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The Zlatník Group – Variscan ophiolites on the northern border of the Gemeric Superunit (Western Carpathians)

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Abstract

Northern margin of the Gemeric Superunit is build up by various lithostratigraphic units of Early Paleozoic. Upper Carboniferous and Permian in age. Detailed petrographic, mineralogical and geochemical studies of the rock complexes originally termed as the Zlatník Fm., classified as a part of the Upper Carboniferous Dobšiná Group and supposed to be composed mostly of black shales and epimetamorphosed basic volcaniclastics led us to complete revision of this knowledge and to definition of new individual lithostratigraphic unit – the Zlatník Group. The group forms narrow (max. 2 km wide) arcuate belt ca. 70 km long with interruption in its central-eastern part. Geological position of the Zlatník Group is tectonic – it is underlaid by rock complexes of the Klátov Group (Early Paleozoic) and Rudňany Fm. (Upper Carboniferous) and overlaid by the Krompachy Group (Permian). Lithologically it could be characterized as dismembered incompleted metamophosed ophiolites. The Zlatník Group can be divided into two formations: (1) the Grajnár Fm., a complex of lava flows containing the aphyric or plagioclase--phyric metabasalts with the redeposited dacitic metapyroclastics in its upper part and (2) the Závistlivec Fm., represented by ophiolite mélange with blocks, enclaves and clasts of metabasalts, metadolerites, metagabbros and rarely also acid differentiates embeded in metamorphosed pelitic and psammitic matrix. Metabasites display transitional character among N-MORB, E-MORB and BABB types. Chemical compositions of the metamorphosed sedimentary rocks point to three sources of the sedimentary material: (1) acid arc volcaniclastics, (2) disintegrated basic igneous rocks of the Zlatník Group and (3) disintegrated and altered mantle ultrabasic rocks. The Grajnár Fm. underwent very low-grade metamorphism partly overprinted by the metamorphism under the greenschist facies conditions. Polymetamorphic evolution is typical for the Závistlivec Fm. – besides same events as in the Grajnár Fm. also ocean-ridge type and blueschist facies metamorphism has been identified. The Zlatník Group represents originally upper part of the oceanic basin crust formed nearby an active volcanic arc and obducted afterwards (Grajnár Fm.) or destroyed and transformed into sedimentary mélange (Závistlivec Fm.) in the accretion prism. The age of the group is probably Upper Devonian (ca. 385 Ma). The Zlatník Group is a relic of Variscan ofiolite suture tectonically reworked during the Alpine orogeny separating originally two paleoplates with the different Variscan geological history. It is speculated, that together with the similar Pernek Group (Little Carpathians) they could be represented relics of the same ocean termed as the Pernek Ocean.

Key words: lithostratigraphy, ophiolites, Upper Devonian, Western Carpathians

Introduction

The northern border of the Gemeric Superunit belongs probably to the most lithologically variable areas in the Western Carpathian realm. No wonder that it has been attracting geologists´ attention as early as the 19th century. History of its geological study seems to be a continual story of new concepts of geological evolution or definitions and re-definitions of the lithostratigraphic units, which reflects not only the complicate geological structure of this area but its great theoretical and practical importance as well. Therefore it is not so surprising that our study concerning the Paleozoic basic volcanics and related sedimentary rocks during several last years resulted in the continuation of the above mentioned tradition – in a definition of a new lithostratigraphic unit – the Zlatník Group. More surprising seems to be the fact, that on the northern border of the Gemeric Superunit there has been untill now overlooked lithostratigraphic unit potentially of great importance for the interpretation of the geological structure of the Western Carpathians – an ophiolitic unit as a vestige of the ancient Variscan ocean. Data on its lithology, petrography, geochemistry and metamorphic as well as tectonic history are presented in this paper.

Review of previous findings and arguments for the definition of the Zlatník Group

Metamorphosed igneous rocks in the Paleozoic rock complexes of the northern border of the Gemeric

Superunit belong to the most widespread rock types. They were originally accepted as a part of one lithostratigraphic unit – the Early Paleozoic Rakovec Group (termed as the Phyllite-Diabase Series at this time; e.g. Kamenický and Marková, 1957). Some geologists (Ogurčák, 1954; Pecho and Porpreňák, 1962; Rozložník, 1963; Hudáček, 1963) pointed out lately that a part of metabasalts in the area between Dobšiná town and Rudňany village together with surrounding metasediments could be the Upper Carboniferous in age. Bajaník et al. (1981) classified the Late Paleozoic sequences here into lithostratigraphic units and their classification with some modifications has been used till now. The term the Zlatník Formation (Fm.) was firstly applied in this classification as a name of one from four formations of the normal stratigraphic sequence of the Carboniferous Dobšiná Group. Zlatník Fm. was defined as volcano-sedimentary formation of the Upper Carboniferous age, overlying psefitic-psammitic sediments of the Rudňany Fm. and extending in the western part of the northern border of the Gemeric Superunit (area between Dobšiná town and Rudňany village) and in the eastern part of the Gemeric promontory (area between Ochtiná and Brádno villages). According to Bajaník et al. (1981) graphitic phyllites with sandstone intercalations are present in the lower part of the Zlatník Fm., locally (Dobšiná town, Mlynky village) also with carbonates and sporadic products of basaltic volcanic activity. In the middle, dominant part of the formation, the mostly fine-grained metamorphosed basic volcaniclastic rocks occur. In less amounts also bodies of aphanitic, fine-grained and locally porphyroblasic metabasalts are present together with intercalations of graphitic schists and sandstones. Metamorphosed graphitic schists with intercalations of fine-grained psammitic schists and sandstones would built up the uppermost part of the Zlatník Fm., locally also with thin layers of carbonates. In the same way the Zlatník Fm. was presented in the geological map of the Slovenské rudohorie Mts. 1 : 50 000 and related explanations (Bajaník et al., 1983, 1984), as well as in the synthetic monography on the Late Paleozoic in the Western Carpathians (Vozárova and Vozár, 1988). This concept of the Zlatník Fm. has not been changed in the relevant geological papers concerning to the northern part of the Gemeric Superunit during next thirty years. The Zlatník Fm. was accepted as a component of the normal Upper Carboniferous stratigraphic sequence all the time, which follows under the underlying Rudňany Fm. and is highly dominated by sedimentary or volcanosedimentary rocks. In the scenario of geodynamic evolution the Zlatník Fm. is considered as a constituent of the Carboniferous molasse – i.e. of the infill of basins created during collapse of the Variscan orogeny (Grecula, 1994a, 1994b; Ebner et al., 2008; Grecula et al., 2009). However, substantial changes took place in the concept of the geological structure of the northern border of the Gemeric Superunit as well as in lithostratigraphic division of the Carboniferous rock complexes. From the Rakovec Gr. there was detached the complex of amphibolites and gneisses previously regarded as plutonic rocks and designated as the Klátov Gr. (Hovorka et al., 1984; Spišiak et al., 1985). Occurrences of this group in the form of discontinuous belt are located to the north of the Rakovec Gr. belt. Maheľ (1986) assumed, that four formations comprised in the Carboniferous Dobšiná Gr. could be in fact individual lithostratigraphic units. Ivan (1996) based on petrographic and geochemical study of the metamorphosed igneous rocks from these formations supported such opinion. Vozárová (1996) detached from the Dobšiná Group the Ochtiná Fm. and redefined it as individual lithostratigraphic unit – the Ochtiná Group.

Detailed petrographic and geochemical studies, which we performed along the whole extention of the Zlatník Fm., indicated dominantly effusive character of included rocks and the geochemical signatures of metabasalts close to those from the recent back-arc basins and very different from riftogeneous metabasalts of the Rakovec Gr. Metagabbros and metadolerites have been found here and the lithology of this complex was interpreted as similar to uppermost parts of the oceanic crust (Ivan, 1997). Newly obtained results of the ongoing geochemical studies indicate, that source rocks of the metamorphosed sediments of the Zlatník and Rudňany Fms. are quite different (Méres et al., 2007, 2008b), moreover preliminary results of the geochronological dating point to Upper Devonian age of the Zlatník Fm (Putiš et al., 2009). In the light of these new findings seems to be the original concept of the Zlatník Fm. no more tenable.

Definition of the Zlatník Group

As for the extent of the Zlatník Group in the western and central parts of the northern border of the Gemeric Superunit, it is largely identical with the extent of the original Zlatník Fm. in the official geological map 1 : 50 000 by Bajaník et al. (1983). We preferred to maintain for the practical reasons the original name also after its redefinition in the new individual lithostratigraphic unit, repeating the procedure used in the case of the Ochtiná Gr. (cf. Vozárová, 1996).

The Zlatník Gr. (similarly to the original Zlatník Fm.) was named after the Zlatník brook S of village Poráč, where it builds up both slopes of the valley. However rightfully its name could be equally derived from the Zlatník hill (969.3) E of settlement Štolverk near the village Hnilčík, where the Zlatník Gr. is present in the typical form.

As the Zlatník Gr. we designate a rock complex including mainly metamorphosed basaltic effusives and their subvolcanic and abyssal equivalents accompanied in the lower and uppermost parts of this complex by the metamorphosed sediments containing dominantly the volcaniclastic material or detritus of magmatic rocks.

Geological position of the Zlatník Group

According to the contemporary knowledge the Zlatník Gr. is located nearby northern border of the Gemeric Superunit in the form an attenuated belt of rocks variable in width (from ca. 100 up to 2 000 m) conformably oriented with arcuate shape of main geological structures in this area (Fig. 1). The belt begins near the Lányiho huta settlement on the west, continuing eastward up to the area N of the Poráč village. In the stretch between Poráč and Veľký Folkmar villages no rock complexes belonging to the Zlatník Gr. have been identified yet. More to east, the Zlatník Gr. probably forms, as can be concluded from several individual occurrences, thin belt extended probably up to Jahodná area (NW of Košice town).

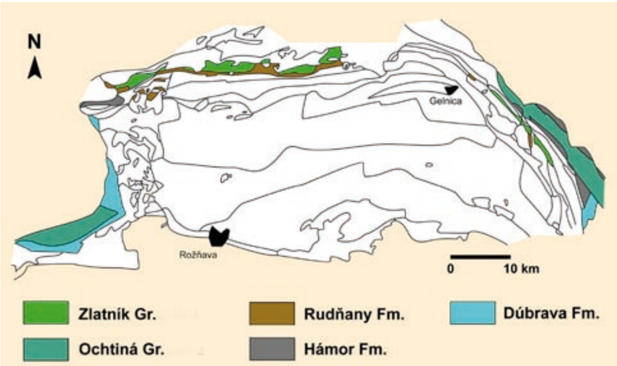

Fig. 1. Geological sketch-map of the extension of the Zlatník Group in the northern part of the Gemeric Megaunit (Ivan, 2008).

