Mineralia Slovaca, Web ISSN 1338-3523, ISSN 0369-2086, https://doi.org/10.56623/ms.2024.56.1.3
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Geological structure of the Strelnica massif (Muráň Plateau, Central Slovakia) based on new biostratigraphical data and geological mapping

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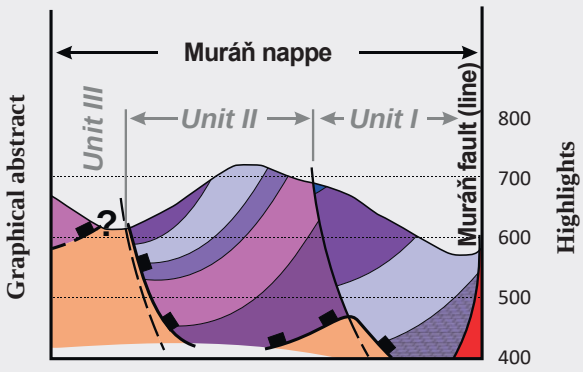
Abstract: The Strelnica massif is a part of the Muráň Plateau near Tisovec town. The massif is of prolonged triangular shape and is sharply defined by faults from all sides: the Muráň fault (line) on the SE side, the Mýto-Tisovec fault system from the SW side and a thrust/fault line with unclear character in the Martinová valley on the N side. The massif was supposed to be built by Lower to Middle Triassic carbonate complexes, however our new biostratigraphic data had proven that in fact most of these light grey carbonates belong mostly to Upper Triassic, which makes necessary the reinterpretation of the structure of the whole massif. Despite of new and more complicated structural interpretation, our new age data are in better agreement with earlier works from the Tisovec quarry as it was in earlier geological maps.
Our mapping works also confirmed, that the Strelnica massif itself is built by two facially very different blocks: a deep-water type of succession with Reifling and Raming type limestones and a strongly tectonically reduced succesion from probably lower Carnian up to Liassic age. These two blocks are in tectonic contact along a fault line and both are lying on the Lower Triassic shaley complex which forms the basal horizon of the Muráň nappe. The Muráň fault (line) is covered by Quaternary deposits in the aera, but in addition we suppose also at least two newer fault systems: a NNW-SSE normal fault system, parallel with the Mýto-Tisovec fault system in the Rimava valley and a roughly WNW-ESE system with probable sinistral strike-slip kinematics. Both systems were locally known from the Tisovec quarry, or the structural measurements from the Dielik cave in the NE part of the massif, however not mapped in the whole massif.

Key words: Strelnica massif, Muráň Plateau, Triassic, biostratigraphy

Graphical abstract



Highlights

- Based on new biostratigraphic data as well as geological mapping we suppose, that the Strelnica massif is built by two lithologically different Triassic succesions, which are in tectonic contact with their underlying Lower Triassic basal formation. One of these sequences (unit I) is built by a reduced Upper Triassic carbonatic reef/lagunar strata (Tisovec and Dachstein limestones with rare Jurassic remnants), while the other (unit II) is of deep-water to slope facies (Reifling and Raming-type limestones). Unit III occurs in neighbouring Šarkanica massif, which shows a typical Lower Triassic to Ladinian strata of a carbonate platform.
- The contact between these blocks is along thrust/shear zones subparallel with the Muráň fault (line). Moreover we also detected two younger fault system: one NNW-SSE normal fault system parallel with the Mýto-Tisovec fault system and a roughly WNW-ESE slightly oblique, probably strike-slip fault system.

Introduction

The Strelnica massif is located in the SW part of the Muráň Plateau, NE of the Tisovec town. The massif forms a roughly elongated triangular mountain range sharply bordered by faults from each side. From the SE it is the Muráň fault (line) covered by Quaternary sediments of the Skalička and Paseky valleys, from the N side the massif is cut by the Martinová valley, which separates the Strelnica massif from the Šarkanica massif and finally the valley of the Rimava river, situated on the Mýto-Tisovec fault zone (Fig. 1). Our geological mapping, biostratigraphic and structural evaluation of the Muráň Plateau was realized in the framework of the projects of the Ministry of Environment of the Slovak Republic Nos. 16 06 and 17 13 (2010–2020): Update of the geological structure of problematic areas of the Slovak Republic by new maps at a scale of 1 : 50 000 (Kronome et al., 2019).

In the area of the Muráň Plateau, the works of Foetterle (1867, 1868 in Bystrický, 1959b) were the only source on the geological structure until the works of Zoubek (1932) and Andrusov (1935a, b). After World War II, a research team led by Pouba has mapped the central part of the Muráň Plateau (Pouba, 1951). Bystrický continued this work and presented modern comprehensive understanding of the geology of the Muráň Plateau. His geological maps (Bystrický, 1959 a, b) summarized the results of mapping carried out between 1956 and 1958. These maps were later integrated in a slightly modified and simplified version into the 1 : 50 000 scale Geological map of the Slovenské rudohorie and the Nízke Tatry Mts. (Klinec, 1976), which is the only comprehensive geological map of the area to date. In this map, the Strelnica massif appears as a relatively simple unit, composed mainly of Middle Triassic Gutenstein and Steinalm formations, with the exception of the Tisovec quarry, where Upper Triassic ages were already known at that time.

Another issue is the presence of two nappe structures – lower and upper – within the Muráň nappe, where the "lower" is supposed to be deep-water and the "upper" is shallow-water carbonate platform in character (Havrila, 1997). Our geological mapping (Kronome et al., 2019) confirmed the existence of at least two thrust structures, but the tectonic structure of the Muráň Plateau is more complex and the "lower thrust – deep-water vs. upper thrust – shallow-water" scheme may not be valid everywhere. Most recently Hók and Olšavský (2023) assigned the lower Muráň nappe into the Hronicum as its uppermost subunit – Vernaricum, but it should be noted, that the upper nappe also has numerous differences from the "classic" Silicicum, as well, as many similarities with the Hronicum, so its position is also unclear (Kronome et al., l.c.).

Problems of the Upper Triassic strata

Since one of our most important results is the presence of Carnian / Norian limestones in the massif of Strelnica, we need to look in detail at the issue of Upper Triassic limestones. Above the Wetterstein Fm. limestones / dolomites, or Hauptdolomites, respectively, in the Western

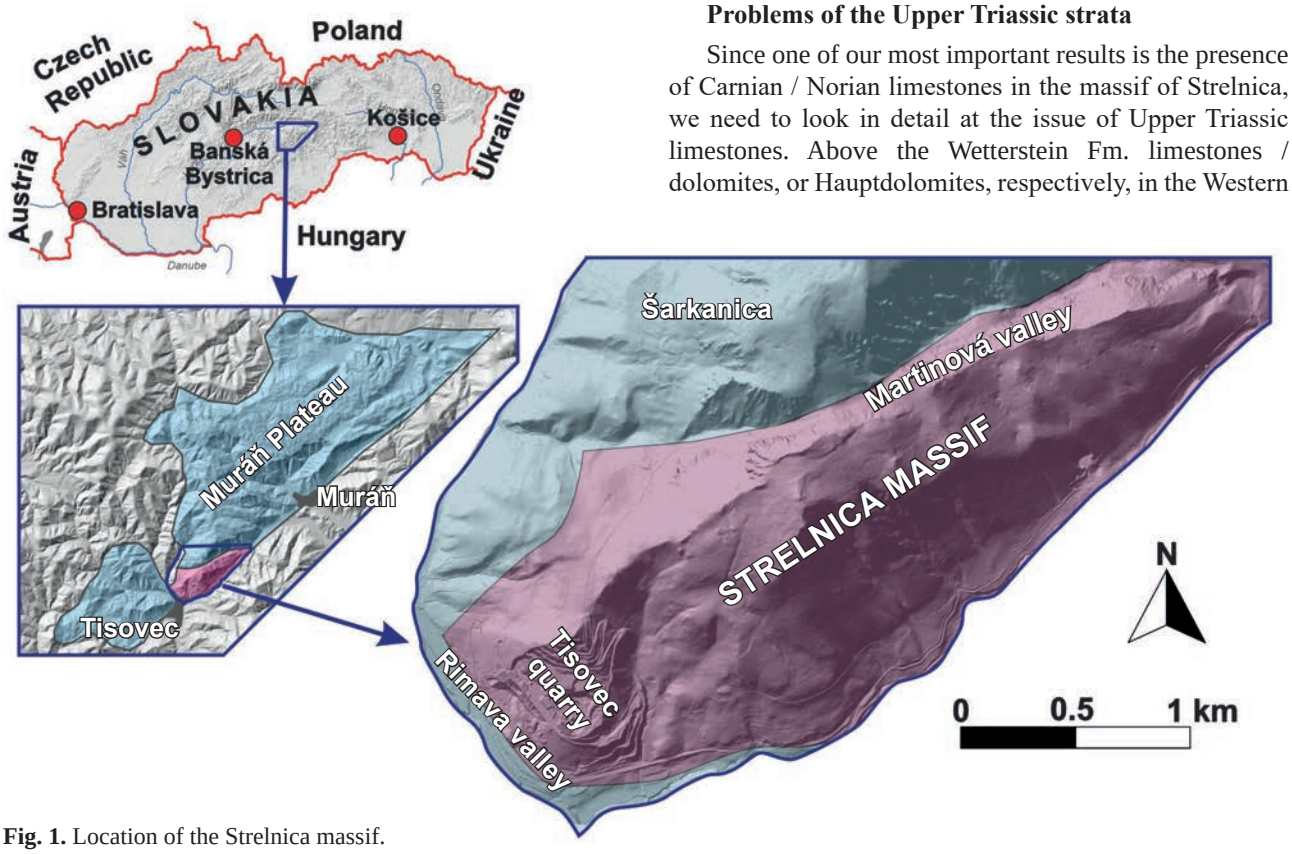


Fig. 1. Location of the Strelnica massif.

