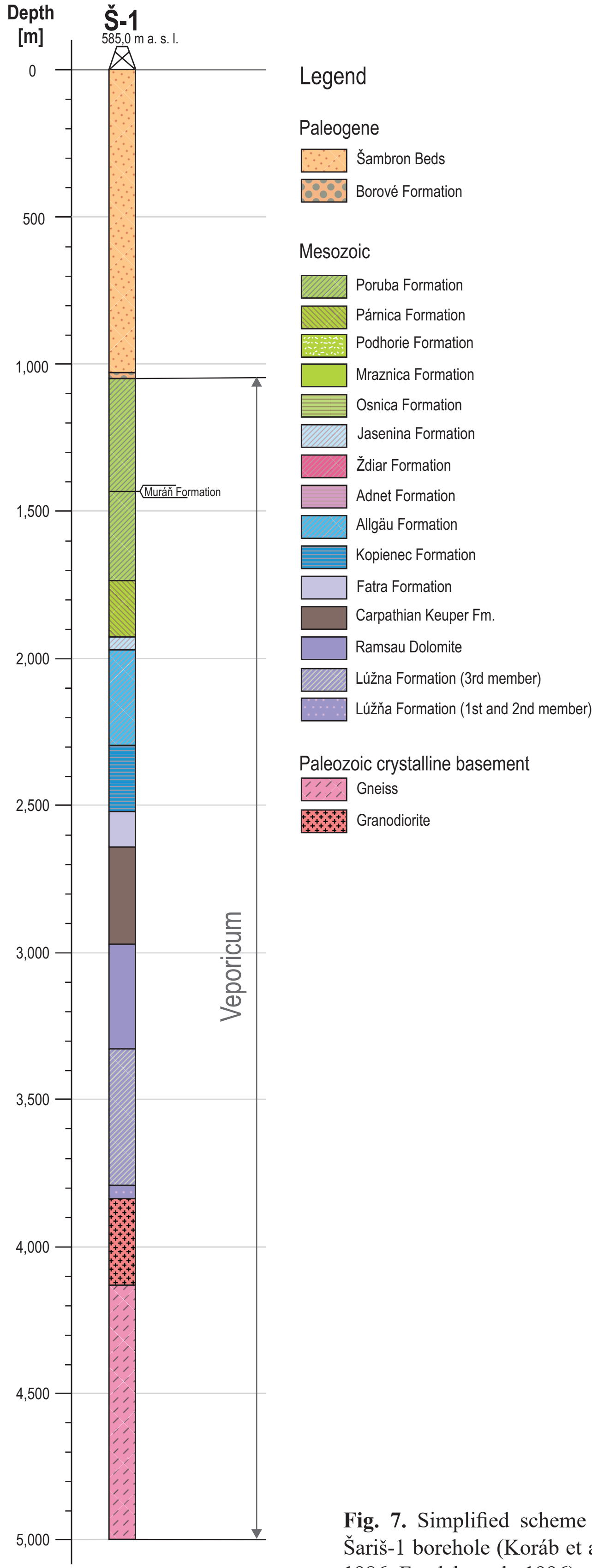

Fig. 7. Simplified scheme of Šariš-1 borehole (Koráb et al., 1986; Fendek et al., 1996).

occurrences of Veporic sedimentary cover exposed on the surface. Similar results were also obtained from the P-1 (Prešov-1) borehole (Mořkovský & Filková, 1978).

The boreholes of the Lipany series (L-1, L-2, L-3, and L-5) penetrated Lower Jurassic rocks, Norian Carpathian Keuper Formation, and Middle Triassic dolomite beneath the Paleogene sedimentary sequences (Leško et al., 1982; Rudinec, 1992). In the tectonic map of the pre-Cenozoic basement (Fusán et al., 1987), these rock complexes are assigned to the Fatricum together with the rocks in borehole Š-1. At the same time, the area between Branisko Mts. in the west and Čierna hora Mts., in the south, is classified within the Tatricum (Fusán et al., 1987).

