Lithology and tectonic structure of the HP/LT metamorphosed composite Bôrka Nappe: An important clue to the Meliata Ocean geological history

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Abstract: The composite Bôrka Nappe (Meliatic Superunit) is built up by a stack of partial nappes representing the lithotectonic formations of oceanic and continental affinity which underwent of the HP/LT subduction zone metamorphism but differ in metamorphic paths. Oceanic formations of the Mesozoic age are formed by sedimentary mélanges containing mostly igneous and sedimentary rocks of the intraoceanic suprasubduction origin, in lesser amount only basalts and deep-sea sediments of the ocean floor. Mélanges were originated as components of an accetionary prism during Late Jurassic subduction of the Meliata Ocean slab. Volcano-sedimentary formations of the continental provenance are the Early Palaeozoic and Permian in age and were involved in the subduction zone in the final collisional stage of the Meliata Ocean closing.

Introduction

Although most geologists are familiar with the idea, that the HP/LT metamorphosed rock complexes are former components of oceanic plates involved in subduction zones, the reality could be quite different and variable rocks complexes including those of the continental provenance can be present there. The aim of this work is to introduce a new scheme of lithological division of the HP/LT metamorphosed composite Bôrka Nappe and to decode the complex geological history of individual lithotectonic units connected with the final stages of evolution of the Mesozoic Meliata Ocean basin.

Geological backround

Eoalpine orogeny in the Western Carpathians is supposed to be related to the closing and further tectonic history of the Triassic–Jurassic Meliata Ocean. Relics of rocks complexes directly related to this ocean are preserved in inner Western Carpathians southward of the Lubeník–Margecany line and are denoted as the Meliatic Superunit. The composite Bôrka Nappe is a one of subunits of the Meliatic Superunit and it is positioned between the Paleozoic volcano-sedimentary units of the Gemeric Superunit (the Gelnica and Gočaltovo Groups) and carbonate complexes of the Triassic Silica Superunit. Unlike other part of the Meliatic Superunit, the Bôrka Nappe is built up exclusively by HP/LT metamorphosed rocks of a wide age interval from the Early Palaeozoic to Mesozoic (Mello et al. 1998; Faryad & Frank 2011). The Bôrka Nappe is a nappe stack composed of several partial nappes (or slices) where every nappe is represented by the individual lithostratigraphic (lithotectonic) formation. Tectonic structure seems to be a product of several nappe-forming events finally modified during the Upper Cretaceous.

Lithotectonic division of the Bôrka Nappe

Our proposal of a new scheme of lithotectonic units composing of the Bôrka Nappe is improved and modified version of the older preliminary concept developed by Ivan (2007). Based on the present-day state of knowledge six following lithotectonic formations can be discerned in the Bôrka Nappe: (1) Nižná Slaná Fm., (2) Jasov Fm., (3) Bučina Fm., (4) Hačava Fm., (5) Kobeliarovo Fm., and (6) Steinberg Fm. Up to now still remain questionable definition of further (7) Rudník Fm. due to paucity of necessary data. According to their age, these formations can be classified into three groups: (1) Early Paleozoic units (Nižná Slaná and Rudník Fms.), (2) Permian units (Jasov and Bučina Fms.) and Mesozoic units (Hačava, Kobeliarovo and Steinberg Fms.). Only Mesozoic units are directly related to the oceanic environment and contain rocks originated as components of an oceanic basement, whereas

the Paleozoic formations display continental provenance. More or less preserved original stratigraphy is typical for continental units unlike formations of oceanic origin representing sedimentary ophiolite mélanges. All discerned units experienced HP/LT metamorphic alteration but they display marked differences in the metamorphic paths.