The western part of the Zlatník Gr. belt is tectonically restricted from the south by the significant Mlynky line (Maheľ, 1983). Along this line the belt is in contact mostly with slices of the strongly tectonically reduced Carboniferous sediments of the Rudňany Gr. (Fig. 2). Taking into account the subsurface geological structure in the vicinity of the Mlynky and Rudňany ore deposits (e.g. Bajaník and Hovorka, 1981; Jančura, 1995), it could be assumed, that rocks of the Rudňany Fm. together with close related metamorphic rocks of the Klátov Gr. (cf. Méres et al., 2008b) represent tectonic underlier of this belt. On its opposite side the belt of the Zlatník Gr. is overlaid by conglomerates of the Knola Fm. representing of the lowermost part of the Permian Krompachy Gr. In the eastern part the thickness of the belt is strongly reduced and rocks are intensively tectonically deformed. In the present day geological structure of the northern border of the Gemeric Superunit represents the Zlatník Gr. similarly to other related lithostratigraphic units a tectonic sheet finally formed during the nappe stacking in the Cretaceous time.

In the sense of our definition is the Zlatník Gr. absent in the Gemeric Superunit westward of the Štítnik fault. Rock

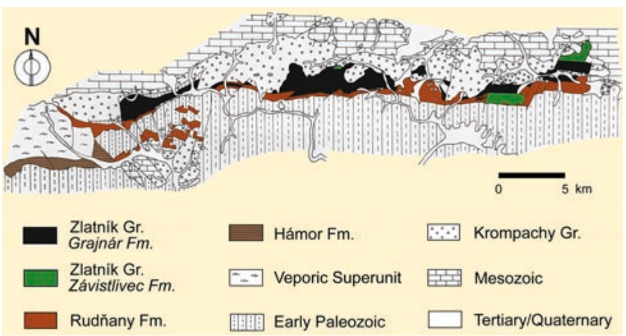

Fig. 2. Spatial extension of the Zlatník Group in the western part of the northern border of the Gemeric Superunit in the area between the Dobšiná town and Poráč village.

complexes, regarded as the Zlatník Fm. by Bajaník et al. (1981, 1983), are quite different in lithology and rather they seem to be an equivalent of the unit, which was designated by Fusán (1959) as the Dúbrava Fm. and later included into the Meliatic Superunit. Also layers of graphitic schists locally with carbonate lenses originally included in the former Zlatník Fm. are not components of the newly defined Zlatník Gr.

Lithology of the Zlatník Group

Idealized lithological scheme of the Zlatník Gr. is showed in Fig. 3. The Zlatník Gr. consists of two formations: (1) upper one, which we designate as Grajnár Fm. according to the pass near the Hnilčík village and lower one, which we named as the Závistlivec Fm. after small settlement near to the village Rudňany.

The ***Grajnár Fm.*** is dominantly composed of the various petrographic types of metabasalts alternating vertically in profiles, more evolved derivates are present in the subsidiary amount only. Primary structural and textural features of metabasalts were considerably obliterated, but preserved relics indicate that this formation is represented by a complex of subaquatic lava sheets. It follows from the petrographic variability in the scale lower than several metres and findings of thin (several cm) intercalations of metamorphosed sedimentary rocks between metabazalt bodies in the Chmeľová záhrada (Hopfgarten) area near the Dobšiná town. Also structures resembling the pillow

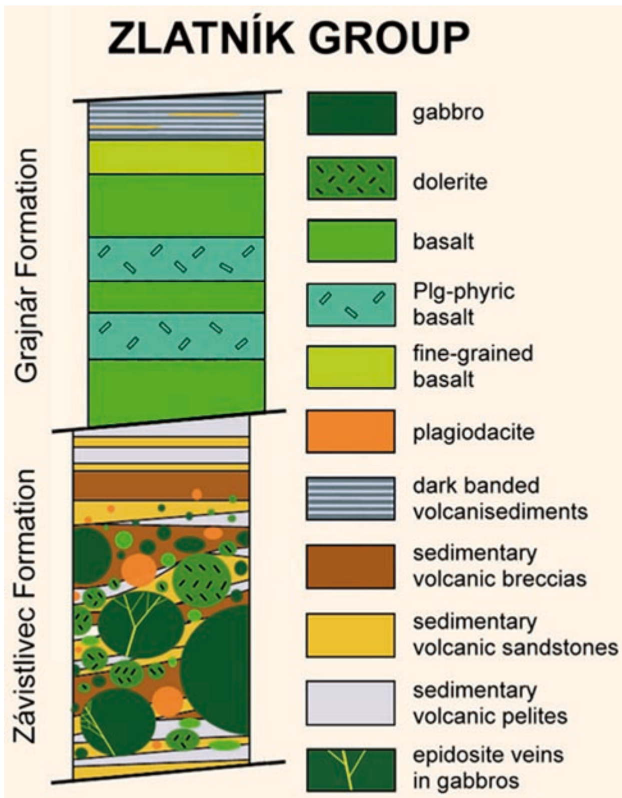

Fig. 3. Lithological column of the Zlatník Group.

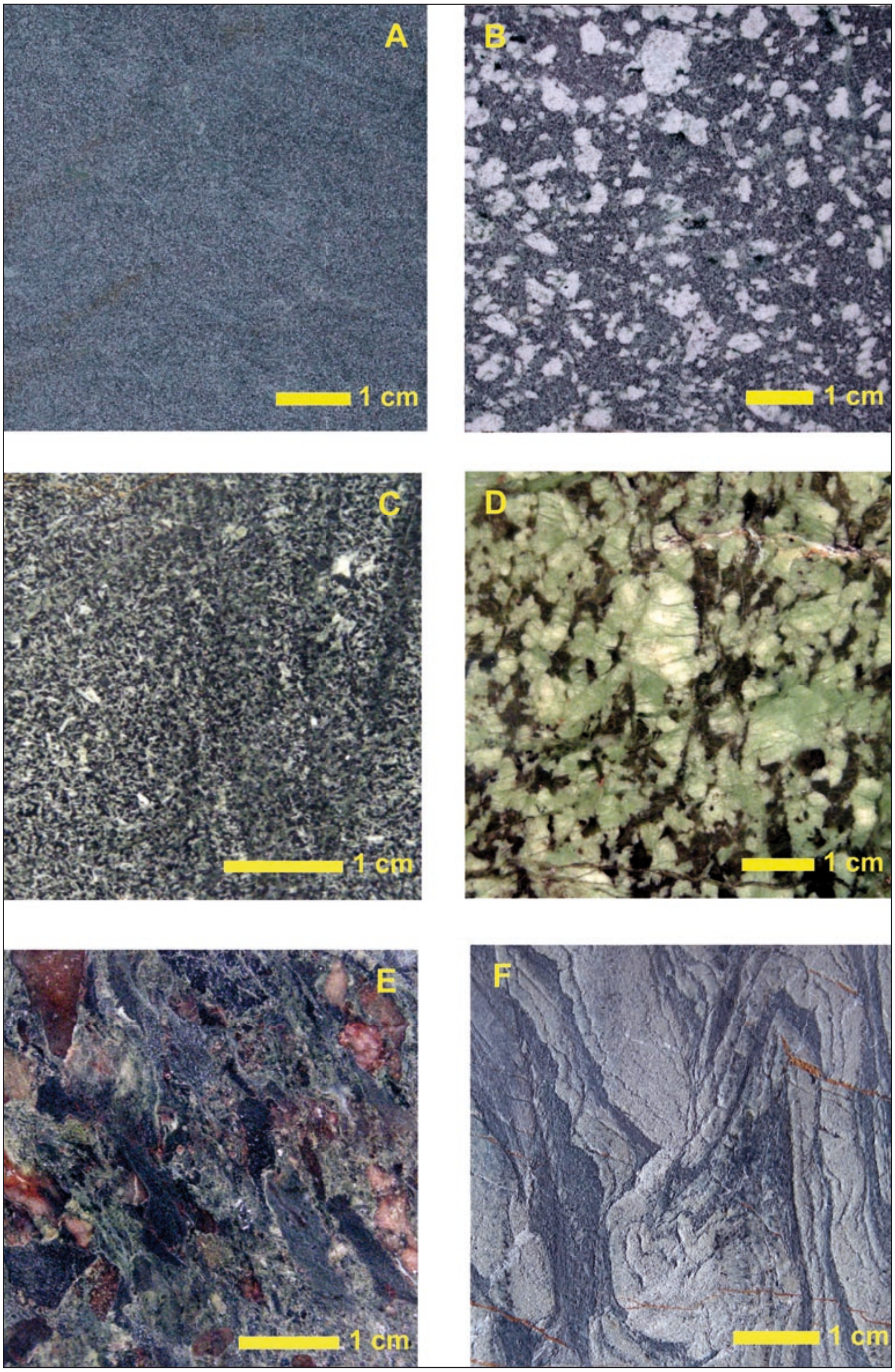

Fig. 4. Macroscopic view on some typical rock types of the Zlatník Group. **A** – aphyric metabasalt from the Grajnár Fm., locality Grajnár saddle, sample FD-312;; **B** – porphyric metabasalt from the Grajnár Fm., locality Grajnár saddle, sample FD-217; **C** – doleritic metabasalt from the Závistlivec Fm., locality Rudňany-Závistlivec village, sample FR-428; **D** – metagabbro from the Závistlivec Fm., locality Rudňany--Závistlivec village, sample FR-343; **E** – metamorphosed breccia from the Závistlivec Fm., locality Rudňany-Závistlivec village, sample FR-496; **F** – banded metamorphosed pyroclastic rock of dacitic composition from the Grajnár Fm. – surface of the drill core, locality Mlynky village, borehole BM-1. 511 m, sample FR-496.

lavas have been observed here. Changing of aphyric and plagioclase-phyric types of metabasalts seems to be the main manifestation of their petrographic variability. The upper part of the Grajnár Fm. consists of metamorphosed sedimentary rocks representing partly by the material of the sea floor weathering of basalts, however dominantly by the redeposited volcaniclastic material of dacitic composition. These rocks were mostly mapped as graphitic phyllites/phyllitic shists of the Zlatník Fm. in the geological map 1 : 50 000 by Bajaník et al. (1983). The type profile across the Grajnár Fm. is observable from the Štolwerk settlement (W of Hnilčík village) in parallel direction with the way to the Grajnár saddle, along its eastern side up to altitute ca. 980 m, then along its western side, where the metamorphosed sediments followed by various types of metabasalts could be observed in small cliffs and stony debris occurrences. The same profile can be studied in the parallely oriented Hliniskový potok valley.