As already mentioned in the case of pre-Cenozoic rocks in borehole Š-1, the presence of the Tatricum is unacceptable, like the situation in Branisko Mts. and, to some extent, in the northeastern Tatry Mts. (Fig. 8). In this case, the Mesozoic sedimentary sequences in the borehole profiles of the Lipany and Plavnica series have been correctly assigned to the Fatricum (Kullmanová & Rudinec, 1988). Although their stratigraphic range is reduced, they contain Carpathian Keuper Formation in a continuous lithostratigraphic sequence and are clearly tectonically separated from their crystalline basement (cf. Leško et al., 1979; Leško et al., 1982). The interpretation that the boreholes penetrate the Hronicum (Gross et al.,

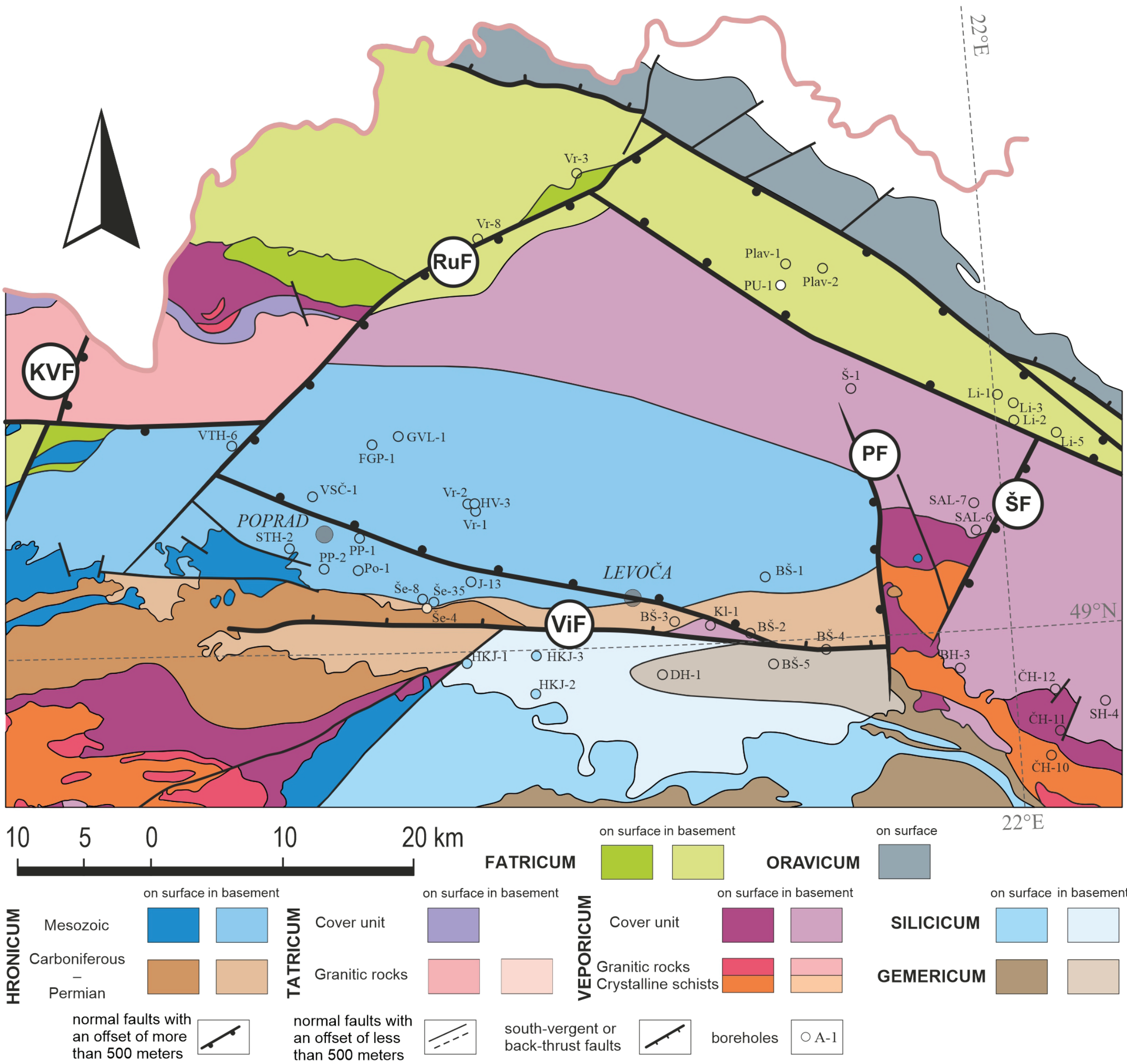

Fig. 8. Tectonic map of the pre-Cenozoic basement. KVF – Kôprová dolina Valley Fault; RuF – Ružbachy Fault; ViF – Vikartovce Fault; PF – Poľanovce Fault; ŠF – Šindliar Fault.