Carpathians an Upper Triassic complex of light to grey organodetritic limestones follows, the naming of which was (and is) problematic. It has long been known that both Carnian and Norian members are present in the strata, and distinguishing them during the field works is virtually impossible. The problem is, that these Carnian carbonates are of shallow-water to reef facies, where important leading fossils are rare, so although their age is clearly Carnian, their precise biostratigraphy is uncertain, without detailed zonation. Already in these first stratigraphic schemes, the authors encountered the problem of the Upper Triassic assemblages, which Pouba (1951) called "Carnian Wetterstein limestones", and Bystrický (1959a, b) describes them only as "light limestones", while he calls the similar Norian light limestones "light and grey thick bedded limestones with megalodonts (Dachstein limestones)". While in the Alps for the Carnian part of these Upper Triassic limestones the terms "Oponitz reef limestone" (Kristan-Tollmann, 1958 in Andrusovová et al., 1989) or "Carnian Dachstein limestone" (Lein and Zapfe, 1972 in Andrusovová et al., 1989) and for the Norian to Rhaetian part the term "Dachstein limestones" (Krystyn et al., 1990) was used, in Slovakia for the Carnian limestones the term "Tisovec limestones" and for the Norian ones the term "Furmanec limestones" were introduced by Kollárová-Andrusovová (1960). However, as both Austrian and Slovak authors pointed out, the main differences are in the facies development: while the "Tisovec" limestones are rather lagoonal, the "Furmanec" limestones represent a reef environment, where both could have existed simultaneously.

The situation is moreover complicated by the fact that intensive mining in the last six decades removed parts of the quarry in which the "Tisovec" limestones were originally defined. Krystyn et al. (1990), when reinterpreting archival material taken by Bystrický during mapping in the late 1950s and published by Kollárová-Andrusovová (1962) and comparing them with conodont samples found that the Carnian ages assigned to the Tisovec limestones are somewhat younger, however, today, after three more decades even the sampling localities of Krystyn and his colleagues are missing. Later, Slovak authors also agreed, that the term "Tisovec limestone" is unsatisfactory due to the lack of a precise lithological and lithofacies definition, while for the similar Norian they keep the term Furmanec limestones (Andrusovová et al., 1989). Krystyn et al. (1990) proposed the term "Waxeneck Limestone" for similar Carnian limestones because of its better defined type profile at the Kleine Waxeneck locality in Austria. On the other hand, Soták, on the basis of his study of the Tisovec quarry, expressed that the use of the term "Tisovec limestone" is well established and only its redefinition is needed, based on a new basic stratotype (Soták, 1990). We, aware of the aforementioned problems of nomenclature, will use in this paper the term "Tisovec limestones" for the Carnian and "Dachstein limestones" for the Norian part of this assemblage.

Lithological strata of the Strelnica massif

The Strelnica massif, as a part of the Muráň nappe is overthrust on the Veporic unit, even if this nappe contact is less visible along the Muráň fault (line) because of thick Quaternary cover. However along the Skalička valley from the saddle Dielik to town Tisovec the Upper Triassic parts of the Muráň nappe are lying directly on a Lower Triassic shaley complex, evidently belonging also to the Muráň nappe – thus we see a large hiatus from Lower Triassic up to Lower Carnian. In the Martinová valley the situation is similar. For our final geological map see Fig. 2.

Veporicum

The Veporic Unit is of smaller importance from our point of view, it is represented by the usually tectonically reworked porphyric granitoids of the Kráľova hoľa Complex in the western part of the area north of Tisovec town and exceptionally were also found in the lower part of the wide valley between the Strelnica and Čremošná massifs. They are followed by the Föderata-type cover sequence, built primarily by Lower Triassic quartzites. Higher parts of the cover sequence, as we know them in other places as the Strundžaník and Klátov grúň hills, Hrdzavá valley etc. are preserved only as fragments incorporated in the thick complex of rauhwackes.

Rauhwackes

A massive range of rauhwackes, or rauhwackized members of both the Föderata cover and the Muráň nappe stretches along the western edge of the Šarkanica massif, i.e. in the zone where we assume normal nappe contact. In this rauhwacke belt we made a distinction between parts generated from only Föderata rocks and assigned them to Veporicum as its tectonically reworked cover, and the "real" rauhwackes indicating the overthrust of the Muráň nappe.

The Muráň nappe

The contact of the Muráň nappe with the underlying Veporicum on the western side of the Muráň Plateau is a nappe overthrust. In the area W of the Šarkanica massif this contact seems to be normal, and on the Lower Triassic strata the Gutenstein, Steinalm etc. formations follow. From a wide valley between the Čremošná and Strelnica massifs to the NE the situation gets more complicated, because there is a quite huge tectonic hiatus between the Lower Triassic strata and its younger (mostly Upper Triassic) overlying sequence.

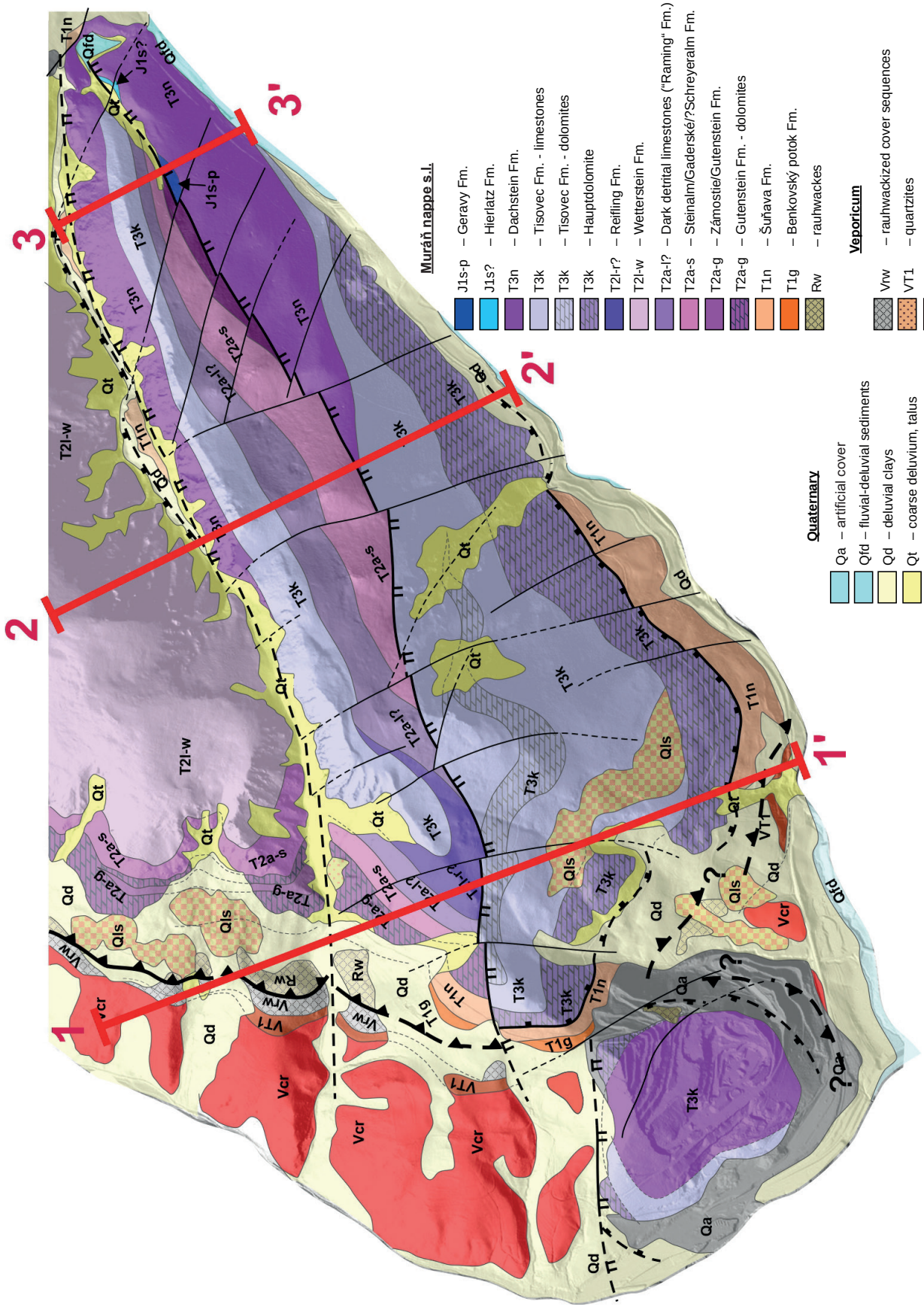


Fig. 2. Geological map of the Strelnica massif (based on Kronome et al., 2019, strongly modified).