Lithotectonic units in the Bôrka Nappe

Hačava Formation

Hačava Fm. is a HP/LT metamorphosed sedimentary ophiolite mélange containing blocks of ophiolitic and also non-ophiolitic rocks various in size (typically first metres or first tens metres) embedded in matrix composed of mostly pelitic, rarely also psammitic clastic sediments metamorphosed as a whole in the blueschist facies conditions. Ophiolitic rocks are represented by metabasalts and metadolerites, less frequently also by strongly serpentinized ultramafics and rare metagabbros. Metamorphosed black or red deep-sea silicic sediments are present as well. Group of non-ophiolitic rocks forms blocks of white or grey marbles, rarely metamorphosed marls. Some of basalts are directly connected with marbles originally extruding in the lime mud, whereas other ones are closely associated with deep-sea sediments. Matrix of mélange is composed of by the redeposited mostly basic volcanic material transformed to banded blueschists or sericite, chlorite-sericite and quartz-albite phyllites. Blueschist facies mineral association in mafic rocks reflects only progressive metamorphic path. Magmatic clinopyroxene is sometime preserved, while Na-pyroxene, Na-amphibole, (glaucophane), epidote, garnet, white mica, albite, chloritoid, titanite, magnetite/haematite or pyrite are newly-formed phases. Pumpellyite, actinolite and chlorite can be present as relics of previous low-grade metamorphic alteration. Zonal Na-amphiboles, Na-pyroxene, spessartite, tremolite iron oxides and apatite in fine-grained quartz are typical for metacherts. Local retrogression connected with transformation paragonite to white mica can be observed in phyllites from matrix (Plašienka et al. 2019). Serpentinized ultramafics with typical mesh texture are composed mostly lizardite and chryzotile with less amount of magnetite, accessory crystals of brown chromian spinel, Mg-chlorite and rare Na-amphibole. At some places also primary pyroxenes and olivine have been found. Age of the Hačava Fm. is still unknown, its upper limit 150–160 Ma (Late Jurassic) follows from the age of HP/LT metamorphism (Faryad & Henjes-Kunst 1997; Dallmeyer et al. 2008).

Kobeliarovo Formation

Geological structure of the Kobeliarovo Fm. is similar to the Hačava Group — it is also ophiolite mélange but with blocks of marbles, metabasalts and metadolerites only. Also matrix of mélange is similar — sericite and chlorite-sericite phyllites combined with metamorphosed redeposited basic volcanic material. Some of metabasalts erupted directly in the unconsolidated carbonate environment. Most pronounced difference is the complete areal retrogression to the greenschist facies conditions. Albite, epidote, Na-actinolite and chlorite together with some carbonate, white mica and very conspicuous magnetite octahedrons up to 1 mm in size are typical mineral association here. Teeny relics of magnesioriebeckite are important witness of the former HP/LT metamorphic event. Exact data of age of this formation are still missing.

Steinberg Formation

Steinberg Fm. is located in the immediate neighbourhood of the Dobšiná town. Previously it was mapped as part of various Palaeozoic units of the Gemeric Superunit. Steinberg Fm. is represented by ophiolite mélange with blocks of metabasalts with relatively well-preserved original magmatic textures occurring in association with red deep-sea metacherts and metamorphosed sediments composed of disintegrated basaltic material. Blocks are embedded in the matrix built up by the dark sericite-albite-quartz phyllites or sericite phyllites. The mélange as a whole was metamorphosed in the blueschist facies and retrogressed to the greenschist facies conditions. Typical mineral association in the metabasalts is represented by albite, Na-actinolite, chlorite, epidote, leucoxenized ilmenite, rarely also white mica is present. Presence of magnetite octahedrons (up to 1 mm) is a good attribute for identification of these rocks. Relics of glaucophane and winchite as indications of the HP/LT metamorphic stage are relatively frequently preserved. Quartz, Fe-oxides, chlorite, Na-actinolite, epidote and white mica are more widespread mineral components of the metamorphosed cherts and related mafic sediments, but also relic riebeckite, ferroglaucophane and Na-Ca pyroxene have been identified. Data on age of the Steinberg Fm. are fully missing, but based on close lithological similarity to the Jaklovce Group of the Meliatic Superunit it can be

speculate about Late Triassic age for ophiolite blocks and Middle Jurassic age for matrix sediments.

Nižná Slaná Formation

Despite its relative spatial extension the Nižná Slaná Fm. has not yet been recognized and was mapped as the Hačava Fm. The Nižná Slaná Fm. is the polymetamorphosed volcano-sedimentary complex with locally preserved original stratification, but mylonitized and tectonized in some parts. Metamorphosed basaltic volcaniclastic rocks locally intercalled by various types of pelitic sediments including those rich in organic matter are most widespread here. Bodies of metamorphosed basalts, dolerites and gabbros are also components of this formation. The Nižná Slaná Fm. underwent a multistage metamorphic alteration with the oldest stage in the epidote-amphibolite facies conditions. Association of magnesiohornblende, plagioclase, clinozoisite/epidote, Mg-chlorite, white mica, garnet (in sediments) and typically rutile sometime rimmed by ilmenite are characteristic for this stage. Overprint in the blueschist facies conditions is connected with formation of glaucophane, winchite, jadeite, garnet and titanite, clinozoisite is transformed to epidote. Local retrogression to greenschist facies conditions led to final association of Na-actinolite, albite, and chlorite together with white mica, carbonate and some titanite. Age of the Nižná Slaná Fm. is not exactly known, its upper limit is age of the oldest metamorphic phase (ca. 370 Ma, Late Devonian). Age of HP/LT metamorphic overprint seems to be the same like in the Hačava Fm. (Faryad & Frank 2011).