The ***Závistlivec Fm.*** builds up tectonically bordered area, rhomboidal in shape, located to the S of Rudňany village between the eastern branch of Zimné valley and parallelly oriented valley to the east of Závistlivec settlement. Other less important occurrences have been found in the Zlatník valley near Poráč village and in the eastern branch of Slatviny valley cca 1.5 km S from the southernmost promontory of the Ružín dam, The Závistlivec Fm. represents sedimentary mélange containing blocks of metagabbros, metadolerites, metabasalts, including their differentiates and epidosites, variariable in size (from more than several tens meters up to small clasts of psammitic fraction), which are embedded in the metamorphosed sedimentary matrix. Although this area seems to be relatively rich in outcrops and stony debris occurrences, it is very difficult to get reliable idea about the real geological structure here. Individual enclaves are directly observable near the summit of the Sivá skala hill (862.2), typify profile with individual blocks and matrix rocks is observable along the eastern ridge of the Rudniansky les valley.

Petrography of the rocks of Zlatník Goup

Magmatic origin is typical for the majority of rocks included in the Zlatník Gr. Moreover, also sedimentary rocks are closely related with the igneous rocks, because redeposited volcaniclastic rocks or less frequently weathered and disintegrated igneous rocks also seem to be prevailing source material of sediments. Extensive petrographic variability caused by multistage metamorphic alteration is a typical feature of originally magmatic rocks in the Zlatník Gr. Petrographic variability combined with the loss of some textural features was the cause of erroneous identification of these rocks in the past.

The rocks of magmatic origin in the Zlatník Group can be divided by their petrography as follows: (1) effusive metabasalts, (2) subvolcanic metadolerites, (3) intrusive metagabbros, (4) intermediate to acidic differentiates and (5) hydrothermalites.

Metabasalts belong to most widespread rock types of the Grajnár Fm. Even by the naked eyes the following types can be discerned: (1) aphyric, (2) porphyric with variable content of plagioclase phenocrysts and (3) cumulitic types, where plagioclase phenocrysts substantially prevailed over matrix (Figs. 4A and 4B). Metabasalts with small phenocrysts of clinopyroxene have been rarely found. Significant part of metabasalts of the Grajnár Fm. displays unusually pale white-greenish or grey-greenish colours and contain disseminated pyrite impregnation. Other ones are grey-green to green in colour and typically occur in the neighbourhood of tectonic faults or hydrothermal veins. Aphyric metabasalts were originally characterized by ophitic or subophitic textures and were composed of clinopyroxene, basic plagioclase and Fe-Ti oxides. Potential presence of olivine cannot be revealed due to intensity of alteration. For the relatively less altered types the presence of clinopyroxene with pink or brownish-pink shades in microscope is typical. Plagioclase was replaced by the small alternating aggregates of fine-grained albite and radially oriented fine-grained muddied clinozoisite (Fig. 5A). Fe-Ti oxides were leucoxenized. Replacing of plagioclase does not show characteristic pseudomorphosis, moreover metabasalts during the alteration easily undergo plastic deformation, so magmatic texture is not preserved. As alteration intensity increased, the clinopyroxene was gradually replaced by colourless tremolite-actinolite and/or chlorite, the clinozoisite and carbonate blasts appeared as well. Plagioclase phenocrysts in the porphyric metabasalts were transformed into intensively dimmed radially oriented intergrowths of zoisite/clinozoisite/epidote and albite together with some chlorite. White mica, fine-grained aggregate of albite and carbonate infill the fissures in former phenocrysts.

Further increasing of the alteration intensity was characterized by the appearance of the epidote blasts and also greenish actinolite and chlorite, which replaced last relics of magmatic clinopyroxene. Along hydrothermal veins and tectonic faults due to higher water/rock ratio the metabasalts were altered to green rocks of epidote--chlorite-albite or carbonate-chlorite-albite compositions. At immediate contacts with hydrotermal veins the grey or yellow albit-quartz-carbonate metasomatic rocks formed.

Subvolcanic metadolerites occur in small amount only in association with dominant metabasalts in the Grajnár Fm., where they can be discerned mostly on the basis of the size of their clinopyroxene grains. More frequently they are present as constituent of the Závistlivec Fm. forming here individual bodies or dykes in the gabbros. Macroscopic variability is typical feature of these rocks – their colour is changeable in the wide span from grey through greenish-white up to dark green or bluish green (Fig. 4C). Structure of metadolerite textures is also variable – they vary from the massive blastoporphyric up to oriented lepidoblastic--heterogranoblastic and mylonitic textures. Minerals of the magmatic origin were fully replaced by the metamorphic mineral assemblage, which only poorly follows the original textural arrangement. Mineral composition varies depending on the metamorphic grade and intensity. Plagioclases were replaced by microscopic overgrowths clinozoisite/epidote and albite (saussuritization) eventually

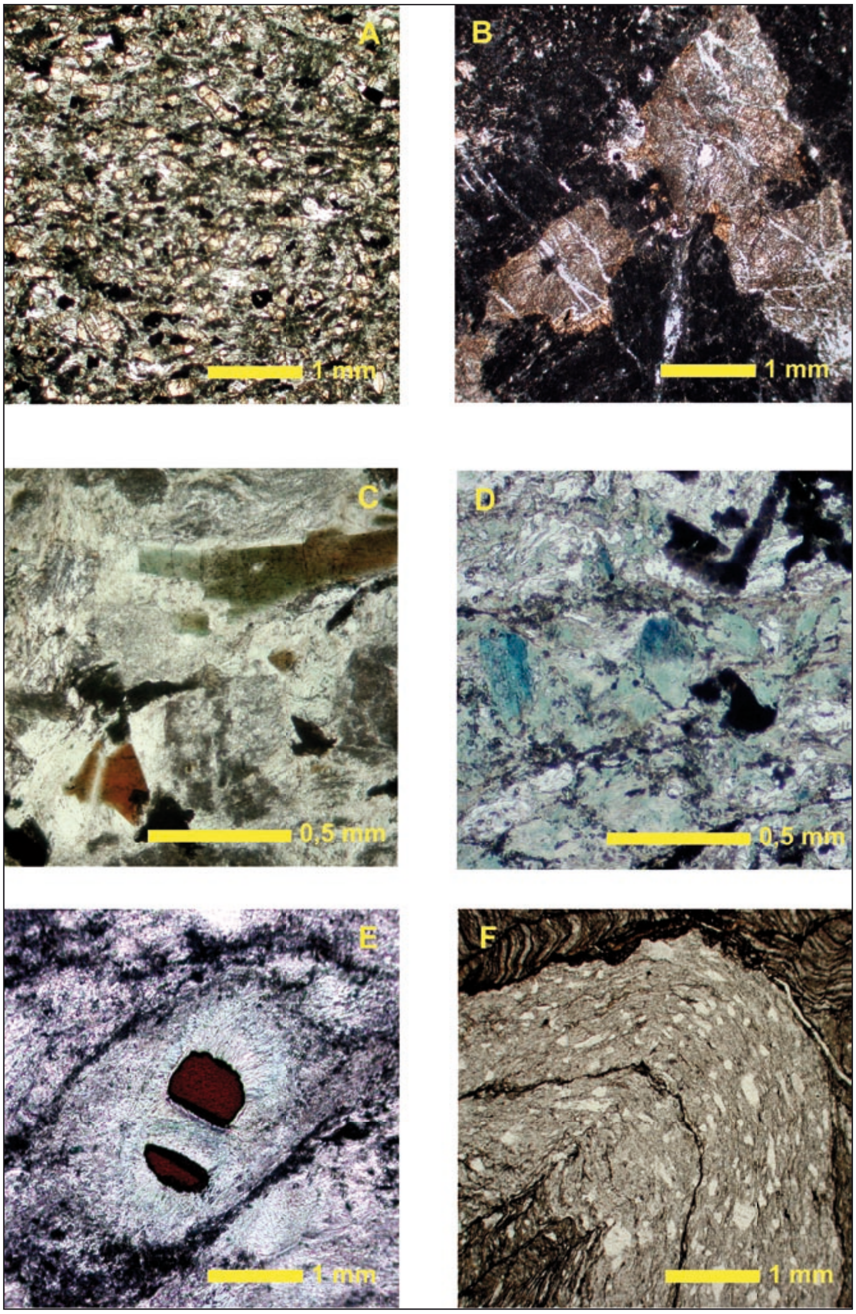

Fig. 5. Microscopic view on some important rock types from the Zlatník Group and their mineral constituents. **A** – aphyric metabasalt originally with the ophitic texture deformed during very low-grade metamorphism, II N. Magmatic clinopyroxene (pink) was practically unaffected by alteration, basic plagioclase was replaced by aggregates of clinozoisite/epidote and albite together with less chlorite. Leucoxenized ilmenite and pyrite are also present, Grajnár Fm., locality Grajnár Saddle, sample FD-312. **B** – polymetamorphosed gabbro originally of clinopyroxene-plagioclase in composition, II N. Plagioclase was transformed into cloudy fine-grained aggregate of clinozoisite with some albite (grayish-black), relic magmatic clinopyroxene is replaced from the edge by brown amphibole and penetrated by framework of veins filled by greenish to colorless amphiboles, Závistlivec Fm., locality Rudňany-Závistlivec settlement, sample FR-367. **C** – Growing--up of the brown amphibole by brown-green, green, bluish-green and colorless amphiboles respectively created as a result of the ocean ridge-type metamorphism. A part of the colorless amphibole (mostly uralite) seems to be a product of the very low-grade metamorphic overprint. Clinozoisite/epidote (dark grey, cloudy), chlorite (light grey) and leucoxenized ilmenite (black) are also present, II N. Metadolerite from the Závistlivec Fm., locality Rudňany-Závistlivec settlement, sample FR-307. **D** – relic sodic amphibole (magnesioriebeckite, blue) in metabasalt of the Závistlivec Fm. Albite, chlorite (greenish) and titanite together with iron oxides are further mineral components of this rock. **E** – chromspinelide (brown with black rim) with aureole of chlorite (yellow-greenish) and fuchsite (greenish) in the metamorphosed sandstone of the Závistlivec Fm., IIN. Locality Rudňany-Závistlivec settlement, sample FR-341. **F** – banded metamorphosed pyroclastic rock dacitic in composition from the upper part of the Grajnár Fm., intensively folded, II N. Light band is composed mostly by fine-grained albite with volcanogenic quartz grains, dark band contains mostly white mica, black pigment is represeted by iron oxides. Locality: Dobšiná town. Dobšinský kopec Mt., sample KG-30.

even by the aggregate of albite and epidote. Clinopyroxene was gradually replaced by amphiboles variable in colour even in the framework of one sample or by chlorite. Zonal amphiboles with the gradual or strictly defined boundaries between individual zones frequently occur. Metadolerites containing the oldest brown amphiboles followed or rimmed by amphiboles of brown-green or green colour and youngest colourless (usually acicular) or bluish amphibole frequently occur (Fig. 5C). Also varieties with dominate bluish-green and bluish amphiboles are relatively common (Fig. 5D). Leucoxenized ilmenites originally mostly forming automorphic crystals belong to the important mineral constituents of metadolerites, whereas carbonate, pyrite, white mica and locally also axinite and tourmaline are present in less amounts.