1999) cannot be accepted for several reasons. Similar sedimentary rock complexes occur on the surface in the Humenské vrchy Mts., southeast of the studied area, where they are likewise assigned to the Fatricum (Žec et al., 1997).

At the northern margin of the Gemeric region (Galmus and Slovenský raj, Fig. 2), south-vergent reverse faults (back-thrusts) were documented in borehole BŠ-4 (Haluška, 1993; Vozárová, 1995). The borehole is in the vicinity of the eastern continuation of the Vikartovce Fault (ViF), the tectonic transport is interpreted to have been directed southwards (Marko et al., 2022), although its current tectonic activity should be regarded as normal fault (Vojtko et al., 2011). The pre-Cenozoic basement in the central part of the studied area contains Mesozoic formations of the Hronicum. These formations were documented in boreholes in the Vrbov area (HV-3, Vr-1, Vr-2), Veľká Lomnica (GVL-1), Stará Lesná (FGP-1), Veľký Slavkov (VSČ-1) (Fendek et al., 1996; Pereszlényi in Daniel et al., 1998; Halás et al., 2008).

Discussion

Classifying the rock complexes in the pre-Cenozoic basement is closely linked to the arrangement of the formations exposed at the surface. When interpretating the pre-Cenozoic basement in the area of the Sub-Tatra Group in north-eastern Slovakia, two problematic areas were identified. In the eastern part of the Tatry Mts. (west of the Kôprová dolina fault, Fig. 4), the original classification of the crystalline basement thrust sheets, together with their Mesozoic cover, in the area between the Javorinka Valley and the Bielovodská dolina Valley as part of the Tatricum is largely arbitrary (Nemčok et al., 1994). The Mesozoic sedimentary sequence is divided here without justification. The outliers of the crystalline complex, together with the Lúžňa Formation, at the Široká (2,210 m a.s.l.) and Horvátov vrch (1,902 m a.s.l.) are depicted correctly. However, in the case of the third, structurally highest thrust sheet between Horvátov vrch Hill and the elevation point 1,674 m a.s.l., the sedimentary sequence normally continues with Middle Triassic carbonates, which may form a normal sedimentary sequence with an overlying Jurassic and Cretaceous formation originally considered to be the Fatric Havran partial nappe. A similar situation is also found further east on the southern slope of the Hlúpy hill (2,061 m a.s.l.). In this work, we consider repeated sequences composed of granite and Mesozoic sedimentary cover overlying the rocks of the Tatric tectonic unit to be part of the Veporicum.

Such an alternative interpretation may be considered unconventional or speculative and raises a nomenclatural problem regarding tectonic classification. Mesozoic rock complexes representing the hangingwall of the Tatricum are traditionally classified as Fatricum (Andrusov & Samuel, 1983), in the past also referred to as the Krížna nappe (Maheľ, 1986) or the Lower Sub-Tatra nappe (Andrusov, 1936).

The Tatricum in the Nízke Tatry and the Tribeč Mts., (Biely et al., 1992; Ivanička et al., 1998) occurs beneath a crystalline complex that is considered to represent Veporicum. Overlying this crystalline basement complex is a second crystalline basement unit, which includes subautochthonous Mesozoic sedimentary sequences ranging from the Lower Triassic to the Lower Cretaceous. A crystalline basement complexes beneath the Mesozoic cover are also present in the Starohorské vrchy Mts. (Polák et al., 2003), Žiar Mts. (Kováčik et al., 2015), and in the Tatry Mts. (Nemčok et al., 1993). Although, their tectonic origin is undoubtedly Veporic, problem arises with the correct tectonic affiliation.