Fig. 3. Legend to the geological map, structural scheme and cross sections.

The internal structure of the Strelnica massif is composed of – at least – two lithologically very different elongated blocks with a thrurt / shear(?) zone between them. We provisionally distinguished them as "unit I" and "unit II", where "unit III" is the part of the Muráň Plateau north of the Martinová valley beginning with the Šarkanica massif, already out of our study area with a normal, tectonically not disturbed structure (Fig. 2). For the location of our biostratigraphic samples with added earlier data see the Fig. 3.

Benkovský potok and Šuňava Fm. – Lower Triassic

Since the Muráň nappe shows many lithological similarities with both the Hronic and Silicic nappe systems, as we already discussed in the final report of our mapping project (Kronome et al., 2019), we consider at least the "lower Muráň nappe" to be a part the Vernár nappe / Vernaricum, which, according to the structural concept of Hók and Olšavský (2023) represents the uppermost subunit of the Hronicum. For that reason in the naming of the Lower Triassic formations we will use the "Hronic terminology" (Benkovský potok and Šuňava fms.) instead of the usual "Silicic" terms (Bódvaszilas and Szin fms.).

In the study area the lower Benkovský potok Fm. is relatively rarely preserved, mostly in the NW part of the nappe contact zone with the Veporicum and along the rauhwacke horizon. In contrary the younger Šuňava Formation is present in huge volumes practically along the whole basal zone of the Muráň nappe. The formation is built by the usual Lower Triassic rock types: reddish-yellowish to light greenish fine-grained sandy shales.

Their contact to the underlying Veporicum – where it is visible at all – is clearly a nappe overthrust with a well developed rauhwacke zone, however the overlying Muráň nappe sequences differs in all units. Interestingly, never was a rauhwacke horizon detected between the Lower Triassic basal part and the Upper Triassic strata above it, neither in the S slopes of the massif, nor in the Martinová valley, so the character of their contact is not clear. Based on the mining report from the Tisovec quarry (Hruškovič et al., 1990) the situation there is similar: below Middle / Upper Triassic carbonates a tectonically reworked layer of Lower Triassic was proven by all drills, but the thickness of the formation is unknown. Based on the SW part of the Strelnica massif and the W slopes of the Šarkanica it is probably not thicker than 100 m, however the rheological

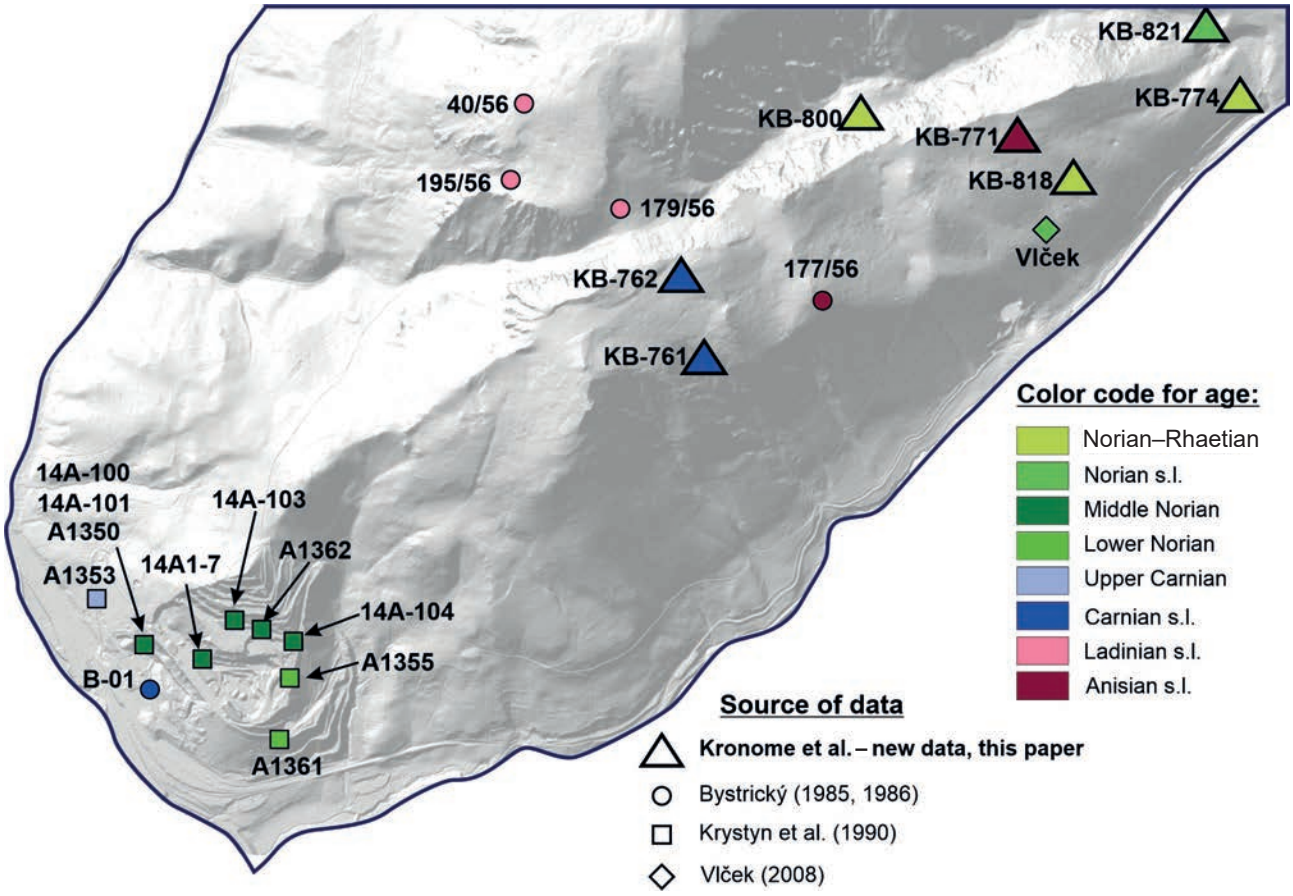


Fig. 3. Location, source and age data of positive samples, compiled from our data (this paper), Krystyn et al. (1990) and Bystrický (1985, 1986).

character of that shaley complex enables high variability in its thickness, as we can see in other places in the Muráň Plateau (Hrdzavá valley, Sitárka etc.).

Gutenstein Fm. – Anisian (Aegean–Bythinian)

The Gutenstein Formation is built by dark grey to black bituminose limestones and dolomites and is present in units II and III. In the unit III they occur as a member of a normal stratigraphic sequence of the Muráň nappe (Šarkanica and further to the north of it), where the dolomite types are unusually abundant for the Muráň nappe. The second occurrence is in the unit II, in a narrow strip in the NE part of the massif. In this locality they are mixed with debris of other dark limestone types (Zámostie and Raming type detritic limestones), so the contours of that body and their relation to the underlying Lower Triassic are unclear.

Steinalm Fm. – Anisian (lower and middle Pelsonian)

The Steinalm limestones, as well as the Gutenstein Fm. occur in two units: the unit III on the W slopes of the Šarkanica and in the unit II in two positions: along with the strip of Gutenstein Fm. in the NW part of the Strelnica massif, and as a stripe parallel with the Gutenstein limestones in the NE part of the massif, in both places as the formation overlying the Gutenstein Fm. In the second locality of the unit II the presence of the Steinalm limestones is proven by microfauna from our samples and also by dasycladal algae (Bystrický, 1985, 1986, doc. point 177/56, age: Pelsonian–Illyrian). The precise shape of the stripe is unclear for the same reason as in the case of the Gutenstein limestones: extensive talus cover of very different carbonates from both sides of the supposed thrust plane.

