Slovak Geol. Mag., 6, 4(2000), 347–361

The Sparistá dolina Granitic Mylonites – the Products of the Alpine Deformation

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Abstract. Granitic rocks deformed into mylonites and ultramylonites during the Alpine collisional and/or shear zone deformation were studied in the Veporic unit, north of the village of Bacúch (Central Western Carpathians). The brittle-ductile to ductile deformation shows penetrative character throughout the granitoid body. S-C mylonite fabric due to an increase of strain and grain-size reduction is transformed into a single foliation fabric. New metamorphic mineral assemblage replaces the primary magmatic mineral composition. Allochemical processes documenting the mobility of some major and trace element accompanied these mineral changes. Mass-transfer, depending on progressive deformation, was facilitated only moderately by the percolation of external fluids. The composition changes reflect a loss of Fe, Mg, Mn, Ca, Sr, Ba and Ti, and/or a gain of K, Li and Rb. The phengite content up to 7.1 pfu of white mica in the assemblage muscovite-K feldspar-biotite-quartz reveals a peak pressure of ca. 12 kbar, reflecting conditions of the Cretaceous metamorphism in the Veporic basement. However, we infer for the first (progressive stage) of deformation an average pressure ca. 9 kbar, reflecting the creation of ultramylonites, while mylonites in the second period show only 6 kbar of average pressure. These pressure conditions, together with a temperature of 350 – 550°C, are common for orogenic belt metamorphism at convergent plate margins. The well-defined $^{40}Ar/^{39}Ar$ age spectra with 78 ±1.3 Ma (PA and TGA), indicates formations of these white micas during the second deformation period. This age reflects the cooling in the consequence extensional processes leading tectonic unroofing and/or exhumation of basement during the Late Cretaceous, which generally followed the peak time of burial and post-thickening thermal relaxation.

Key words: Western Carpathians, Veporic unit, granitic rocks, mylonites, chemical changes, dynamic metamorphism, $^{40}Ar/^{39}Ar$ dating, tectonic evolution.

Introduction

The polymetamorphic and polyorogenic character of the Veporicum crystalline basement had already been identified by Zoubek (1936). Later this interpretation was supported by Vrána (1966), Kamenický (1977) and Hovorka et al., (1987) among others. Zoubek´s conception (l.c.) of the Veporicum division into regional zones was overcome by a nappe-style classification proposed by Klinec (1966). The distinct sign of the whole Veporicum basement is its deformation. The intensity of the deformation varies from relatively non-deformed domains to ulramylonite zones, commonly indicating the existence of shear and thrust zones. The Alpine tectonic – metamorphic strain deformation of the Veporicum increases not only in the direction from northwest to southeast (Vrána, 1964), due to collision-subduction under the overthrusting Gemericum, but also from the margins to centers of thrusting and shear zones, as for example the Pohorelá lineament and Muráň fault (Hók and Hraško, 1990; Putiš et al., 1997). The Alpine deformation and the recrystallization of the Veporicum crystalline complexes is related to the Middle Cretaceous collision (Andrusov, 1968; Biely, 1989), or to the closing of the Meliata Ocean during the Late Jurassic to Early Cretaceous (Kozur, 1991; Plašienka, 1991).

During the metallogenetic research of the northern Veporicum – Kráľová Hoľa part, several occurrences of granitic rocks were thoroughly studied in the eastern part of the Nízke Tatry Mts. Among others, granitic rocks of the Sparista dolina type, in sense of Miko et al. (1982), were studied. The purpose of this article is to present the existence of the significantly deformed granitoid rocks – mylonites and ultramylonites, in northwestern part of the Veporicum. Based on mineral transformations, the chemical and metamorphic changes in the rocks are discussed. The high-pressure character of the deformation is identical with the degree of deformation of the granites in southeastern part of the Veporicum, in sense of Plašienka et al. (1999). The Late Cretaceous age of the tectonic-metamorphic processes, slightly postdating the movement of the superficial Mesozoic nappes in the Central Western Carpathians (CWC), is a reflection of the exhumation of the basement due to extension movement after collisional crustal thickening.