The Fatricum is therefore considered to be a heterogeneous cover nappe consisting of the Vysoká and Zliechov facies. These facies are composed of Mesozoic lithostratigraphic units that have been tectonically detached from their original Variscan crystalline basement. They have also been displaced over a distance several orders of magnitude greater than their vertical thickness. In the eastern part of the Tatry Mts., the Veporic tectonic unit (Havran structure) can be interpreted. The Bujačí structure, which was previously considered a partial nappe of the Fatricum, can now be interpreted as part of the Fatricum cover nappe itself.

The rock complexes in the Branisko Mts. belong to the Veporicum. Crystalline basement rocks, as well as Paleozoic and Mesozoic sediments from the Branisko and Čierna hora regions, undoubtedly extend southeastwards into the pre-Cenozoic basement of the East Slovak Basin.

Conclusions

The area in the north-eastern part of the Internal Western Carpathians is largely covered by Paleogene sedimentary sequences of the Sub-Tatra Group (Figs. 1, 3 and 8). Based on a re-evaluation of surface geology, borehole data, geophysical evidence and structural relationships, the pre-Cenozoic basement of the study area is interpreted as comprising the Fatricum, Veporicum and Hronicum (see Fig. 8). Alternative interpretations are based on a critical review of published geological maps. They represent a different view of the crystalline basement and its cover in the Šariš-1 borehole (Fig. 7), as well as the structure of the crystalline basement duplexes in the eastern Tatry Mts. and Branisko Mts.

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Predkenozoické podložie severovýchodnej časti interných Západných Karpát z perspektívy geologickej stavby Tatier a Braniska

Oblasť medzi Tatrami a pohorím Branisko, ktorú zo severovýchodu ohraničujú povrchové výskyty oravika a na juhu vikartovský chrbát, Slovenský raj a pohorie Galmus, predstavuje plošne najrozsiahlejšiu oblasť s výskytom sedimentov podtatranskej skupiny (*sensu* Gross et al., 1984; Gross, 2008) v interných Západných Karpatoch (obr. 1 a 3). Tektonické pomery predkenozoického podložia zhodnotili Fusán et al. (1987).

Na základe podrobnej analýzy povrchových geologických štruktúr v pohoriach Tatry a Branisko, ktorá je doplnená údajmi z vrtov a geofyzikálnymi interpretáciami, sú v práci prehodnotené existujúce poznatky o geologickej stavbe povrchových štruktúr v Tatrách a Branisku, ako aj predkenozoického podložia. Sú hodnotené hlavne z hľadiska tektonickej kategorizácie tatrických a veporických horninových komplexov.

Východná časť Tatier (Vysoké Tatry a Belianske Tatry) je zobrazená na geologickej mape Tatier v mierke 1 : 50 000 (Nemčok et al., 1994). Na geologickej stavbe sa podieľajú tektonické jednotky tatrika a fatrika. Fatrikum sa člení na príkrov Havrana a príkrov Bujačieho (Nemčok et al., 1993). V tektonickom nadloží sedimentov tatrika spočívajú v alochtónnej pozícii granity s autochtónnymi sedimentmi mezozoika, ktoré tvoria s granitmi kontinuálny litostratigrafický sled príkrovu Havrana (obr. 4 a 5). Celý spomenutý horninový komplex je možné považovať za súčasť tektonickej jednotky veporika (severného veporika, *cf.* Hók et al., 2019). Príkrov Bujačieho predstavuje alochtónny horninový súbor sedimentov mezozoika patriaci k tektonickej jednotke fatrika.

Geologická stavba pohoria Branisko je zobrazená na geologickej mape Braniska a Čiernej hory v mierke 1 : 50 000 (Polák et al., 1996). Tektonická príslušnosť horninových komplexov kryštalinika bola opísaná dvojznačne (tatrikum/veporikum), s čím súvisí aj tektonické zaradenie sedimentov mezozoika. Na základe priestorového usporiadania povrchových výskytov horninových komplexov a údajov z vrtov je možné presvedčivo preukázať, že na geologickej stavbe pohorí Branisko a Čierna hora sa podieľajú tektonické jednotky veporika (severného veporika) a hronika (obr. 6).