Dark detrital limestones – Zámostie Fm. (upper Pelsonian) / Raming Fm. (lower Carnian)

From the upper Pelsonian stage the stratigraphic sequences of the III and II units begin strongly differ (the unit I begins as late as in the Carnian with no preserved Middle Triassic members). While the unit III strata (Šarkanica and further to the north) represents the "classical" evolution of the Wetterstein carbonate platform, in the unit II the deep water / slope environment sedimentation is alternating the Wetterstein platform facies. This type of strata is usually taken as typical for the "lower Muráň nappe" (sensu Havrila, 1997) and is usually correlated with the Vernaricum.

In the unit II this type of sedimentation is starting with dark detrital limestones above the Steinalm Fm., which we can correlate with the Zámostie Fm., defined in the Choč nappe (Kochanová & Michalík, 1986) as an upper Pelsonian to Illyrian formation built by dark grey biomicritic limestones with abundant fossil relics (lower member – Jasenie Beds) and by thick layered dark grey calcarenites and crinoidal limestones (upper member, Ráztoka Beds). These beds are considered the product of the so-called (Photo 1a, b) "Reifling event" ("Reiflinger wende" sensu Schlager & Schöllnberger, 1974), which signalizes the beginning of tectonic activity in this area, corresponding with opening of the Meliatic basin. This event is manifested even in the parts of the carbonate platform with no significant tectonic disturbances in the form of breccia layers and neptunic dykes in the Steinalm Fm.

Among our samples the black organodetritic limestone (KB-771, see Kronome et al., 2019, app. 3 and 4, for the localization of the sample see Fig. 3) can be ranged into that formation containing the following Anisian foraminifera assemblage:

Frondicularia woodwardi Howchin

Nodosaria sp.

Meandrospira sp. (*Meandrospira deformata* Salaj, *?Meandrospira* cf. *cheni* Ho)

Photo 1a, b. Grey, dark grey to black organodetritic and detrital limestones from the Strelnica massif.

Agathammina austroalpina Kristan-Tollmann et Tollmann

These rocks were formerly mapped as Gutenstein Fm. limestones, but based our new age data this interpretation is incorrect.

Reifling (Partnach?) Fm. – Ladinian to Lower Carnian

In the western part of the Strelnica massif, near to the saddle between the Strelnica and Čremošná massifs smaller cliffs and rocky outcrops of grey cherty limestones were found in an oblique strip in the unit II in tectonic contact with light dolomites of the I unit (Photo 2a, b). Bedding planes show that the bed forms an assymetrical synclinal structure, eastward these limestones are gradually changing into the mentioned dark detrital limestones, however the problem with talus cover is remaining, so the precise contours of the body are unclear. Presently we have no biostratigraphic data for the age of these beds, but because of their stratigraphic position between the underlying dark biodetritic limestones and overlying light grey shallow water to reefal limestones (Tisovec Fm. – see below) we correlate this strata with the Reifling Fm. In the geological map of Klinec (1976) these limestones were also assigned to Gutenstein Fm.

Wetterstein Fm. – Ladinian

Despite the fact, that the Wetterstein Limestone are the most common lithotype in the whole Muráň Plateau they are not present neither in unit I (the succession begins with lower Carnian), nor in the unit II, where they are substituted by detrital and deep-water limestones. They build a thick strata in the unit III (Šarkanica) which is already out of the strictly taken Strelnica massif and represents a "normal" carbonate platform type of succession typical for the upper Muráň nappe. In the neighbouring Šarkanica massif Bystrický had proven their Ladinian age (1985, 1986,

Photo 2a, b. Dark grey cherty limestones.

Photo 3a. Loferitic dolomite of the Wetterstein / Hauptdolomite Fm., small quarry in the Dielik saddle.

Photo 3b. Dark grey dolomite to dolomitic limestone, small quarry in the Dielik saddle.

samples 179/56, 195/56 a 40/56, see Fig. 3) by dasycladal algae.

Wetterstein Dolomite / Hauptdolomite Fm. – upper Ladinian to lower Carnian (Tuvalian)

The thick dolomitic part of the Wetterstein Fm. in other localities of the Muráň Plateau is continuing into the Carnian, however rarely a bed of shales and fine-grained sandstones can be preserved, correlated with the Rheingraben / Lunz Fm. Dolomites above that horizon should be ranged already into the Hauptdolomite Fm., but when the shaley horizon is not present – and usually is not – we can not distinguish the lower Wetterstein part from the upper Hauptdolomite part of the strata (Photo 3a, b).

Loferitic light to darker grey dolomites build a massive bed in the SE slopes of the Strelnica massif, e.g. in the unit I. Since this dolomitic horizon is situated below the horizon of Tisovec Lmst. with proven age, we suppose, that in the SE and S slopes of the Strelnica massif they should belong to the Wetterstein / Hauptdolomite Fm., however their upper Ladinian / lower Carnian age was not documented yet. Probably the same horizon is proven by several drills in the Tisovec quarry (Hruškovič et al., 1990).

Tisovec („Waxeneck") Fm. – upper Carnian

The most dominant rocks of the Strelnica massif are light grey organodetritic limestones and dolomites (Photo 4a, b) forming the steep ridge on the northern side of the massif as well as supposedly most of its southern slopes (see Fig. 2). Since between these two belts the above mentioned Anisian and Ladinian formations are located, these two belts must be different, belonging to different tectonic blocks.

The northern belt forms a narrow ridge along the northern edge of the massif in the form of very steep cliffs to the Martinová valley on the north, but also shows a sudden morphological elevation from the southern side to the neighbouring Middle Triassic to lower Carnian formations. A sample of dark grey to black organodetritic nodular limestones with already Lower Carnian age (KB-762, see Kronome et al., 2019, app. 3 and 4) represents a transitional type to the deep-water Reifling type or detrital Raming limestones (see below):

incertae sedis: *Thaumatoporella parvovesiculifera* Raineri

foraminifera: *Trochammina almtalensis* Koehn-Zaninetti
Agathammina austroalpina Kristan-Tollmann et Tollmann
Bispiranella ovata Samuel, Salaj et Borza
Frondicularia woodwardi Howchin
Endothyra kuepperi Oberhauser

This Lower Carnian age at the stratigraphic boundary between detrital dark limestones and the overlying Tisovec limestones implies, that in the unit II the deep water / slope environment limestones were most probably formed during the whole Ladinian and Cordevolian.

We have obtained biostratigraphic data also from the southern belt, which in general does not form as impressive rock walls but builds almost the whole S and most of the SE slope of the massif.

KB 761 – light grey – grey organodetritic limestone – Carnian

foraminifera: *Bispiranella ovata* Samuel, Salaj et Borza
Aulotortus sinuosus Weynschenk
Duostomina sp.

The southern slope of the massif built by the Tisovec Fm. contains also a significant and roughly continuous stripe of light grey dolomites exposed from the saddle

Photo 4a, b. Light grey organodetritic reefal limestones of the Tisovec Fm., southern edge of the Strelnica massif.

near the tectonic contact with the Reifling Fm. further in the S-SE slopes. Good outcrops of dolomites can be found between the first cliffs on the southern edge of the massif. Since at this southern slope the bulk thickness of the Tisovec Fm. limestones and dolomites strongly exceeds their average thickness in other places, we can not exclude some hidden tectonic complications in this area. In this case the mentioned dolomitic belt in fact could belong to the stratigraphically underlying Wetterstein / Hauptdolomite strata and its presence can signify a smaller "hidden" overthurst plane, however without further age data we cannot prove this idea.

Dachstein („Furmanec") Fm. – Norian

Bystrický presented only one sample of Anisian age (Bystrický, 1985, 1986, sample 177/56) from the Strelnica massif. This only sample was probably the reason, why was the massif interpreted in former geological maps (Bystrický, 1959; Klinec, 1976) as built by Anisian limestones (the concept of former maps was roughly: light grey – Steinalm Fm., darker to black – Gutenstein Fm.) (Photo 5a).

Since Bystrický's mapping and sampling until now only one biostratigraphic age was proven by Vlček (2004) from the cave Dielik and its surroundings, who identified megalodont bivalves:

Neomegalodon complanatus Gümb.

Neomegalodon triqueter dolomiticus Frech, resp. *Neomegalodon* cf. *triqeter dolomiticus* Frech

Our samples confirmed Vlček's findings and in several localities offered Norian or Norian to Rhaetian ages (see Fig. 3).