Metagabbros relatively widespread in the Závistlivec Fm. are characterized by the gabbro texture and variability in size of their mineral components frequently more than one order of magnitude at the distance of several first cm (Fig. 4D). They were originally composed mostly of clinopyroxene and plagioclase in variable proportions. Clinopyroxene is preserved in some metagabbros. Actual mineral composition of metagabbros is practically the same as in metadolerites with only difference in better preservation of progression in transformation of magmatic mineral association to its metamorphic derivatives. Alteration has evolved gradually along intergranular and cataclastic fissures (Fig. 5B). Furthermore the metagabbros are penetrated by veinlets of the pale yellow fine-grained epidosites (see e.g. Kornprobst, 2003 for definition) variable in thickness and with aureole of more intensive alteration along them characterized by the absence of clinopyroxene relics and plenty of albite, epidote and carbonate inside.

Evolved metaigneous rocks, intermediate to acidic in composition, have been found in the Závistlivec Fm. in the form of clasts or blocks up to several metres in diameter. They are macroscopically massive rather fine-grained rocks intersected by framework of thin quartz veins and composed mostly of quartz and/or albite. Microscopically they resemble the keratophyres. Sodic plagioclase dominates in composition whereas quartz, chlorite, epidote. Fe-oxides and titanite are secondary components. Preserved texture relics indicate that they were consisted mainly of plagioclase phenocrysts together with secondary phases as mafic phenocrysts and basic xenoliths, which were embedded in fine-grained matrix. Also primary oriented types of these differentiated rocks (tufs?) have been identified.

Hydrothermalites are in the Zlatník Gr. presented by epidosites and also by hydrothermal-metasomatic rocks mostly of sericite-quartz-carbonate composition from the periphery of sulphide-siderite veins. Epidosites are fine-grained rocks, yellow-green in colour, composed almost solely of aggregate of epidote crystals. They formed veins up to several tens cm thick or also small blocks in the mélange of the Závistlivec Fm.

The rocks of sedimentary origin in the Zlatník Gr. are petrographically very variable. They largely maintained not only their primary lithological variability but also the original sedimentary textures. Magmatic rocks were unequivocally dominated source of the clastic sedimentary material. Differences in petrography however exist between the metamorphosed sediments of the Grajnár and Závistlivec Groups.

Metamorphosed sediments of the Grajnár Gr. display mostly pelitic character. Based on petrographical properties they can be classified into following types: (1) greenschists, (2) sericite-chlorite phyllites, (3) chlorite-sericite phyllites and (4) albitic rocks with sericite admixture (Méres et al., 2007).

Greenschists are related to the base of sedimentary succession of the Grajnár Gr., rarely also as the thin (several cm) intercalations between the metabazalt bodies. They are very fine-grained rocks, grey-green to dark grey-green in colour. Planar-parallel, schistose or banded structures as well as heteroblastic or lepidogranoblastic textures are typical. Very fine-grained matrix is composed mainly of chlorite, albite, quartz and carbonate. The ore pigment and epidote are present as secondary phases. Typically they contain lithic clasts of basic rocks.

Sericite-chlorite phyllites are the grey to grey-green rocks, very fine-grained and usually strongly detailed folded. Alternation of light grey laminas (1 mm) with darker grey-green ones can be usually observed. Schistose, planar-parallel, banded, striped or detailed folded structures and heteroblastic, lepidogranoblastic and microfolded textures characterize this category of the rocks. In the very fine-grained matrix the chlorite, sericite, albite and quartz have been identified as the main components. Ore minerals, tourmaline and apatite are present as secondary phases. Quartz aggregates as metamorphosed clasts of volcanic quartz and chlorite aggregates as metamorphosed clasts of mafic minerals/rocks have been also found here.

Chlorite-sericite phyllites are macroscopically light to dark grey rocks, being usually detailed folded, fine-grained, oriented with linear cleavage. Alternation of light and dark grey bands as well as dark colour of the foliation planes similar to graphitic phyllites are typical features of these rocks (Fig. 4F). They are characterized by mostly parallel, fine-banded or schistose structures and by heteroblastic, lepidogranoblastic or microfolded textures. Clasts of altered mafic minerals or basic rocks are fully absent. Main mineral components are represented by quartz, chlorite, albite, sericite and chlorite. Ptygmatic folded bands composed of quartz, albite and chlorite (grain size ca. 0.01 mm) are alternated with bands with significantly prevailing sericite (up to 1 mm thick). Numerous small sharply angular quartz grains (0.1 mm) with traces of magmatic corrosion are concentrated in some bands of chlorite-albite-quartz composition (Fig. 5F). Submicroscopic Fe-oxide pigment follows the rock foliation and is closely related to sericite-rich bands.

Albitic rocks with small proportion of sericite are typically fine-grained, green rocks, with angular disintegration and conchoidal fracture, white in colour, when are weathered. They form thin (up to 15 cm) intercalations in above-mentioned metamorphosed sediments. Albitic rocks are comprised of fine-grained albite aggregate (grain size ca. 0.01 mm) with some disseminated minute flakes of sericite.

Metamorphosed sediments of the Závistlivec Fm. represent matrix of mélange and are characterized by wide variability in terms of their sedimentary material and granularity as well. Thickness of individual layers is considerably variable from laminar (mm) up to rudely bedded (several metres). Due to poor exposition of these rocks in the field it is impossible to observe them in any significant continuous profiles. Based on petrographic standards, three fundamental rock types can be discerned there: (1) metamorphosed sedimentary breccias, (2) metapsammites and (3) phyllites variable in composition.

Metamorphosed sedimentary breccias are macroscopically variegated rocks mostly in various green tones depending on intensity of alteration. Albite, chlorite, amphibole and quartz prevail above in their mineral composition, in less amount also sericite and leucoxenized ilmenite are present. Clasts highly prevail matrix and their

Tab. 1
Selected whole-rocks analyses of metabasalts metadolerites, metagabbros and metamorphosed sediments from the Zlatník Group

	1	2	3	4	5	6	7	8	9	10	11	12	13
Sample	FD-398	FD-210	FD-222	FD-233	FR-305	FR-350	FR-352	FR-343	FR-367	FR-463	FD-268	KG-4	FR-414
Form.	Gr. fm	Gr. fm	Gr. fm	Gr. fm	Gr. fm	Záv. fm	Záv. fm	Záv. fm	Záv. fm	Záv. fm	Gr. fm	Záv. fm	Záv. fm
Rock	mbaz	mbaz	mbazp	mbazp	mbazp	mdoler	mdoler	mgabro	mgabro	aciddif	ChlSerf	mpsam	zelbridl
SiO_2	46.03	46.92	47.08	44.29	44.31	47.39	48.57	45.85	48.32	69.33	72.71	70.50	50.67
TiO_2	1.32	1.95	1.49	1.28	1.35	2.18	2.24	0.31	0.05	0.34	0.51	0.55	1.38
Al_2O_3	17.90	16.82	19.11	19.02	17.84	14.94	13.60	20.92	17.58	13.54	11.39	13.08	15.03
Fe_2O_3	9.68	10.05	8.38	8.77	9.16	14.06	12.86	5.71	5.78	5.58	4.56	4.71	14.52
MnO	0.13	0.15	0.13	0.17	0.14	0.19	0.20	0.11	0.12	0.05	0.06	0.05	0.13
MgO	7.48	6.49	5.34	8.73	6.26	5.27	7.21	5.66	8.51	1.86	1.55	2.50	4.51
CaO	10.20	9.91	10.81	9.49	11.55	12.23	7.98	11.84	11.93	1.01	1.69	0.26	3.09
Na_2O	2.58	3.53	3.21	2.92	3.42	1.49	4.03	1.97	1.96	5.78	2.34	3.92	6.32
K_2O	0.88	0.39	0.97	0.28	0.21		0.17	1.12	1.16	0.43	1.65	1.71	0.82
P_2O_5	0.10	0.20	0.16	0.12	0.15	0.30	0.36	0.06	0.14	0.06	0.11	0.15	0.25
LOI	3.50	3.22	2.99	4.68	5.50	3.29	2.62	4.58	3.82	2.00	3.40	2.40	3.30
Sum	99.80	99.63	99.67	99.75	99.89	101.34	99.84	98.13	99.36	99.98	99.97	99.83	100.02
Cr	274	234	249	261	219	108	119	575	575		55	82	21
Co	45	52	48	52	36	28	50	31	57	7	10	8	30
Ni	118	56	72	98	76	41	56	120	203	2	24	16	15
Sc	36	35	31	30	31	59	47	41	48	18	9	11	40
V	241	203	154	152	215	435		110		11	70	113	328
Rb	21.1	5.8	14.2		4.8					21.1	59	60.4	19.2
Sr	212	311	365	126	291	400	365	160		57	46	21	21
Ba	44		59		19			230		78	237	362	92
Zr	74	140	105	81	96	107		9		140	161	139	46
Y	28	32	25	23	25					53	19	11	19
Hf	2.3	4.0	3.2	4.5	2.6	4.3	3.6		1.0	4.8	4.5	4.3	1.7
Th	0.20	0.36	0.28		0.30					2.60	5.30	7.60	0.80
Ta	0.10	0.19	0.21	0.12	0.10					0.30	0.50	0.70	0.10
Nb	1.1				1.8					5.6	7.2	8.9	1.4
La	2.6	7.6	5	4.3	3.8	12.0	8.6	0.5	2.3	10.5	19.9	7.7	2.4
Ce	7.4	23.3	17.5	14.5	11		23.6		6.0	27	43.4	17.9	5.5
Pr	1.49				1.98					3.96	5.18	2.31	0.98
Nd	8.7	19.3	14.1	11.5	10.5	25.4	16.2		5.5	17.1	20.8	10.3	5.8
Sm	2.9	4.6	3.7	3.2	3.1	6.0	5.2	0.8	1.8	5.1	3.8	1.7	1.9
Eu	1.18	1.75	1.30	1.30	1.21	2.10	1.90	0.42	0.56	1.45	0.87	0.35	0.80
Gd	4.06				3.99		3.10		6.30	6.26	3.31	1.56	2.68
Tb	0.79	0.96	0.76	0.74	0.74	1.20	1.20		0.43	1.30	0.61	0.32	0.49
Dy	4.80				4.39					8.57	3.25	1.86	2.93
Ho	0.90				0.94					1.86	0.64	0.39	0.54
Er	2.75				2.69					5.82	1.90	1.24	1.87
Tm	0.37	0.52	0.35	0.35	0.37					1.00	0.28	0.21	0.25
Yb	2.53	3.00	2.45	2.00	2.40	3.70	4.10	0.53	1.25	6.03	1.58	1.42	1.77
Lu	0.39	0.55	0.36	0.31	0.36	1.20	0.71	0.15	0.19	0.97	0.29	0.28	0.32

Explanations: mbaz – metabasalt; mbazp – Plg-phyric basalt; mdoler – metadolerite; mgabro – metagabbro; aciddif – acid differenciate; ChlSerf – chlorite-sericite phyllite; mpsam – metapsammite; zelbridl – greenschist (of sedimentary origin). Analyses 2–4 were taken from Ivan (1997). Analyses 1, 5, 10–13 were performed in the ACME Laboratories Ltd., Vancouver, Canada. Major elements, Cr, Ni and Sc were analysed by ICP AES, others by ICP MS. Major elements in other analyses were performed by XRF (2–4) or ICP OES. trace elements by INAA (Mega Inc., Stráž pod Ralskem, Czech Republic).

size varies significantly, most frequently to the several first cm (Fig. 4E). Angular clasts were originally formed by various types of basalts with diverse solidification rates from the vitritic type up to dolerites. Coarse-grained clasts together with the individual large crystals of ilmenite or epidote probably come from gabbros. Clasts of metamorphosed acid aphyric or porphyric rocks are also present. Albitic rocks with arborescent textures represent most likely devitrified acid glassy volcanics. Matrix of metamorphosed breccia is composed of fine-grained aggregate of albite maybe with some quartz and angular volcaniclasts of both these minerals.