V rámci konštrukcie mapy predkenozoického podložia (obr. 8) boli kritickej revízii podrobené aj názory na tektonické zaradenie hornín zastihnutých vo vrte Šariš-1 (Koráb et al., 1986). Vrt Šariš-1 (Š-1) prenikol v predkenozoickom podloží (od hĺbky 1 050 m) cez kompletný vrstvový sled mezozoika v stratigrafickom rozsahu spodná krieda (alb) až spodný trias (obr. 7). Sedimenty spodného triasu ležia priamo na kryštaliniku tvorenom metamorfovanými granitmi, pod ktorými sú kryštalické bridlice (ruly). Litostratigrafický sled mezozoických sedimentov bol pôvodne tektonicky zaradený do fatrika. Kryštalinikum sa považovalo za súčasť tatrika (Koráb et al., 1986), a to aj napriek tomu, že neexistuje relevantný dôvod klásť príkrovový kontakt medzi horniny kryštalinika a sedimenty spodného triasu, ktoré spoločne s vyššími litostratigrafickými členmi tvoria autochtónny mezozoický obal kryštalinika. V danom prípade je však správne mezozoické sedimenty vo vrtoch série Lipany a Plavnica zaradiť do tektonickej jednotky fatrika (Kullmanová & Rudinec, 1988; Plašienka et al., 1998), aj keď ich stratigrafický rozsah je redukovaný, ale je jednoznačne tektonicky odlúčený od svojho kryštalinického podložia (*cf*. Leško et al., 1979). Nemôže byť akceptovaný predpoklad, že v uvedených vrtoch je prítomná tektonická jednotka hronika, ako to uvádzajú Gross et al. (1999). Z interpretovaných seizmických rezov realizovaných v oblasti vrtu Plavnica-1 (Mořkovský, 1981) je zrejmé, že kontakt mezozoických komplexov fatrika so sedimentmi bradlového pásma je sprostredkovaný výrazným poklesovým zlomom generálneho smeru SZ – JV, ukloneného smerom na JZ (obr. 8).

Pri severnom okraji gemerika (Galmus a Slovenský raj, obr. 3) boli vo vrtoch série Baldovce (Haluška, 1993) dokumentované juhovergentné presuny vo vrte BŠ-4 (Vozárová, 1995). Sú v bezprostrednej blízkosti východného pokračovania vikartovského zlomu považovaného za juhovergentný prešmyk v jeho západnej časti (Marko et al., 2022), aj keď jeho najmladšiu tektonickú aktivitu treba považovať za poklesovú (Vojtko et al., 2011). Na juhovergentný prešmyk poukazujú aj výsledky vrtu Kl-1 (Klčov-1, Gross et al., 1966), kde boli s veľkou mierou pravdepodobnosti zastihnuté súvrstvia veporika (strednotriasové dolomity, spodnotriasové kremence, permské bridlice a arkózy). V danom priestorovom usporiadaní a pri dokumentovaných juhovergentných vrásach v sedimentoch mezozoika Braniska (Polák, 1987), ako aj vo vrte BŠ-4 (Vozárová, 1995), sa alternatíva spätného, juhovergentného násunu javí ako najprijateľnejšia.

Centrálna časť územia (oblasť spišsko-šarišského paleogénu, sensu Vass et al., 1988) bola interpretovaná (obr. 8) hlavne na základe vrtov v oblasti Vrbova (HV-3, Vr-1, Vr-2), Veľkej Lomnice (GVL-1), Starej Lesnej (FGP-1) a Veľkého Slavkova (VSČ-1) a na základe interpretovaných seizmických rezov (Pereszlényi in Daniel et al., 1998).

Možno konštatovať, že predkenozoické podložie v severovýchodnej časti interných Západných Karpát tvoria tektonické jednotky veporika, fatrika a hronika (obr. 8). Nová interpretácia je ovplyvnená odlišným pohľadom na kryštalinické horniny a ich autochtónny mezozoický obal (Šariš-1, obr. 7), ako aj reinterpretáciou tektonického zaradenia horninových súborov vo východnej časti Tatier a v pohorí Branisko (obr. 4 a 6).

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