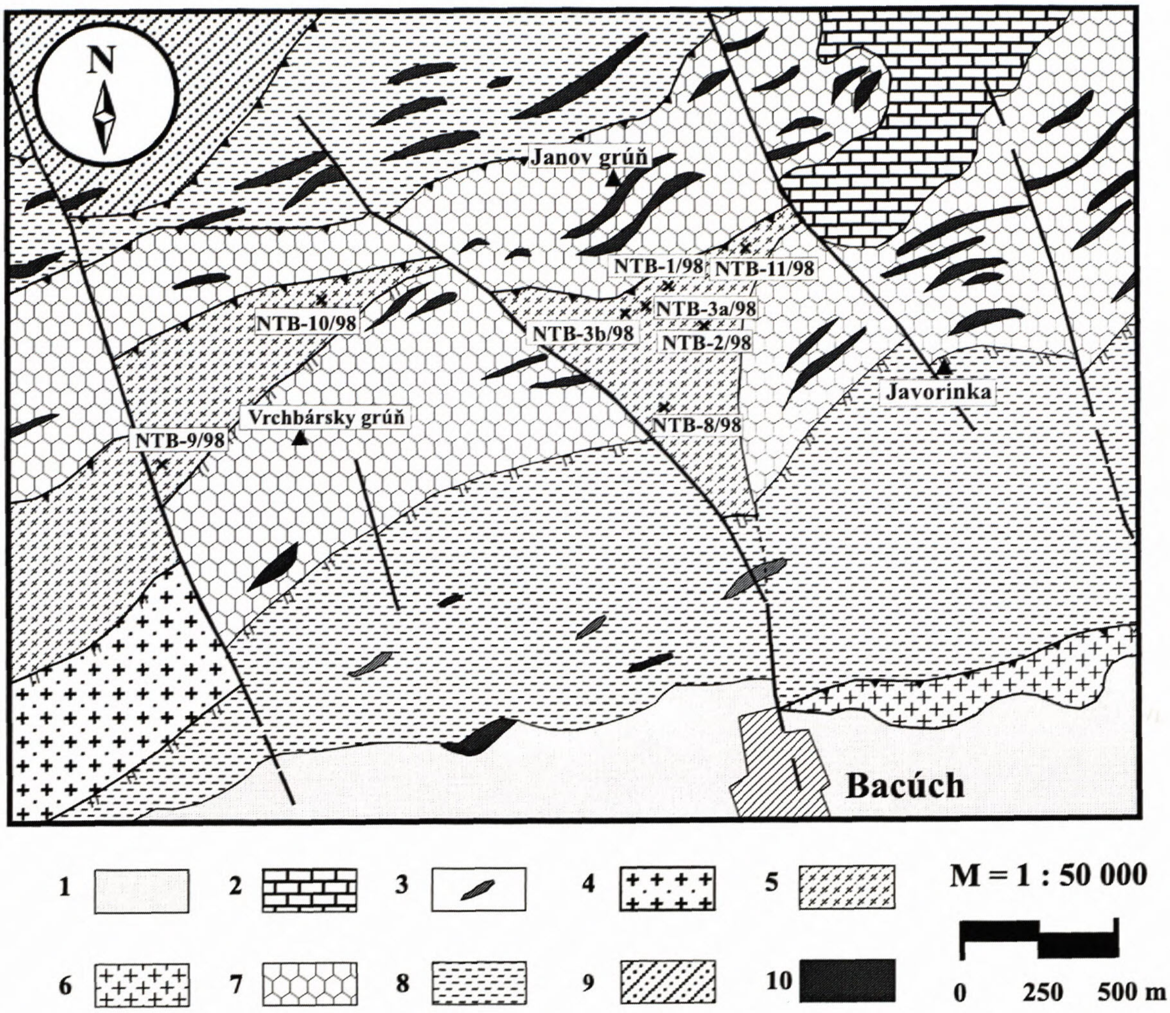

Fig. 1 The geological sketch of the studied area by Biely et al. (1992), slightly modified by authors, with localization of the sample sites. Explanation: 1 – Quaternary, 2 – Mesozoic, 3 – pegmatite and aplite, 4 – muscovite – biotite granodiorite and granite, 5 – SDGM, 6 – biotite granodiorite to tonalite, 7 – chlorite – sericite phyllites of Janov grúň, 8 – mica-schist gneisses – mica schists, 9 – migmatitized gneisses, 10 – metabasalts (green schists ± amphibolites).