Metapsammites are typically grey to greenish-white moderately oriented rocks with variable granularity (0.5 mm to 1 cm). Planar-parallel and schistose structures are most widespread. Palimpsest blastopsammitic to heteroblastic or lepidogranoblastic structures are characteristic for these rocks. Mineral association is the same as in the case of metamorphosed breccias. Pre-metamorphic granularity and inhomogeneity of metapsammites is indicated by volcanogenic quartz, epidote blasts replacing basic plagioclase, grains of the leucoxenized ilmenite and the metamorphosed lithoclasts of basalts, ultrabasic rocks or acid volcanics. In the metamorphosed lithoclasts of ultrabasic rocks composed of the chlorite aggregate the microscopically identifiable brown chromspinelide grains in various stages of metamorphic alteration are frequently present (Fig. 5E). Matrix in metapsammites is the same like in metamorphic breccias. Identification of metapsammites is usually complicated not only by metamorphic transormation but by hydrothermal alteration and similarity to blastomylonites of the metabasic rocks as well.

Phyllites represent originally the most fine-grained sediments of the Závistlivec Fm. Lamellar to schistose textures and various composition of sedimentary material are typical. Combination of the plastic deformation up to convolute folded forms and brittle deformation resulted in the formation of foliation planes. Numerous microdislocations are frequently observed. Differences in composition of individual lamellas or layers are results of variations in quantity of the individual main mineral components – albite, chlorite, amphibole, epidote and hematite/magnetite. Sericite and carbonate are secondary components only. In some samples blue sodic amphibol as relic mineral was preserved. Although the fine-grained fraction (ca. 0.01 mm) prevailed in the pre-metamorphic fraction of sediments the frequently present crystalloclasts of quartz, plagioclase, leucoxenized ilmenite and epidote as well as lithoclasts mostly of basic rocks point to its unsorted character. Thin intercalations of originally psammitic sediment are also common in phyllites.

Geochemical characteristics of the Zlatník Gr. rocks

Selected analyses of major and trace elements in typical rocks of the Zlatník Gr. are summarised in Tab. 1.

Varied association of rock types included in the newly defined Zlatník Gr. has not been geochemically studied yet. Metabasalts of the Grajnár Gr., which were found as different from the metabasalts of the Rakovec Gr. (Ivan, 1997) were only an exception. Distribution of major elements in the metamorphosed basic magmatic rocks corresponds to their basaltic composition, although there are some specifics. Increasing of loss on ignition (2.70–5.90 %) and also Na_2O at the expense of CaO as a result of metamorphic alteration and sodic metasomatosis (spilitization) respectively are typical for samples altered to greenschists. As follows from the TiO_2 vs. Al_2O_3 diagram (Pearce, 1983; Fig. 6) only a part of them is compositionally close to basaltic liquids, others represent cumulates or differentiates of Fe-Ti-basalt type. Distribution of the trace elements indicates, that parental basaltic magma which these rocks were formed from was close to tholeiites of MORB type as is obvious e.g. from diagrams Zr vs. TiO_2 (Pearce, 1982) or Ti/1000 vs. V (Shervais, 1982). However more detailed specification of its geochemical type displays some differences from the typical oceanic N-MORBs as resulted e.g. from the diagram Zr vs. Y (le Roex et al., 1983) or from the chondrite normalized REE patterns (Fig. 7).

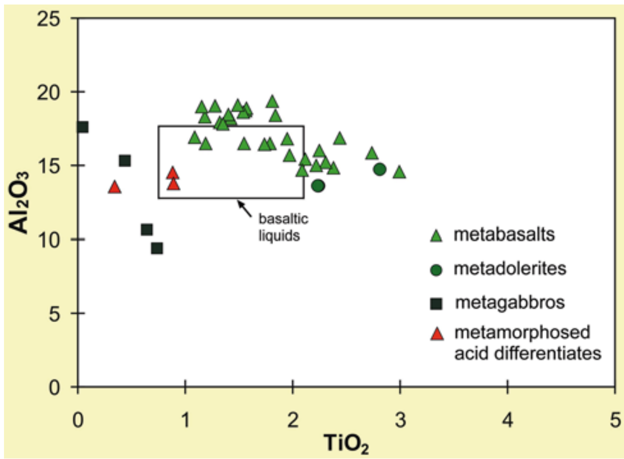

Fig. 6. TiO_2 vs. Al_2O_3 diagram (Pearce, 1983) for metabasalts, metadolerites and metagabbros of the Zlatník Group.

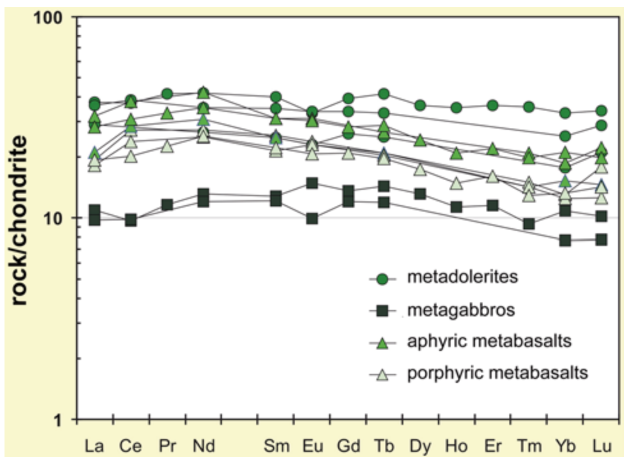

Fig. 7. Chondrite normalized REE patters for the selected metaigneous rocks from the Zlatník Group. Normalization by McDonough and Sun (1995).

Diagrams used for detailed discrimination, which are based mostly on relatively immobile HFS elements (Hf/3-Th-Ta, Wood, 1989; 3Tb-Th-2Ta, Cabanis and Thiéblemont, 1988; La/10-Y/15-Nb/8, Cabanis and Lecolle, 1989) plot the metabasalts of the Zlatník Gr. on boundary of BABB, N-MORB and E-MORB types. The same follows from the Nb/Yb vs. Th/Yb diagram (Pearce and Peate, 1995; Fig. 8).

Metagabbros correspond to the identical geochemical type as metabasalts and metadolerites but display lower concentrations of total REE and other incompatible elements. Some of them bear the evidence to plagioclase fractionation as follows the negative Eu-anomalies. Acid differentiates are characterized by the low total REE content and also LREE enrichment is absent (Fig. 9), which is similar to oceanic plagiogranites (e.g. Rollinson, 2009). Variations in their REE patters could be a result from the difference in fractionation mechanism and/or parental magma.

Petrographic variability of the metamorphosed sedimentary rocks of the Zlatník Gr. is reflected by their chemical composition (Tab. 1). Mostly stable Al_2O_3 concentrations (around 18 %) in comparison to variability of related SiO_2 contents (52 to 75 %) display the samples analysed up to date. Lowest SiO_2 contents characterize the greenschist, whose whole-rock composition approximates to metabasalts (Méres et al., 2008).

Chlotite-sericite and sericite-chlorite phyllites of the Grajnár Fm. are relatively homogeneous in composition and they are plotted in the SiO_2 vs. Al_2O_3 diagram in the field of sediments with low mineralogical and chemical maturity, what is typical for rocks derived from less altered and unsorted acid to intermediate arc magmatic rocks (Fig. 10). Metapsammites of the Závistlivec Fm. are plotted in this diagram in the same field but specific trend of SiO_2 decrease with Al_2O_3 content is observable. The same results supporting similarity in composition of metabasalts and metamorphosed sediments of greenschist type, influence the basic source material on the composition of sericite-chlorite phyllite and also close analogy between the composition of chlorite-sericite phyllites and dacitic

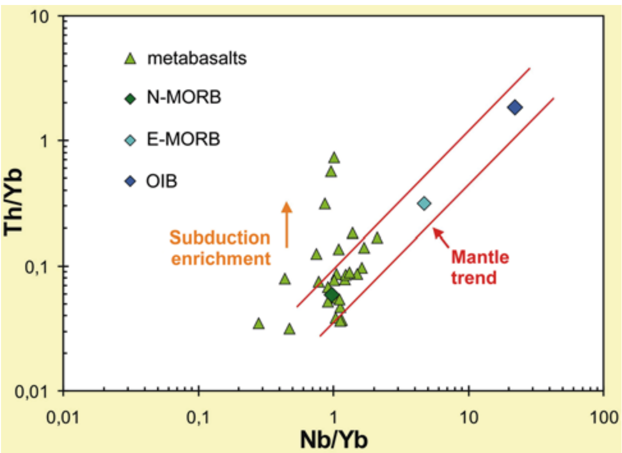

Fig. 8. Metabasalts of the Zlatník Group in the Nb/Yb vs. Th/Yb diagram by Pearce and Peate (1995).

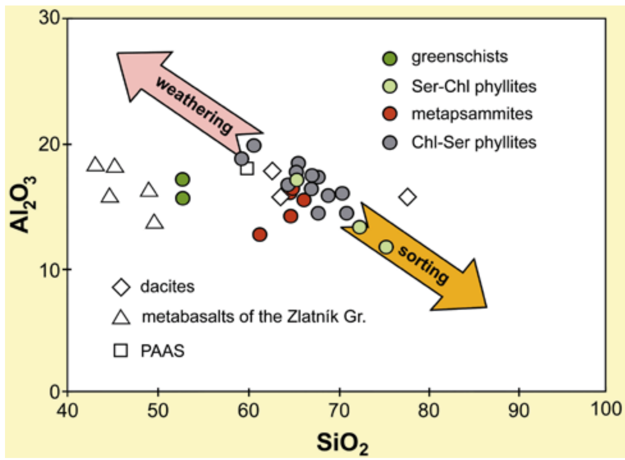

Fig. 10. Metamorphosed sedimentary rocks of the Zlatník Group in the diagram SiO_2 vs. Al_2O_3. Except for greenschists they are similar in composition to dacites of magmatic arcs.