Jasov Formation

Volcano-sedimentary Jasov Fm. is composed dominantly by metamorphosed psammitic sediments with small lenses of metaconglomerates in the lower part of formation. Metasiltstones and metapelites occur mostly in its upper part (Mello et al. 1998). Small bodies or thin layers of metamorphosed rhyolites and their volcaniclastics sporadically occur the lower part of rock complex. Quartz and plagioclase (albite) phenocrysts are preserved in metarhyolites, typical mineral association for acid volcanic is quartz, muscovite and sometime albite. The same minerals associated with paragonite, chlorite and chloritoid can be observed in metamorphosed sediments. The Permian age of the Jasov Fm. was determined by U-Pb SHRIMP dating on zircons from metarhyolites (266±1.8 Ma Guadalupian; Vozárová et al. 2012).

Bučina Formation

Complex of metamorphosed acid volcanics and volcaniclastic rocks with lesser admixture of clastic components was denoted as Bučina Fm. (Mello et al. 1998). Original granularities of sediments vary from fine-grained pelitic sediments up to conglomerates with pebbles several cm in size. Clasts in conglomerates are represented exclusively by quartz and lesser amount of felsic volcanics. Widespread hydrothermal silicification and turmalinization is typical in all rock types of this formation. Quartz and white mica are highly prevailing mineral components here. The Permian age for the Bučina Fm. is supposed based on lithological similarity with the surrounding Permian units as Jasov Fm. or Gočaltovo Fm. in the Gemeric Superunit.

Rudník Formation

Rudník Fm. is recently defined only conditionally based on two isolated findings of of high-grade metamorphic rocks (amphibolites, amphibolite gneisses) overprinted in HP/LT metamorphic conditions (cf. Faryad 1988). Cover of younger geological formations disables to assess extent and details of geological position of these rocks. Analogues to these rocks occur in the Klátov Group (Gemeric Superunit) of the Early Palaeozoic age.

Plate tectonic setting of volcanic rocks in the Bôrka Nappe lithotectonic units

Close relations of the HP/LT metamorphosed Mesozoic mafic volcanic rocks of the Bôrka Nappe to subduction of the Meliata Ocean are generally accepted (e.g. Mello et al. 1998; Plašienka et al. 2019). However geochemical studies of these rocks surprisingly indicate that only metabasalts of the Steinberg Fm. associated with deep-sea sediments display signature close to typical oceanic N-MORB or back-arc basalts. Metabasalts of the Hačava Fm. erupting in the carbonate or marl environment display similarity to arc basalts (island arc tholeiites — IAT or calc-alkaline basalts — CAB) whereas metabasalts associated with radiolarian chert and pelitic sediment have strongly depleted N-MORB signature usually related to forearc settings. Blocks of metagabbro show surprisingly E-MORB affinity. Trace element distribution in metabasalt from the Kobeliarovo Fm. indicates also similarity to IAT.

In the Early Paleozoic Nižná Slaná Fm. two types of metabasalts have been identified: one type is geochemically similar to E-MORB, but the second type with trace element distribution pointing to the subduction related CAB is dominantly present. In the Permian formations mafic volcanics have not been found, but composition of metarhyolite from the Jasov Fm. indicates its calc–alkaline affinity (Vozárová et al. 2012).