Geology Settings

Northerly of the village Bacúch in the valley of Bacúch creek, Leňuša, Kršková, Zamrzlá and Sparistá valleys there are bodies of granitoid rocks in the form of imbricated plate slices. They are tectonically incorporated into the Hron complex in the sense of Klinec (1966) or in the formation of the Janov grúň in the sense of Miko (1981) (Fig. 1).

The first remarks about the sheared granites in the Krakľová zone of the Veporicum at the ridge part of the Nízke Tatry Mts. were done by Zoubek (1935). He considered this rocks as an abyssal analogue of the Permian intrusion, part of these hybrid igneous rocks he identified as „Muráň orthogneiss". Klinec et al. (1971, 1973) and Klinec (1976) proved the tectonic position of the granitoid blocks overlapping the metamorphites of the Hron nappe, in the area Domárky – Kolesárová – Veľká Vápenica. The Permian age of the granitoids from the Bacúch area was unfixed by the authors (l.c.), based on the conformable fabric. During the late 70-ies and early 80-ies Miko (1981) was working in this area. Within the frame of the Hron complex, he distinguished weakly metamorphosed beds of the Janov grúň formation and tectonically imbricated granite slices. Based on the chemical composition of these granitic rocks the author l.c. assumed their affinity to plagiogranites of the early-orogene gabbro-plagiogranite formation. Miko et al. (1982) gave the first semiquantitative and qualitative geochemical characteristics of these deformed granitoids and for their clear distinction from other Veporicum granitic rock occurrences he named them „granitoids of Sparista dolina type". During the following periods these rocks were subjected to mineralogical studies; different aspects of chemical composition and typology of accessory minerals were studied mainly by Hraško (1983) and Hraško & Miko (1990). The typology of the zircon expressly excluded the mantle origin of these granitoids.

The age of these problematic rocks has not been reliably resolved yet. The influence of Zoubek´s inferences lasted until the end of 70-ies and it was reflected in the cartographic plots of the general geological maps of CSSR at 1:200,000 and 1:500,000 scales. In these maps were marked these primary igneous rocks as Late Paleozoic – Permian intrusions (Maheľ et al., 1964). Klinec et al. (1971; 1973) classified the deformed granitoids of the

Bacúch area into the Early Paleozoic rock complexes. This opinion was also supported by the U-Pb dating of zircons from the Leňušska valley – 370 Ma (Cambel et al., 1977), which until now is the only relevant date from these deformed granitoids that suggests the time of their primary origin. Although the Early Paleozoic time classification was accepted in the published maps of the Nízke Tatry Mts. at a 1 : 50,000 scale (Biely et al., 1992) and Slovakia at 1 : 500,000 scale (Biely et al., 1996), the primary origin of these deformed igneous rocks is not yet adequately established, due to the intensive Alpine metamorphism. The tectonic-deformation metamorphism of the studied rocks is significant enough. The connection with the Alpine Orogeny is the traditional one, now accepted for a long time, and it was proven of the „granitoids of the Sparistá dolina type" by Bagdasarjan et al. (1977) by means of the K-Ar method. The age determined was 104 – 97 Ma.

Methods

For the needs of complex research, we took 10 geochemical samples with weights of 10 – 15 kg, from which we have selected 8 samples for the detail geochemical study. The chemical composition of the samples was analyzed in the Geoanalytical Laboratory of GSSR in Spišská Nová Ves with use of AES ICP (Atomic Emission Spectrometry with Inductively Coupled Plasma) and XRF (X-Ray Fluorescence Spectrometry) methods. Quality control was verified on natural, international standards GM (granite) and BM (basalt) from ZGI Berlin. More analytical details are available, for example, in the Geochemical Atlas - rocks of SR (Marsina et al., 1999).

The mineral composition was analyzed in the laboratory of Electron Microanalysis of GSSR in Bratislava with JEOL – 733 Superprobe and KEVEX Delta, energy dispersion analyzes (EDS) under standard conditions 15kV and 12^{-10}A, with the use of natural and synthetic standards Taylor.