KB 774 – light grey organodetritic limestones – Norian (Salaj et al., 1983) or Norian–Rhaetian (Gale et al., 2013)

incertae sedis: *Thaumatoporella parvovesiculifera* (Raineri)

foraminifera: *Agathammina austroalpina* Kristan–Tollmann et Tollmann

?Decapoalina schaeferae Zaninetti, Altiner, Dager et Ducret

Opthalmidium sp.,

Ostracoda div. sp.,

Tubiphytes sp.

KB 800 – light grey organodetritic limestones – Norian–Rhaetian

incertae sedis: *Thaumatoporella parvovesiculifera* (Raineri)

foraminifera: *Frondicularia woodwardi* Howchin

Aulotortus sinuosus Weynschenk

Decapoalina schaeferae Zaninetti, Altiner, Dager et Ducret

Angulodiscus sp.

Trochammina sp.

Duostomina sp.

Planiinvoluta sp.

Tubiphytes ?obscurus Maslov, resp. *Tubiphytes* sp.

KB 818 – light grey organodetritic limestones – Norian–Rhaetian

foraminifera: *Galeanella panticae* Zaninetti et Brönnimann, resp. (Photo 5b)

Opthalmidium sp.

Duostomina sp.

?Decapoalina sp.

KB 821 – light grey organodetritic limestones – probably Norian

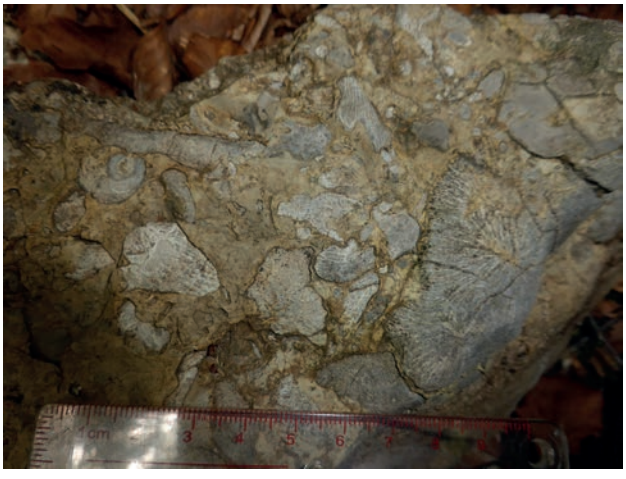


Photo 5a. Light grey reef limestone of the Dachstein Fm., SE slope of the Strelnica massif.

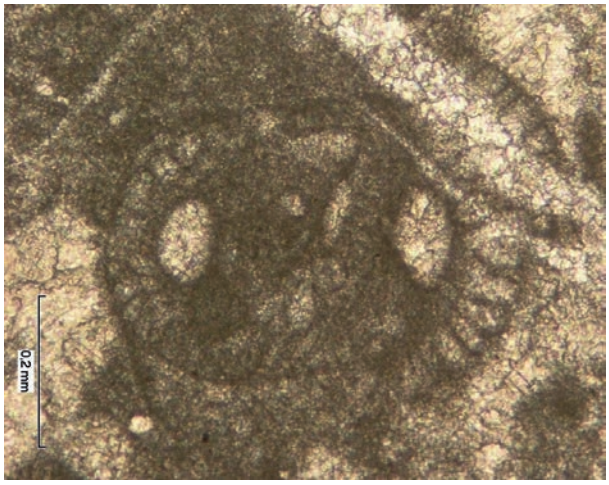


Photo 5b. Microphoto of foraminifer *Galeanella panticae,* SE slope of the Strelnica massif (sample KB-818).

Spiroloculina cf. *praecursor* Oberhauser

Photo 6a. Pinkish crinoidal limestones, NE end of the Strelnica massif, entry of the Martinová valley.

Photo 6b. Iron ore from the shear zone between units I and II, entry of the Martinová valley.

Miliopora cuvillieri Broennimann et Zaninetti

Trochammina sp.

?Hierlatz Fm. – Jurassic, ?Hettangian

At the entry of the Martinová valley in the near vicinity of the belt of Dachstein Limestones we found pinkish crinoidal limestones without identifiable fauna or flora, which we correlate with the lowermost Jurassic Hierlatz type limestones because of their lithological character and superposition above the Dachstein Limestones (Photo 6a). Rakús and Sýkora (2001) found similar limestones at the Tesná skala massif, and however the rare and crushed fauna did not provide age data, Rakús and Sýkora (l.c.) supposed Sinemurian age for them.

In that place the thrust/shear plane between the units I and II is located which is bound with iron ore mineralization, which was also mined in the past (Photo 6b). We can find here remnants of former mining activities as a small spoil tip and an entry of probably collapsed mining / exploration shaft.

Geravy Fm. – Jurassic, Pliensbachian?

The youngest lithological member of the succession of the unit I are represented by grey marly limestones and marls which were not mentioned by former authors (Photo 7a, b). Their occurrence is very limited, and similarly as the supposedly Jurassic Hierlatz Fm. limestones nearby, they occur in the close vicinity with the Dachstein Fm. limestones. Based on dating in other places, where the age of this formation was established as Pliensbachian (Rakús & Sýkora, 2001), we must propose a stratigraphic hiatus between the Dachstein and Geravy formations.

Similar Jurassic rocks are very rarely preserved in the Muráň nappe, they were observed only in the axis of the narrow synclinal structure from Javorina saddle to Mokrá

Photo 7a, b. Dark grey – grey marly limestones of the Geravy Fm. from the NE part of the Strelnica massif.

Poľana valley in the Tesná skala massif, in some enigmatic blocks at a highly situated small plane in the slopes of the Hrdzavá valley and a little different type (detritic limestones in neptunic dykes) at the Goštanová hill, north of Tisovec (Vojtko, 2000). All these occurrences are rather small and almost always bound to tectonically complicated zones, often in the vicinity of the Muráň fault (line).

The Tisovec quarry

For its importance we need to summarize the published data about geological structure and age data of the Tisovec quarry, which are in good agreement with our results. The most important works on stratigraphy of the quarry were carried out by Kollárová-Andrusovová (1960, 1961, 1962), Soták (1990) and Krystyn et al. (1990), very valuable data about the structure of the massif were provided in the mining exploration report by Hruškovič et al. (1990; Fig. 4).

However most of the biostratigraphic data originate from the Tisovec quarry, there are problems with their exact localization, mostly because of the continuing mining removed the original sampling places. Kollárová-Andrusovová identified samples collected by Bystrický in the late 1950s, and also the places sampled by Soták and Krystyn in the latest 1980s, were extracted since then. The place where Kollárová-Andrusovová (1962) defined the "Tisovec Formation" existed in 1990, when Krystyn et al. (1990) based mostly on conodonts determined their ages a little younger and thus shifting the boundary already into Norian – into the Dachstein / Furmanec Fm. In the same year Soták (1990) objected, that their samples were also not from those exact places as Kollárová-Andrusovová studied, the quarry is most probably built by both Carnian and Norian limestones, and rather than reject the term "Tisovec Fm." and substitute it with the term "Waxeneck Fm." allowing better to find a proper stratotype.

The excellent exploration report (Hruškovič et al., 1990) was not focusing on stratigraphy, rather on quality of the carbonates, the purity of limestones and the limestone / dolomite ratio, but its number of boreholes and cross sections show a structure which is in very good agreement