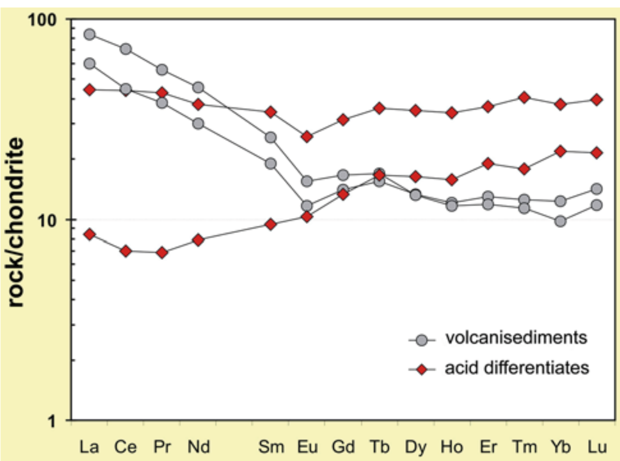

Fig. 9. Chondrite normalized REE patterns for the metamorphosed acid magmatic differentiates from the Zlatník Group. Normalization by McDonough and Sun (1995).

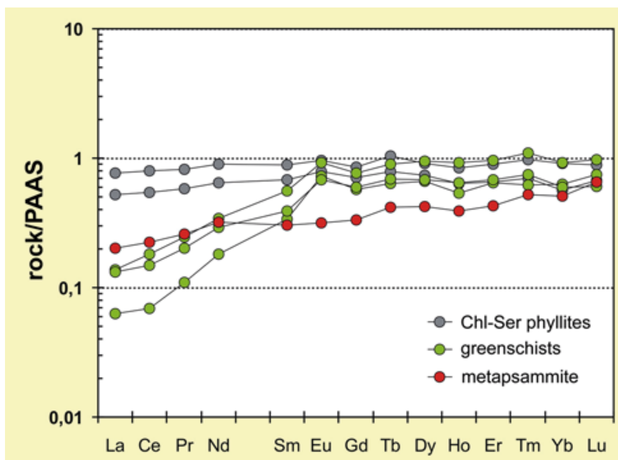

Fig. 11. PAAS-normalized REE patters for the selected types of the metamorphosed sediments from the Zlatník Group. PAAS normalizing values by Taylor and McLennan (1985).

volcanics without any sign of the weathering trend follow from the ternary diagram A-CNK-FM (Nessbit and Young, 1989). Immature and unsorted character of the original sediments seems to be obvious also from the SiO_2/Al_2O_3 vs. Na_2O/K_2O (Pettitjohn et al., 1972; not shown) where they are plotted in the fields of lithic arenites and greywackes. Domination of the volcanic source material, basaltic or dacitic in composition, is indicated also by the diagram Zr/TiO_2 vs. SiO_2 (Winchester and Floyd, 1977), being commonly used for the classification of volcanic rocks. The sedimentary greenschists likewise the metabasalts of the Zlatník Gr. are projected in the basalt field, whereas metapsammites, sericite-chlorite and chlorite-sericite phyllites create the continual linear trend which is compatible with differentiation trend of volcanic rocks from andesites to dacites/rhyodacites. Differences in the source material are demonstrable also from PAAS-normalized REE patterns, where the greenschists are distinctly depleted in LREE relatively to PAAS and their patterns are identical with metabasalts of the Zlatník Gr. Metapsammites and sericite-chlorite phyllites are less depleted in LREE as greenschists and chlorite-sericite phyllites patterns are similar to PAAS and identical to calc-alkaline dacites.

Chemical compositions of phyllites and metapsamites are close to dacites (Fig. 11).

Mineral associations, compositions of mineral phases and metamorphic evolution

The only preserved magmatic mineral phase in metamorphosed magmatic rocks of the Zlatník Fm. is clinopyroxene found in metabasalts and metagabbros. Selected analyses of clinopyroxene are presented in Tab. 2. Classification diagram by Morimoto et al. (1988) classifies it as augite and diopside. As follows from the discriminant diagrams by Leterrier et al. (1982), its composition is similar to clinopyroxenes from the anorogenic and alkaline basalts (Ivan, 1997). In the discriminant diagram $SiO_2/100 – Na_2O-TiO_2$ by Beccaluva et al. (1989), clinopyroxenes from the metabasalts display composition similar to those from E-MORB less N-MORB basalt types (Fig. 12). Relic magmatic clinopyroxenes from the metagabbros seems to be rich in diopside component and display lower concentrations of TiO_2 and Al_2O_3. Curiosity thin rims of metamorphic diopside on the magmatic clinopyroxene have been found (Černák, 2011).

Only partial pseudomorphic replacement of the magmatic mineral assemblage by the metamorphic one is observed. Non-equilibrium seems to be typical feature of the majority of the observed metamorphic associations. Compositional inhomogeneity and zoning of the metamorphic mineral phases or replacement effects are common.

Although there are some similarities between the metamorphic associations of the Grajnár and Závistlivec Fms., both formations differ substantially in the metamorphic history. Metabasalts of the Grajnár Fm. usually contain association Cpx(magm.) + Ab + Zo/Czo/Ep + Act + Chl + Lx ± Pmp ± Ser ± Cal ± Py, less frequently also Cpx(magm.) + Ab + Act + Ep + Lx + Chl (abbreviations by Whitney and Evans, 2010). Radially arranged overgrowths Zo/Czo/Ep and Ab in the place of former magmatic plagioclase phenocrysts were probably created at the expense of prehnite. Increase in intensity of alteration resulted in increasing of abundance of Chl and Cal at the expense of Cpx and Ep or Ab + Ser at the expense of Zo/Czo. Large parts of the occurrences however display association Ab + Ep + Chl + Lx ± Ser ± Cal only, in proximity of hydrothermal veins Ab + Chl + Lx ± Ser ± Cal or Ab + Dol/Sid + Ser just at their contacts. All these associations indicate that the metabasalts of the Grajnár Fm. were metamorphosed in the prehnite-pumpellyite facies conditions, followed by the greenschist facies metamorphism, which characterizes significant activity of fluids (Černák and Ivan, 2006; Černák, 2011). In the metamorphosed sediments of the Grajnár Fm., the only association Ab + Ser + Chl + Q ± Cal with variable proportions of individual components has been found.

Typical feature of the metamorphosed magmatic rocks of the Závistlivec Fm. is extensive variability in included mineral phases as a result of more complex metamorphic evolution in comparison to the Grajnár Fm. No original magmatic minerals are preserved in metadolerites except small sporadic relics of clinopyroxene. Representative association is Czo/Ep + Amp + Chl + Lx + Ab ± Ax ± Pmp ± Ser ± Cal ± Py, where the composition of amphibole is changed in order Prg → Ed → Mhb → Ac (Tab. 2). Prg contains significant concentration of Cl. Also the association Ab + Czo/Ep + Amp + Lx + Chl + Ser ± Cal occurs relatively frequently and it is characterized by amphiboles Mhb → Ac and important presence of Ab and Ser. Peculiar association Ab + Chl + Lx + Mag + Amp + Ser + Ep + Bt, where Amp is mostly Na-Act usually with Mrbk/Rbk and eventually also Wnc has been found in some metabasalts or metadolerites. Similarly to the metabasalts

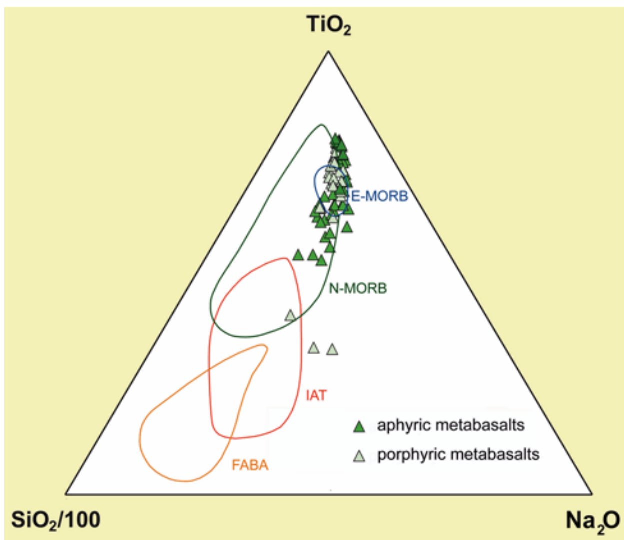

Fig. 12. Magmatic clinopyroxenes from metabasalts of the Zlatník Group in the dicriminating diagram $SiO_2/100$ – Na_2O – TiO_2 by Beccaluva et al. (1989). Explanations: FABA- fore-arc basin basalts.