Lithology of the Bôrka Nappe and geological history of the Meliata Ocean

The composite Bôrka Nappe represents specific segment of the Meliatic Superunit which experienced as a whole HP/LT metamorphism in the subduction zone and so records specific information concerning of late stages of the Meliata Ocean evolution. The Bôrka Nappe consists of strongly imbricated partial nappes or slices, each formed by specific lithotectonic units differing not only in lithologies and tectonic settings, but also in paths of their metamorphic alteration and exhumation. Two groups of lithotectonic units can be discerned according to their position in the former Meliata Ocean basin: (1) Mesozoic units (Hačava, Kobeliarovo and Steinberg Fms.) more or less related to the basin floor and (2) Palaeozoic units representing continental margin of this basin. All oceanic units are metamorphosed sedimentary ophiolite mélanges formed during Late Jurassic subduction of the Triassic–Jurassic Meliata Ocean and consists of blocks of various igneous and sedimentary rocks embedded in the former trench sediments. It is noteworthy that the Steinberg Fm. only contains blocks of metabasalts and metamorphosed deep-sea cherts and pelitic sediments geochemically and lithologically reminding of relics of a typical ocean floor. Blocks of marbles originally probably representing platform limestones together with arc-related metabasalts frequently with evidence of eruption in in the shallow carbonate environment dominate in the Hačava and Kobeliarovo Fms. and might point to a suprasubduction setting of the intraoceanic arc or forearc. Existence of such setting is supported also by findings of the ultradepleted oceanic metabasalts in the Hačava Fm. generated by repeated melting of the depleted oceanic mantle source during forearc or backarc extension (cf. Hickey-Vargas et al. 2018). It can be speculated that presence of light non-oceanic rocks (marbles) and/or larger thickness of crust are the cause of preserving and exhumation just this parts of the subducting Meliata Ocean crust. The Palaeozoic Nižná Slaná, Jasov and Bučina Fms. generated in continental settings display many similarities in lithology and type of volcanism with some parts of the Gelnica or Gočaltovo Groups — their analogues in age from the Gemeric Superunit. Based on this fact it could be supposed that the Meliata Ocean was opened inside lithospheric plate with geological structure remind in principle of the present-day Gemeric Superunit. It cannot be excluded, that this opening developed in parallel direction with the Variscan oceanic suture which relicts has been identified on the northern margin of the Gemeric Superunit (Ivan & Méres 2012).

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References

Dallmeyer R.D., Neubauer F. & Fritz H. 2008: The Meliata suture in the Carpathians: regional significance and implications for the evolution of high-pressure wedges within collisional orogens. In: Siegesmund S., Fügenschuh B. & Froitzheim N. (Eds.): Tectonic aspects of the Alpine-Dinaride-Carpathian system. London, *Geol. Soc. Spec. Publ.* 298, 101–115.

Faryad S.W. 1988: Glaucophanized amphibolites and gneisses near Rudník (Slovenské rudohorie Mts.). *Geol. Zbor. Geol. Carpath.* 39, 747–763.

Faryad S.W. & Frank W. 2011: Textural and age relations of polymetamorphic rocks in the HP Meliata Unit (Western Carpathians). *J. Asian Earth Sci.* 42, 111–122.

Hickey-Vargas R., Yogodzinski G., Ishizuka O., McCarthy A., Bizimis M., Kusano Y., Savov I.P. & Arculus R. 2018: Origin of depleted basalts during subduction initiation and early development of the Izu-Bonin-Mariana island arc: Evidence from IODP expedition 351 site U1438, Amami-Sankaku basin. *Geochim. Cosmochim. Acta* 229, 85–111.

Ivan P. 2007: Lithostratigraphic units of the Bôrka Nappe: brief characteristic and possible genesis. In: Ľ. Jurkovič (Ed.): Gechemistry in the present-day Earth sciences. Cambel´s days, 2007. Bratislava, *Comenius University*, 42–48 (in Slovak).

Ivan P. & Méres Š. 2012: The Zlatník Group — Variscan ophiolites on the northern border of the Gemeric Superunit (Western Carpathians). *Mineralia Slov.* 44, 39–56

Mello J., Reichwalder P. & Vozárová A. 1998: Bôrka Nappe: high-pressure relic from the subduction-accretion prism of the Meliata ocean (Inner Western Carpathians, Slovakia). *Slovak Geol. Mag.* 4, 261–273.

Plašienka D., Méres S., Ivan P., Sýkora M., Soták J., Lačný A., Aubrecht R., Bellová S. & Potočný T. 2019: Meliatic blueschists and their detritus in Cretaceous sediments: new data constraining tectonic evolution of the West Carpathians. *Swiss J. Geosci.* 112, 55–81.

Vozárová A., Šmelko M., Paderin I. & Larionov A. 2012: Permian volcanics in the Northern Gemericum and Bôrka Nappe system: U–Pb zircon dating and implications for geodynamic evolution (Western Carpathians, Slovakia). *Geol. Carpath.* 63, 191–200.