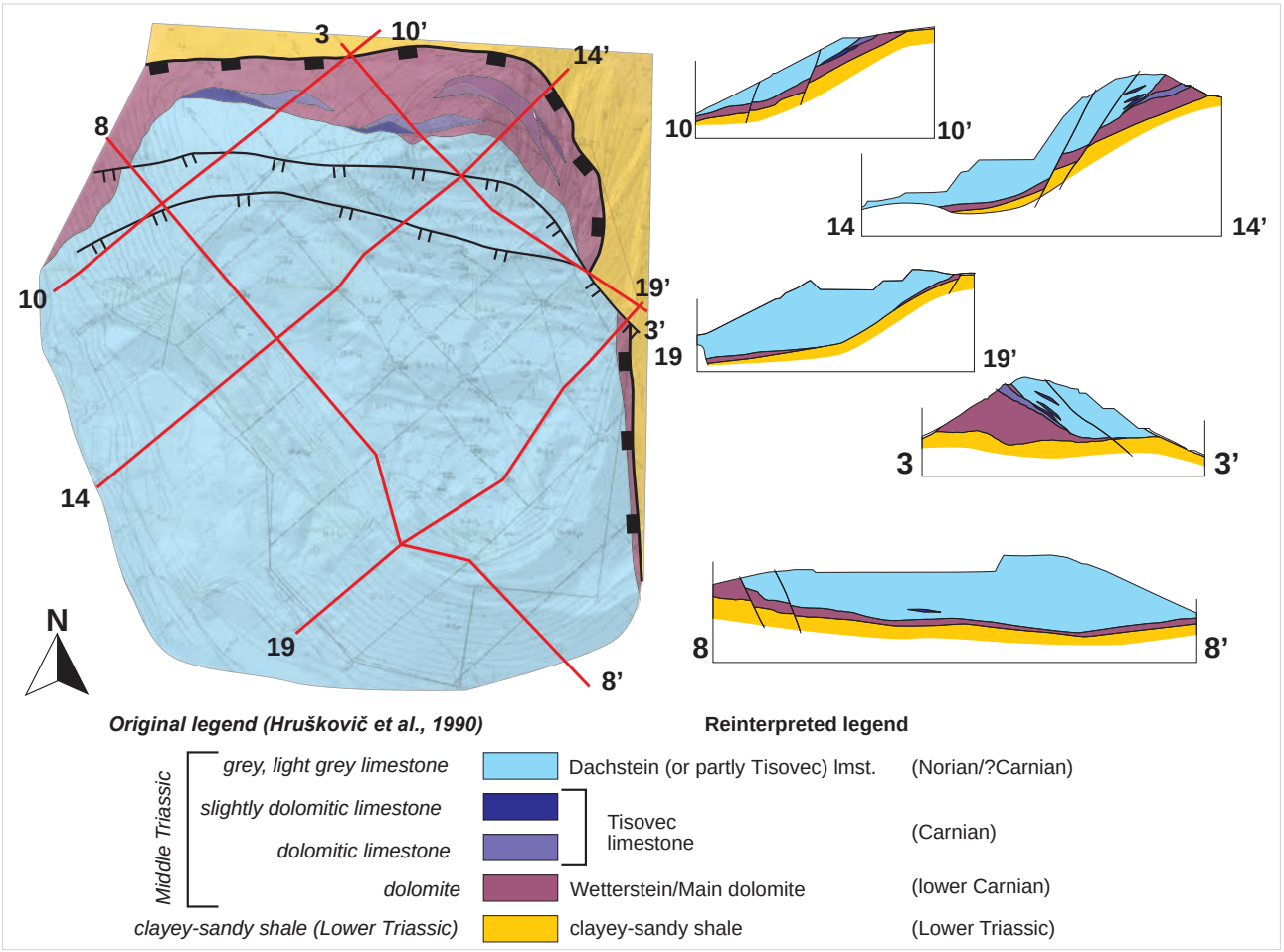


Fig. 4. Attempt to reinterpretate the exploration geological maps and cross-sections of the Tisovec quarry – based on Hruškovič et al. (1990), edited.

with our results (Fig. 4). According to these cross sections below the massive limestone complex a dolomitic horizon is present in the eastern part of the massif, thinning but not missing westward. Soták (1990) correlates these dolomites with the Wetterstein Fm., however they also can be already Carnian – e.g. belonging already to the Hauptdolomite Fm., which in other localities of the Muráň Plateau are immediately underlying Tisovec limestones (see Kronome & Boorová, 2014; Kronome et al., 2019).

Below these dolomites the same Lower Triassic shaley sequence is developed as we saw it in the SE slopes of the Strelnica massif, probably also after a tectonic hiatus (Hruškovič et al., 1990).

Structural results of the geological mapping

According to the above summarized age data together with the structural results of our mapping we suppose, that the Strelnica massif is built by (at least) two tectonically defined units with different stratigraphic succesions. As a third unit we can define the massif of Šarkanica, which is already out of the strictly taken Strelnica massif and represents a normal succession of the Muráň nappe.

The Lower Triassic "base" of all three units has a special function probably because of its ability for ductile behavior. This ductile behavior is documented in the final report on our mapping works during years 2010–2019 (Kronome et al., 2019) and is manifested by formation of duplexes, partial nappe bodies, folding and thus shows extreme variability of the thickness of the Lower Triassic strata in the whole Muráň nappe. In the W slopes of unit III (Šarkanica and further to the north) it seems to be in a stratigraphically normal position. In the Martinová valley the Wetterstein Limestone of unit III as well, as Dachstein Lmst. of unit II are both directly in contact with Lower Triassic shales and sandstones, so here the character of their contact is unclear. In the unit II the character of the relatively short contact of Lower and Middle Triassic strata in the western segment is also unclear (partly because of the talus and other deluvial sediments). In the case of unit I the contact is clearly tectonic in its entire perimeter. Similar situation was documented in the Tisovec quarry (Hruškovič et al., 1990), which we suppose to be the continuation of unit I.

We can characterize in short the three blocks or units as follows (Figs. 6 and 7):

- Unit I is built by a strongly tectonically reduced Upper Triassic to lowermost Jurassic strata, which lie discordantly directly on Lower Triassic complexes of the Muráň nappe, so the whole Middle Triassic is missing. The unit is in a long tectonic contact with the Muráň fault (line) in the NE part and further to the west it is lying together with the Lower Triassic in nappe position on the Veporic crystalline and thin cover complexes. The unit is also with sharp and probably steep fault contact with the unit II, stretching along the ridge

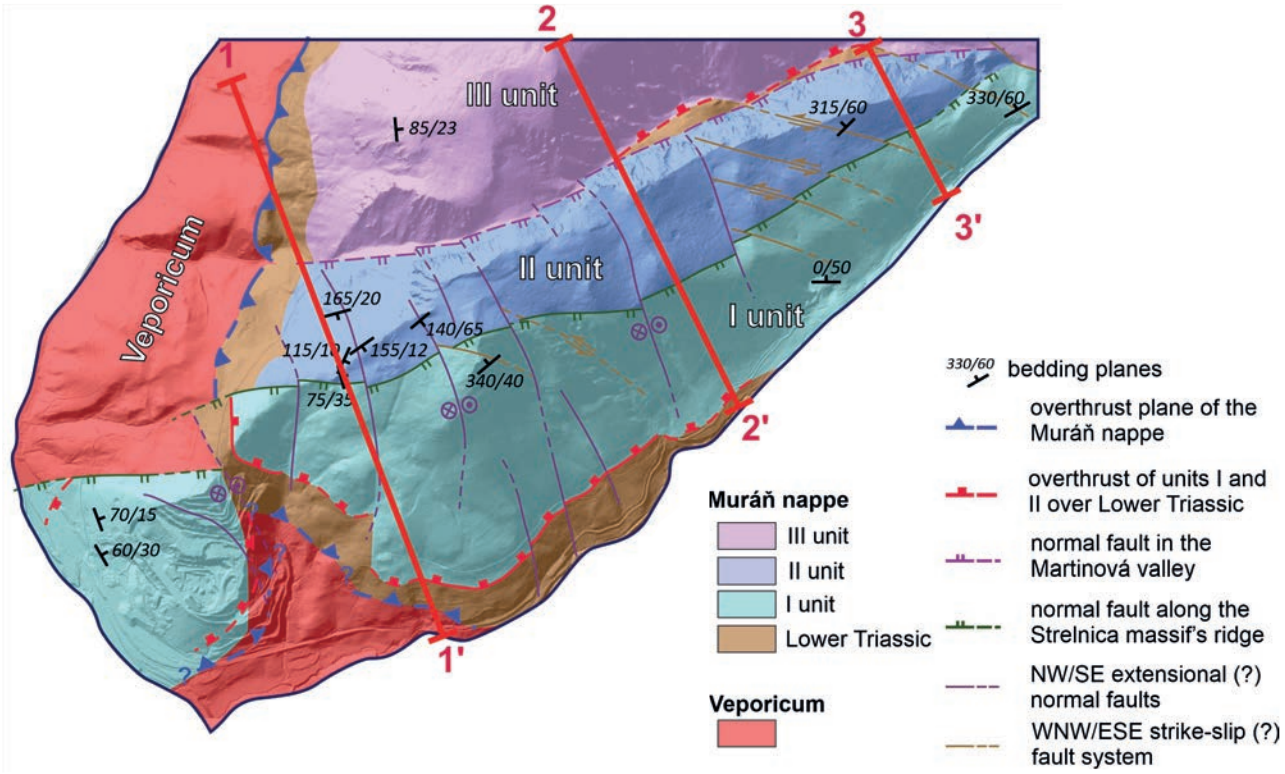


Fig. 5. Schematic structural map of main tectonic units and features.

of the Strelnica massif subparalelly with the Muráň fault (line) Based on both the stratigraphic composition and structural buildup, the Čremošná massif (e.g. Tisovec quarry) is an extension of this unit, cut from it by a roughly NW-SE normal fault and internally blocked with a set of smaller faults of the same sense, parallel with the Mýtna fault zone.