Tab. 2
Representative analyses of minerals in studied samples

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Sample	FR-351b	FD-221	FD-381	FD-421	FR-351b	FR-351b	FR-351b	FR-411	FR-411	FR-411	FR-411	FD-222	FD-214	FR-446	FR-446	FD-420	FD-420	FD-214	FD-214
Mineral	Cpx	Cpx	Cpx	Cpx	Prg	Ed	Act	Ed	Mg-Ktp	Fe-Act	Act	Act	Act	Mg-Rbk	Na-Act	Czoi	Ep	Pmp	Pmp
Analysis	ana10	ana1	ana55	an31	ana61	ana14	ana5	M4_4	M4_2	M5_10	M5_7	ana17	M4_11	M7_2	M3_3	M4_2	M3_2	M1_2	M1_3
Rock	mgabro	mbaz	mbaz	mbaz	mgabro	mgabro	mgabro	mdoler	mdoler	mdoler	mdoler	mbazp	mbaz	mdoler	mdoler	mbaz	mbaz	mbaz	mbaz
Origin	magm	magm	magm	metam	ocmet	ocmet	pumpact	ocmet	ocmet	ocmet	pumpact	pumpact	pumpact	vystlak	zelbridl	pumpact	zelbridl	pumpact	pumpact
SiO_2	51.76	51.00	47.20	53.32	43.66	44.28	55.71	44.95	49.66	52.28	54.94	54.72	56.35	54.82	53.98	39.60	38.62	36.72	38.30
TiO_2	0.53	1.30	4.47	0.01	2.77	1.54	0.00	3.33	1.96	0.09	0.00	0.06	0.00	0.00	0.00	0.04	0.01	0.02	0.05
Al_2O_3	1.85	1.92	4.07	0.06	11.49	9.62	0.33	8.42	4.50	2.23	1.01	1.24	0.84	1.87	1.43	31.96	26.86	25.06	26.12
Cr_2O_3	0.07	0.11	0.12	0.05	0.07	0.02	0.01	0.00	0.01	0.02	0.01	0.00	0.02	0.01	0.00	0.00	0.05	0.00	0.00
FeO	6.75	9.82	11.98	9.49	10.98	12.78	9.21	13.98	15.59	21.91	12.83	10.97	8.04	25.06	17.50	2.06	7.49	6.91	2.11
MnO	0.26	0.13	0.28	0.64	0.10	0.22	0.15	0.25	0.35	0.43	0.22	0.29	0.17	0.24	0.41	0.08	0.05	0.14	0.28
MgO	15.30	14.07	9.73	12.30	14.24	14.10	18.62	13.77	14.17	9.58	16.30	16.94	18.99	7.52	12.96	0.00	0.00	1.03	3.63
CaO	23.22	20.12	21.89	24.33	11.74	12.00	13.56	10.52	9.08	12.55	13.32	13.47	13.11	1.21	9.43	24.91	23.99	23.20	23.35
Na_2O	0.27	0.52	0.62	0.09	2.53	2.10	0.06	3.66	2.75	0.31	0.14	0.24	0.00	6.12	1.73	0.02	0.02	0.08	0.16
K_2O	0.01	0.00	0.00	0.00	0.21	0.20	0.02	0.32	0.57	0.07	0.00	0.05	0.02	0.02	0.08			0.00	0.00
Sum	100.01	98.99	100.35	100.30	97.81	96.86	97.67	99.50	99.10	99.50	98.84	97.98	97.55	96.87	97.52	98.66	97.10	93.17	94.00
Si	1.923	1.927	1.801	2.002	6.345	6.535	7.922	6.565	7.241	7.732	7.833	7.820	7.930	7.973	7.878	2.998	3.019	5.951	6.016
Al^{IV}	0.077	0.073	0.183	0.000	1.655	1.465	0.056	1.435	0.759	0.268	0.167	0.180	0.070	0.000	0.122	2.851	2.475	4.787	4.835
Al^{VI}	0.004	0.012	0.000	0.005	0.313	0.208	0.000	0.013	0.014	0.120	0.002	0.028	0.069	0.322	0.124				
Fe^{3+}	0.090	0.034	0.001	0.000	0.202	0.305	0.000	0.075	0.079	0.029	0.010	0.000	0.000	1.423	0.285	0.131	0.490	0.331	0.170
Cr	0.002	0.003	0.004	0.002	0.008	0.003	0.001	0.000	0.002	0.003	0.001	0.000	0.003	0.001	0.000	0.000	0.003	0.000	0.000
Ti	0.015	0.037	0.128	0.000	0.303	0.171	0.000	0.366	0.215	0.010	0.000	0.006	0.000	0.000	0.000	0.003	0.001	0.003	0.005
Fe^{2+}	0.118	0.276	0.381	0.298	1.133	1.272	1.224	1.632	1.822	2.681	1.520	1.350	0.949	1.638	1.850			0.605	0.107
Mn	0.008	0.004	0.009	0.020	0.013	0.027	0.018	0.031	0.043	0.054	0.026	0.035	0.020	0.029	0.050	0.005	0.003	0.019	0.037
Mg	0.848	0.792	0.553	0.689	3.086	3.102	3.947	2.997	3.081	2.111	3.463	3.609	3.983	1.637	2.820	0.000	0.000	0.248	0.849
Ca	0.924	0.814	0.895	0.978	1.829	1.897	2.065	1.646	1.419	1.989	2.034	2.063	1.977	0.190	1.474	2.020	2.010	4.029	3.930
Na	0.019	0.038	0.046	0.007	0.714	0.602	0.016	1.036	0.776	0.089	0.039	0.067	0.000	1.734	0.490	0.002	0.002	0.026	0.049
K	0.000	0.000	0.000	0.000	0.040	0.038	0.003	0.060	0.106	0.014	0.000	0.008	0.003	0.004	0.014				
Sum kat.	4.029	4.010	4.000	3.999	15.640	15.624	15.123	15.856	15.557	15.099	15.096	15.127	15.002	14.987	15.109				
Na^B					0.114	0.016	0.000	0.240	0.324	0.003	0.000	0.000	0.000	1.734	0.396				

Explanations: abbreviations for rock types – see Tab. 1. Abbreviations for procesess resposible for the mineral origin: magm – magmatic; ocmet – ocean-ridge metamorphism; pumpact – very low-grade metamorphism in the pumpellyite-accinolite subfacies; vystlak – high-pressure subduction-related metamorphism; zelbridl – final metamorphism in the greenschist facies conditions. Mineral analyses were performed by electron microprobe Cameca SX-100 at the State Geological Institute of Dionýz Štúr in Bratislava. Microprobe operated at 15 kV accelerating voltage and 20 nA beam current. counting time 20 s and beam diameter 2–10 μm.

of the Grajnár Fm. the associations Ab + Ep + Chl + Lx ± Ser ± Cal or Ab + Chl + Lx ± Ser ± Cal are located in places of the most intensive alteration. Mineral associations in metagabbros are resembling those in metadolerites, but they are even more variable due to gradual growth of newly formed minerals by replacing of the original magmatic minerals from their boundaries in the coarse-grain textures and also due to wide span of the alteration intensity at the all metamorphic stages. Relics of the magmatic clinopyroxenes are frequently preserved and occur in the same associations as are typical for metadolerites, but additionally Mrbk/Rbk, Wnc a Na-Act may be present. In some samples is magmatic ilmenite instead common Lx replaced by combination of aggregates of Rt and Spn. Metamorphic associations and relative mineral successions indicates that metamorphic history of metagabbros and metadolerites include several stages. During the first stage of alteration they underwent the oceanic ridge-type metamorphism characterized by the relatively fast continual transition from the thermal conditions corresponding to the high-graded amphibolite facies to the greenschist facies conditions, both at relatively low pressures (Ivan and Černák, 2010). This stage is overprinted by the another one at the very low-grade metamorphic conditions (prehnite-actinolite subfacies of the prehnite-pumpellyite facies) with the transition up to high-pressure low-temperature (HP/LT) metamorphism in the blueschist facies conditions. During the last stage, the metamorphism in the greenschist facies conditions, related mostly to the vicinity of tectonic zones, took place. Variability of P-T conditions during the whole metamorphic history is reflected in changes in composition of amphiboles (Fig. 13).

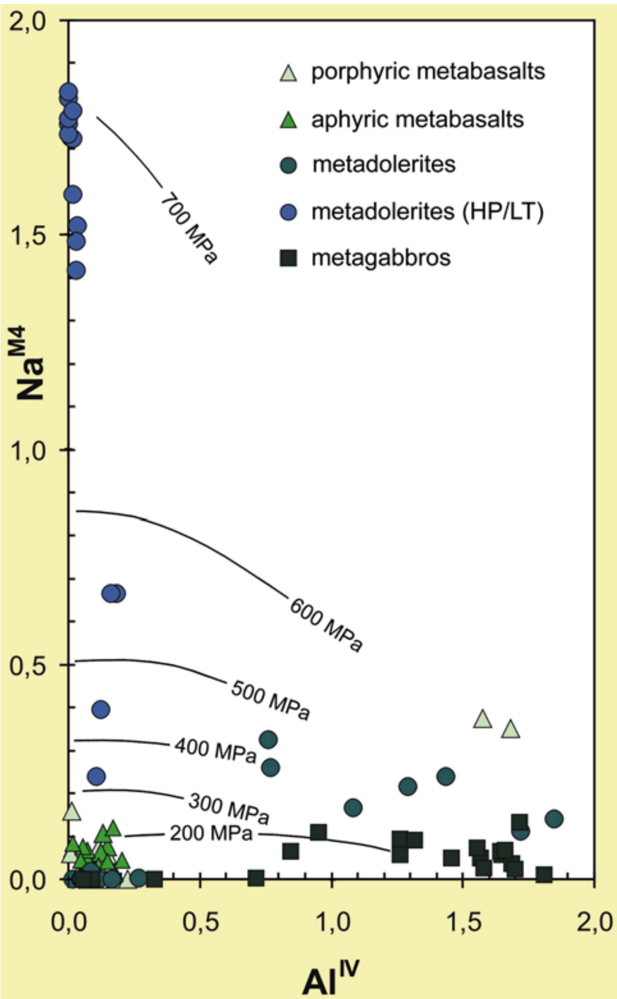

Fig. 13. Al^{IV} vs. Na^{B} diagram for amphiboles from the various types of the metamorphosed basic magmatic rocks from the Zlatník Group documents variability of p, T conditions during their metamorphic history. Pressure values are displayed using empirical geobarometer by Brown (1977).

Mineral associations in the metamorphosed sediments of the Závistlivec Fm. include except rarely preserved clastic grains of magmatic origin the metamorphic minerals only. As a result of variability in source material they are varying extraordinary in the mineral components and their proportions also at short distances. The association Ab + Chl + Hem/Mag ± Amp ± Czo/Ep ± Ser ± Cal ± Bt ± Qz is typical, amphibole is represented by Act or Na--Act, insignificantly also by Mrbk/Rbk and Wnc. The hydrothermally altered samples usually contain association Ab + Ser + Qz ± Dol/Sd ± Py. In some metapsammites the relatively abundant clastic brown spinel (Al-chromite), together with its metamorphic derivatives (Fe-chromite with the higher Zn content), have been found. As a source of spinels the ultramafic rocks of the suprasubduction origin are supposed (Méres et al., 2008a). Preserved metamorphic mineral associations in the metamorphosed sediments of the Závistlivec Fm. are the result of the metamorphism in the greenschist facies conditions, which was preceded by the HP/LT metamorphism in the greenschist facies conditions.

The epidosite veins with the association Ep ± Ab ± Py ± Cal in metagabbros represent the infill of the migration paths of hydrothermal solutions circulated in the oceanic rift environment (cf. Gillis, 2002; Kornprobst, 2003).

Geodynamic setting and geological evolution of the Zlatník Group

The continual profile composing of the metamorphosed basaltic lava flows in the Grajnár Fm. as well as the transitional geochemical signature of these metabasalts among N-MORB, E-MORB and BABB types indicate that the Grajnár Fm. was probably formed as the uppermost part of oceanic crust in the small oceanic basin opened after the rifting in the ensialic magmatic arc environment. The age of metabasalts was preliminary dated as ca. 385 My (Upper Devonian; SHRIMP, U-Pb method on zircon, Putiš et al., 2009). Limited extent of the basin opening is indicated by redeposited arc volcaniclastics in the uppermost part of the sequence (Méres et al., 2008). Very low-grade metamorphic alteration of the Grajnár Fm. could be probably related to obduction at the termination of the closure of the basin (Černák and Ivan, 2006).

In the present day geological structure of the Gemeric Superunit the Grajnár Fm. seems to represent the strongly reduced ophiolite nappe finally emplaced and metamorphosed during the Alpine nappe stacking.