- Unit II stratigraphically represents a sequence with slope / deep water facies during the Middle Triassic and a "classic" carbonate platform facies during the Upper Triassic. This succession is very different from both I and III units, however on the western side near the W end of the Martinová valley the Middle to Upper Triassic succession seems to be in normal position without overthrusting on the Lower Triassic. In the NE part of the Strelnica massif also older Middle Triassic rocks (e.g., Gutenstein and Steinalm Fm.) are preserved, so the unit probably contains the whole Triassic strata. Moreover, in the western part a clear, but probably not too extensive synclinal structure was discovered.
- Unit III is already out of the Strelnica massif. It is contrasting with the unit II and represents a typical evolution of the upper Muráň nappe from Lower Triassic basal horizon through Gutenstein and Steinalm Fms. up to Wetterstein Fm., but no younger members are known in the area.

In addition to these main units, we have identified several structural zones with different character.

1. Overtrust planes:
   a) The main nappe overthrust plane of the Muráň nappe over the Veporicum, which is visible only in the western part of the area.
   b) A partial overthrust zone between the Lower Triassic strata and its overlying complexes, affecting unit I, at least partially also unit II.
2. Steep NE-SW trending faults:
   a) The most important fault structure in the area is the Muráň fault (line), even it is not manifested on the surface because of the Quaternary deluvial and fluvial cover. Analogically from other segments of this line, we suppose its steep normal fault character dipping to the NW. The huge sinkhole in the Dielik saddle, which is roughly on the Muráň fault (line), can signalize, that deeper below an unknown limestone horizon can be present.

   Probably steep antitethic normal faults with dipping supposedly to the SE:
   b) Along the ridge of the Strelnica massif – between units I and II.
   c) In the Martinová valley – between units II and III.

All three normal fault zones were already mapped by Bystrický (1959a, b, also in Klinec, 1976) but without biostratigraphic data incorrectly interpreted.

3. Younger faults with different character:
   a) An extensional, slightly oblique normal fault set of roughly NW-SE direction is developed in the Strelnica massif, most significantly evident between the Strelnica and Čremošná massifs, but with weakening intensity towards NE present in the whole massif. This fault set is parallel with the Mýtna fault system.
   b) Mostly in the NE part of the Strelnica massif a set of smaller WNW-ESE faults can be mapped, its character is probably a sinistral

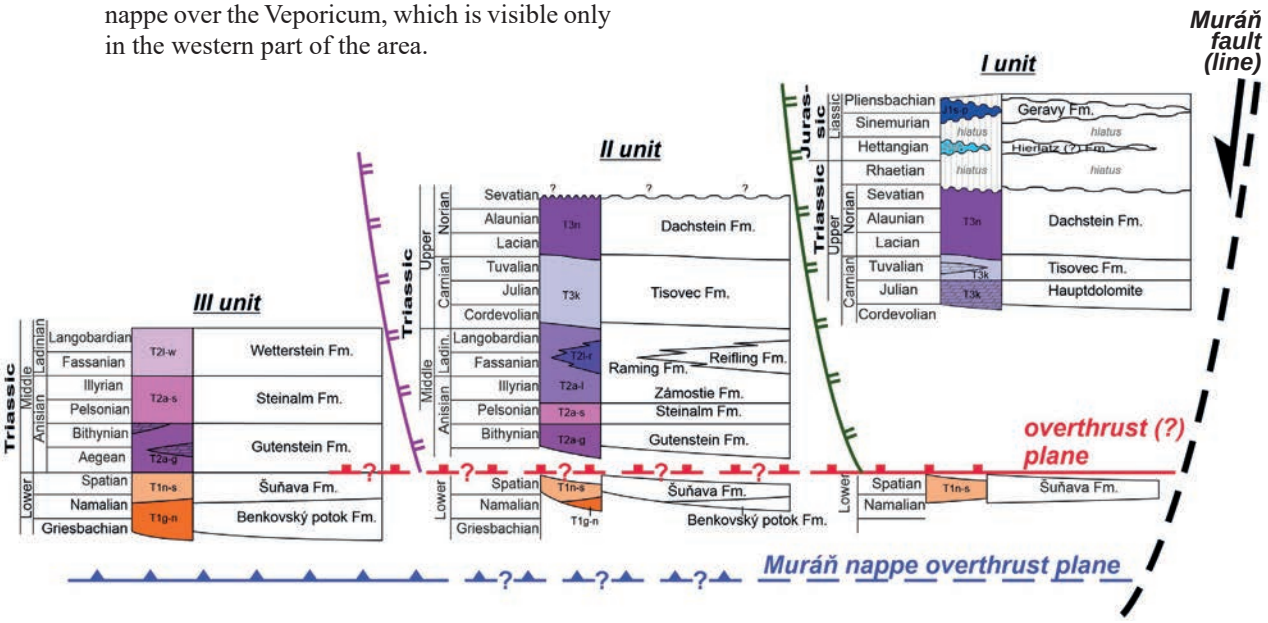


Fig. 6. Stratigraphic and tectonic scheme of the Strelnica massif (for legend / explanations see Fig. 2).

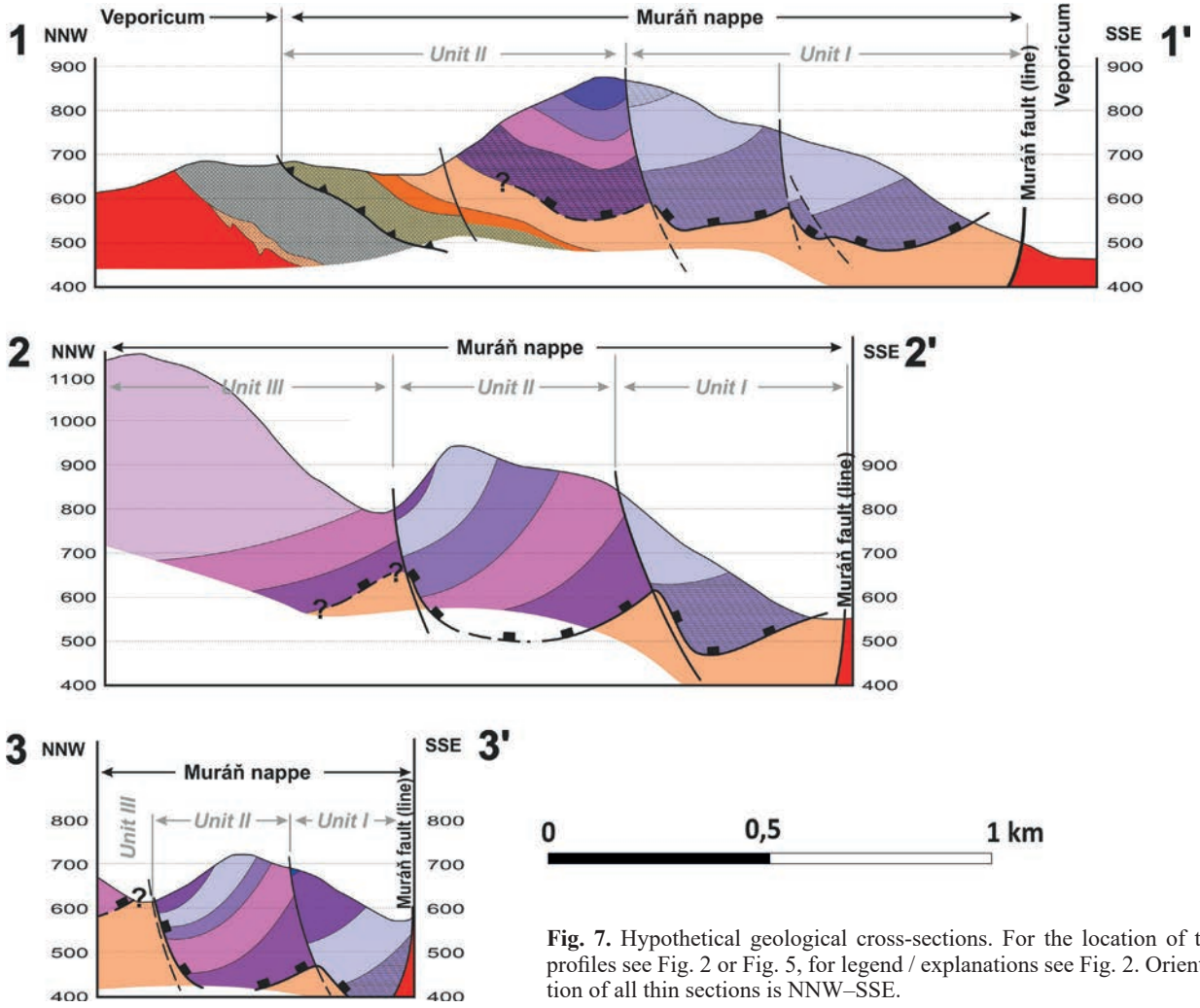


Fig. 7. Hypothetical geological cross-sections. For the location of the profiles see Fig. 2 or Fig. 5, for legend / explanations see Fig. 2. Orientation of all thin sections is NNW–SSE.

strike-slip. On the ridge of the Strelnica massif this fault set is accompanied with a set of usually smaller sinkholes mostly in the Dachstein Fm. and is in accordance with fault measurements in the Dielik cave (Vlček, 2008).

Conclusions

During the geological mapping in the years 2010–2020 we found, that most of the Strelnica massif is built by Upper Triassic carbonates in contrary to the former opinion, where the massif was supposed to be built by lower Middle Triassic rocks (Gutenstein and Steinalm Fms.). Similar age data were already known from the neighbouring Čremošná massif, in which the Tisovec quarry is situated, thus this massif is far better known, than the rest of the Strelnica massif. The spatial distribution of our new and other authors' already published age data indicate a very complicated Paleo-Alpine ApD1c overthrust and ApD2 unroofing tectonic structures (expressed by XD labelling; cf. Németh, 2021) of the massif composed of (at least) three facially different units, which we provisionally called units I, II and III respectively. All three lie directly on the Lower Triassic shaley complexes, sometimes clearly in reverse or normal fault tectonic position, in other places their relation to the Lower Triassic is unclear – it can be a normal sedimentary continuation as well as a hidden tectonic contact.

Unit I is bordered by the Muráň fault (line) and is built by a strongly tectonically reduced uppermost Middle to Upper Triassic strata of carbonate platform development with remnants of the lowermost Jurassic in tectonic contact with the Lower Triassic. The unit II shows a very different lower Anisian to lower Carnian succession with deep water / slope facies carbonates in the Middle Triassic (detrital limestones, Reifling limestones), where the contact with the Lower Triassic is unclear, and finally the unit III is building the massif of Šarkanica already out of the strictly taken Strelnica massif, which shows the "typical" developement of the Muráň nappe with Gutenstein, Steinalm and Wetterstein platform-type limestones and

dolomites seemingly in normal stratigraphic contact with the Lower Triassic.

All three units are in tectonic contact along dip-slip normal fault zones subparallel (but not exactly parallel) to the Muráň fault (line): such is the fault along the ridge of the Strelnica massif (between units I and II) and in the Martinová valley (between unit II and III).

We were able to distinguish two dominant younger Neo-Alpine AnD34 fault systems: an extensional, in the map oblique dip-slip fault set of NW-SE direction and a probably strike-slip system developed mostly in the NE part of the Strelnica massif.

Acknowledgement

The authors express their thanks to Ministry of Environment of the Slovak Republic for funding the Projects Nos. 16 06 and 17 13 (2010–2020): *Update of the geological structure of problematic areas of the Slovak Republic at the scale 1:50 000 maps*, based on which the geological mapping, biostratigraphic and other data collecting and evaluation were performed. Comments of reviewers Ján Soták (Slovak Academy of Sciences), Rastislav Vojtko (Comenius University) and one anonymous reviewer contributed much to improvement of primary manuscript. This paper is also a contribution of the State Geological Institute of Dionýz Štúr (ŠGÚDŠ), Slovakia, for the EC – CINEA HORIZON-CL5-2021- D3-D2 project 101075609 Geological Service for Europe (GSEU) within WP6 – Geological framework for the European geological data & information system.

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Geologická stavba masívu Strelnice (Muránska planina, stredné Slovensko) na základe nových biostratigrafických údajov a geologického mapovania

Masív Strelnice sa nachádza pri meste Tisovec na Muránskej planine. Zo všetkých strán je ostro ohraničený zlomami: muránskou líniou z JV, mýtňansko-tisoveckým zlomovým systémom z JZ a zlomom nejasného charakteru v doline Martinová na S od masívu. V doterajších prácach sa predpokladalo, že masív budujú najmä gutensteinské a steinalmské vápence a aniské súvrstvia, pričom takáto interpretácia sa zakladala iba na nedostatočnom počte biostratigrafických údajov. V stavbe Muránskej planiny sú známe dva typy sukcesií: vývoj karbonátovej platformy reprezentovaný wettersteinskými vápencami a dolomitmi v ladine a hlbokovodný/svahový vývoj, kde ladinské horizonty sú zastúpené detritickými a rohovcovými vápencami. Na základe týchto odlišných vývojov sa uvažovalo o spodnom príkrove s hlbokovodným vývojom a vrchnom príkrove s platformovým vývojom. Spodný príkrov sa považuje za súčasť najvyššieho čiastkového príkrovu hronika (vernárika) a vrchný za silicikum.

Naše biostratigrafické údaje preukázali, že stavba masívu Strelnice je omnoho zložitejšia a skladá sa z troch čiastkových jednotiek, oddelených od seba zlomami (obr. 2). Zlomy sú zhruba, ale nie presne paralelné s muránskym zlomom – pracovne sme ich nazvali jednotka I, II a III. Spodnotriasové súbory majú na Strelnici osobitný význam. Všade tvoria podložie nadložných súborov, niekedy so značným hiátom. Ich styk s nadložím je teda aspoň v časti jednotiek určite tektonický. Jednotka I je najbližšie k muránskemu zlomu. Predstavuje silne tektonicky redukovaný sled začínajúci sa až vrchnokarnskými tisoveckými vápencami a pokračujúci cez dachsteinské vápence až do spodnej jury. Jednotka II je po „klasickom" začiatku s gutensteinskými a steinalmskými vápencami budovaná svahovým až hlbokovodným sledom, kde sú od najvyššieho pelsónu až do spodného karnu zastúpené tmavé detritické vápence rôzneho veku (anis – zámostské, karn, ladin/karn – raminské?), v západnej časti aj rohovcové reiflinské vápence, po ktorých sedimentovali opäť svetlé vrchnotriasové vápence dachsteinského typu. Ako jednotku III sme vyčlenili masív Šarkanice. Tá je už síce mimo orograficky definovaného masívu Strelnice, predstavuje však tretí typ sukcesie, ktorý sa bez viditeľných znakov diskordancií vyvíja zo spodnotriasových súvrství cez gutensteinské a steinalmské vápence do wettersteinských vápencov – ide teda o „klasický" vývoj muránskeho príkrovu. Masív Čremošnej, v ktorom je lokalizovaný samotný kameňolom, podľa publikovaných vekových údajov a prieskumnej správy z kameňolomu v Tisovci patrí do jednotky I.

V masíve Strelnice môžeme rozlíšiť niekoľko tektonických zón odlišného charakteru. Masív Strelnice ako celok leží jednoznačne príkrovovo na veporskom kryštaliniku, niekedy aj na obale föderatského typu. Na tejto násunovej ploche býva často vyvinutý rauvakový horizont. Na báze všetkých čiastkových jednotiek všade nachádzame spodnotriasové bridličnaté súbory, ktoré vďaka svojej náchylnosti na duktilné správanie mohli plniť úlohu akéhosi „mazadla" na báze. Nad týmto horizontom, v prípade jednotky I určite a v prípade jednotky II čiastočne, predpokladáme ďalší násunový horizont. Vyššie triasové súbory jednotlivých jednotiek oddeľujú pravdepodobne strmé zlomové zóny: prvou je samotný muránsky zlom a medzi jednotkami I a II prebieha zlom po hrebeni masívu Strelnice, pozdĺž ktorého nachádzame najmladšie členy jednotky I a najstaršie členy jednotky II. Ďalší výrazný zlom oddeľujúci dachsteinské vápence jednotky II a wettersteinské vápence jednotky III prebieha v doline Martinová, pričom aj v tejto doline sú odkryté a dokumentované výskyty spodnotriasových súborov. Sklon vrstiev vo všetkých troch jednotkách je generálne na SZ, v jednotke II s pravdepodobnou menšou vrásovou štruktúrou vyvinutou v reiflinských vápencoch. Za mladšie zlomové systémy považujeme pravdepodobne extenzné zlomy zhruba sz.-jv. smeru paralelné s mýtňansko-tisoveckým zlomom, najsilnejšie vyvinuté v západnej časti masívu, a zlomy zhruba zsz.-vjv. smeru v sv. časti masívu, ktoré majú pravdepodobne *strike-slipový* charakter.

Doručené / Received: 10. 6. 2024
Prijaté na publikovanie / Accepted: 28. 6. 2024