The Závistlivec Fm. as ophiolite mélange resembles of mélanges frequently forming the lowermost part of some ophiolite complexes (e.g. Bortolotti et al., 2009; Ghikas et al., 2010). Blocks in this formation are derived from the deeper part of the oceanic crust than is present in the Grajnár Fm., whereas detritus contains also fragments of ultramafic rocks from the lowermost part of the ophiolite sequence and some effusive basaltic rocks. The sedimentary mélange matrix is partly derived from the altered and disintegrated rocks of the ophiolite sequence but its significant proportion represented by redeposited volcaniclastic material mostly acidic in composition was originally generated in volcanic arc. Metagabbros and metadolerites bear witness to their formation in the spreading zone in the form of the oceanic ridge-type metamorphism (Ivan and Černák, 2010). Overprinting of this metamorphic stage by very low-grade metamorphism in the prehnite-pumpellyite facies with transition to the HP/LT stage evidently reaching the blueschists facies conditions reflects probably the transport of the oceanic crust from the oceanic rift to accretion prism of the subduction zone. Based on all these facts the Závistlivec Fm. mélange could be classified as subduction mélange according to classification scheme by Festa et al. (2010). The age of the slab subduction and mélange creation are unknown for the present, the Lower Carboniferous as the upper limit could be probable for the reasons summarized bellow, although Jurassic age for HP/LT metamorphic stage (the age of the Meliata Ocean subduction in the inner Western Carpathians) cannot be still fully excluded. The latest metamorphic overprint in the greenschist facies conditions in the Závistlivec Fm. seems to be related to the Alpine tectonic activities and nappe stacking. In present day geological structure forms the Závistlivec Fm. a relatively small tectonic sheet underlie locally the Grajnár Fm.

Because the material generated originally in the oceanic crust prevails in the Zlatník Gr. it can be regarded as an ophiolitic rock complex despite the fact that it comprises a dismembered and incomplete ophiolite sequence. As indicated by the geochemical signature of basalts, the Zlatník Group seems to be most similar to P-type ophiolites in the present-day geochemical ophiolite classification by Pearce (2008). The volcanic rifted plate margin is a frequent geodynamic setting for this ophiolite type. The Alpine ophiolites from the Corsica (Saccani et al., 2008), which are the very close geochemical analogue of the Zlatník Gr. ophiolites, belong to the P-type ophiolites as well.

Potential correlation of the Zlatník Group with analogical units of the Western Carpathians and its significance for the recognizing of the geological structure of the region

Lithologies similar in petrography and geochemistry to the Zlatník Gr. rocks (metabasalts, metadolerites, metagabbros and metaultramafites) are located directly in the northern margin of the Gemeric Superunit and build up the Hrádok and Črmeľ Fms. of the Ochtiná Gr. (Vozárová, 1996; Ivan and Ježová, 2003). Both mentioned formations remind of the Závistlivec Fm. – they are probably mélanges too. The age of the metamorphosed magmatic rocks could be also similar, because the dating of the Ochtinná Gr. (Late Visean to Serpukhovian) is related to conodonts found in the carbonates of the uppermost formation of the group – the Ľubeník Fm. (Kozur et al., 1976). A very close analogue of the Zlatník Gr. in the area outside of the Gemeric Superunit is the Pernek Gr. – an ophiolitic unit from the crystalline complexes in the Malé Karpaty Mts., Považský Inovec Mts. and Suchý and Malá Magura Mts. (Tatric Superunit; Ivan et al., 2001; Ivan and Méres, 2006, 2011; Méres and Ivan, 2005, 2008; Méres, 2005). The Pernek Gr. comprises the rocks geochemically identical to the Zlatník Gr. and it is also close in age (360–380 Ma, Putiš et al., 2006). It seems to be very probable that the dismembered ophiolites, which are components of the Pernek, Ochtinná and Zlatník Grs. represent in current geological structure of the Western Carpathians relics of an ophiolite suture reactivated in Alpine era. This suture would be actually a record of the final evolution stage of the Upper Devonian/Lower Carboniferous oceanic basin, which was termed as the Pernek Ocean (Ivan, 2009). The suture could be interpreted as a fossil boundary separated two lithospheric paleoplates with different Variscan tectono-thermal evolution where the southern plate (in present day coordinates) was spared of the extensive plutonic activities and metamorphic reworking. On the other hand the northern plate displays quite different history – magmatic activity related to the subduction of the Pernek Ocean and formation of the magmatic arc led also to the intensive metamorphic alteration in the upper crust mainly due to increased thermal flow related to granitoid plutonism (cf. Barton and Hanson, 1989). Lower Carboniferous I- and S-type granitoids in the Veporic and Tatric Superunits of the Western Carpathians could be products of this plutonism. Evidence for the existence of the Upper Devonian/Lower Carboniferous ocean, mostly indirect for the time, has been detected also in the Eastern Alps. Neubauer and Handler (1999) supposed that such ocean separated the Noric Terrane (the Upper Austroalpine Superunit) from the more intensively metamorphosed Lower and Middle Austroalpine Superunits. Analogicaly it can be speculated that the northern part of the Gemeric Superunit together with some most external parts of the Tatric Superunit would be equivalents of the Upper Austroalpine Superunit. As possible relics of the Pernek Ocean in the Eastern Alps could be considered e.g. volcanic rocks with the geochemical signatures close to oceanic basalts from the Almont-Selztal area in the eastern part of the Greywacke zone (Schlaegel-Blaut, 1990; Loeschke and Heinisch, 1993).

If the global tectonic schemes (e.g. Stampfli et al., 2002) are taken into consideration then, interpretation of the Pernek Ocean as a small intraterrane basin in the framework of the Hun Terrane seems to be most possible. In the light of new interpretation of Variscan orogeny in the

Eastern Alps (cf. Frisch et al., 2011) also possibility that the Pernek Ocean could be originally an embayment of the Paleotethys Ocean scissors-like widened to the east cannot be excluded. In the Variscan Europe are the ophiolite relics thought to be almost exclusively the Cambrian or Devonian in age. Devonian ophiolites have been described from the NW Spain (Arenas et al., 2007; Sánchez Martinez et al., 2007). Cornwall (Great Britain), Giessen (Germany; Pin, 1990). Vosges (France; Skrzypek et al., 2012) or from the French Massif Central (Berger et al., 2005).

Conclusions

Based on interpretation of data obtained from our field, petrografic and geochemical studies we came to following conclusions:

• In the northern part of the Gemeric Superunit we define a new ophiolitic lithostratigraphic unit probably the Upper Devonian in age – the Zlatník Group (Gr.) has been defined

• The name of the group is preserved from the previously used term – the Zlatník Formation (Fm.), but its position, lithology, age, geodynamic setting and geological history have been fully redefined

• The Zlatník Gr. is divided into two formations: (1) upper the Grajnár Fm. and (2) lower the Závistlivec Fm.

• The Grajnár Fm. is dominated by metabasalts, in the upper part are also metamorphosed sediments present formed mostly from dacitic volcaniclastic material

• The Závistlivec Fm. is represented by sedimentary mélange where blocks of metagabbros, metadolerites, acid differentiates and epidosites are embedded in matrix composed of the sedimentary material with variable granularity (from pelites to breccias) derived from magmatic rocks

• Geochemical signature of the metamorphosed basic magmatic rocks of the Zlatnik Gr. is transitional among N-MORB, E-MORB and BABB types

• Three sources of sedimentary material have been discerned: (1) acid volcaniclastics of the volcanic arc origin, (2) disintegrated and altered basic magmatic rocks of the Zlatník Gr. and (3) disintegrated and altered ultrabasic mantle rocks

• The Grajnár Fm. rocks are metamorphosed in the prehnite-pumpellyite facies variable overprinted by the greenschist facies metamorphism, the Závislivec Fm. underwent the multistage metamorphism from the oceanic ridge type metamorphism trough metamorphism in prehnit--pumpellyite and blueschist facies up to greenschist facies metamorphism

• The Zlatník Gr. was formed as the upper crust of small oceanic basin during its opening in the proximity of volcanic arc and lately obducted (the Grajnár Fm.) or destroyed, transformed on mélange and partly subducted in the accretion prism related to subduction zone (the Závistlivec Fm.)

• The Zlatník Gr. together with the analogous Ochtiná and Pernek Groups probably represent relics of the Upper Devonian/Lower Carboniferous Pernek Ocean

• The Pernek Ocean relics are interpreted as an ophiolite suture which seems to be the boundary between two lithospheric paleoplates with the different Variscan tectono-thermal and magmatic history

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Appendix:

Lokalization of samples presented in the paper:

FD-210: Hnilčík village, Hliniskový potok valley, N 48°52'16.15''; E 20°31'42.08''

FD-214: Hnilčík village, Hliniskový potok valley, N 48°52'12.78''; E 20°31'42.36''

FD-221, FD-222: Hnilčík village, Zimná dolina valley, SE slope, N 48°52'18.60''; E 20°31'32.27''

FD-233: Grajnár saddle, way to Štolwerk settlement, N 48°51'47.38''; E 20°30'44.66''

FD-268: Mlynky village, Havrania dolina valley, borehole BM-1, 511 m, N 48°51'51.80''; E 20°26'20.49''

FD-381: Grajnár saddle, way to Štolwerk settlement, N 48°51'44.17''; E 20°30'43.81''

FD-398: Dobšiná, Kolkova stodola hill, N 48°50'54.89''; E 20°21'18.57''

FD-420: Hnilčík village, Hliniskový potok valley, N 48°52'13.94''; E 20°31'46.03''

FD-421: Hnilčík village, Hliniskový potok valley, N 48°52'14.26''; E 20°31'49.95''

FR-305: Poráč village, Zlatník valley, ridge of W slope, N 48°53'23.87''; E 20°42'30.60''

FR-343: Rudňany village, Závistlivec settlement, Sivá skala hill, N 48°51'53.69''; E 20°39'33.06''

FR-350: Rudňany village, Závistlivec settlement, Rudniansky les area, N 48°52'00.75''; E 20°39'58.82''

FR-351, FR-352: Rudňany village, Závistlivec settlement, Sivá skala hill, N 48°51'49.20''; E 20°39'37.56''

FR-367: Rudňany village, Závistlivec settlement, Sivá skala hill, N 48°51'48.57''; E 20°39'39.13''

FR-411: Rudňany village, Závistlivec settlement, Rudniansky les area, N 48°51'50.54''; E 20°40'01.79''

FR-414: Rudňany village, Závistlivec settlement, Sivá skala hill, N 48°51'47.90''; E 20°39'39.86''

FR-446: Rudňany village, Závistlivec settlement, N 48°52'03.27''; E 20°40'26.79''

FR-463: Poráč village, Zlatník valley, N 48°53'27.60''; E 20°43'02.94''

KG-4: Rudňany village, Závistlivec settlement, N 48°52'00.06''; E 20°39'32.82''

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