The $^{40}Ar/^{39}Ar$ isotopic dating was performed in the joined isotope laboratory of the Geological Survey of Austria (BGA) and the University of Vienna (BVFA ARSENAL). For this purpose we have selected three samples (NTB – 2, 3, and 11) from which mineral phases biotite and white micas – phengite were selected in the separation laboratories of the Department of Isotope Geology of GSSR, Bratislava. The mineral separation was done by mean of standard methods: through the use of a separating Wilfley table, electrostatic separator (made by the Department of Nuclear geology, GÚDŠ), Cook magnetic separator, heavy liquids, manual final cleaning under binocular microscope, and purification by methanol and re-distilled water in ultrasonic scrubber. The procedure for $^{40}Ar/^{39}Ar$ measurements in AVFT AESWNAL is described by Kráľ et al. (1995). The samples (charges of 8 – 10.5 mg) were sealed into siliceous capsules and together with internal standard WAP with the value of radiation parameter J = 0.003274 – 0.00495 (error ±0.4%) irradiated in the ASTRA reactor by a portion of accelerated neutrons about 10^{17} neutrons/cm$_{ˇ}$. The samples were analyzed with the Mass Spectrometer MS VG 5400. Argon was released through a high-frequency generator by mean of a classical process, i.e., gradual temperature releasing (SBSH) in 6–10 temperature steps to 650–1250°C. The measured isotopic conditions were evaluated by a routine process developed by the company VG, with use of the recommended decay constants for the age calculation according to Steiger and Jäger (1977) and based on McDougall and Harrison (1988).

Petrographic Characteristics

„Granitoids of the Sparistá dolina" have a pale-gray to greenish-gray color. They are fine- to medium-grained rocks, mostly with equigranular structure. Layers with homogeneous fine-grained fabric (with a maximum grain size up to 1 – 1.5 mm) are altered within relatively homogeneous layers, where quartz-feldspar porphyroclasts with a size of 1 – 2.5 mm are evenly distributed in the fine-grained groundmass. Layers with inhomogeneous mylonitic – porphyroclastic fabric were observed in the lower extent. Larger, unevenly distributed porphyroclasts, as much as 5 mm in size occur only locally. In this rock we can visually identify quartz, feldspars and biotite porphyroclasts. The matrix comprises fine-grained quartzo-feldspatic layers and fine-grained muscovite – sericite interlayers, forming an anastomosing (dendroidal) network. The dominating feature of all the studied mylonite samples is their penetrative deformation that is characterized by a significant foliation, in most cases with typical twincleavage S-C mylonite fabric (Berthé et al., 1979; Lister and Snoke, 1984), (Fig. 2a). Locally, we can observe extension fractures (discordant to a C shear- plane and parallel with a first S deformation foliation), filled with chlorite, that were consequently in the second deformation stretched and sigma-like folded (Figs. 2c and 3h). The original fabric of the igneous rock was completely overprinted by the effects of the pressure – deformation and metamorphic recovery to dynamofluidal – plane-parallel, eye-shaped up to mylonitic fabric (Figs. 2a-c). The lineation of sericite can be occasionally observed on the foliation planes.

The effects of the cataclasis, ductile deformation and recrystallization of the original granitic mineral assemblage were also observed in a micro-scale (Figs. 3a-f). The deformation is connected with a reduction of the grain-size (quartz and K-feldspar), locally also with the creation of sub-grains and shifts on the grain rims. Quartz commonly forms fine-grained ribbons with grain-size under 0.01 mm (Fig. 3g). The mylonite deformation is also documented by the formation of mica fish (Fig. 3c). Along with the deformation increase, the angle of two foliation planes (S-C) is changed as well, from values of 45 – 30° to 15 – 10°, and in the ultramylonite it disappears totally (Figs. 3a-e) and we observe only one dominant foliation (cleavage). Of the primary minerals there are present: quartz, plagioclase, K-feldspar, biotite, ± muscovite and the accessories: zircon, apatite and monazite. Of the newly developed minerals, the dominant ones are plagioclase with an albite composition and fine-grained

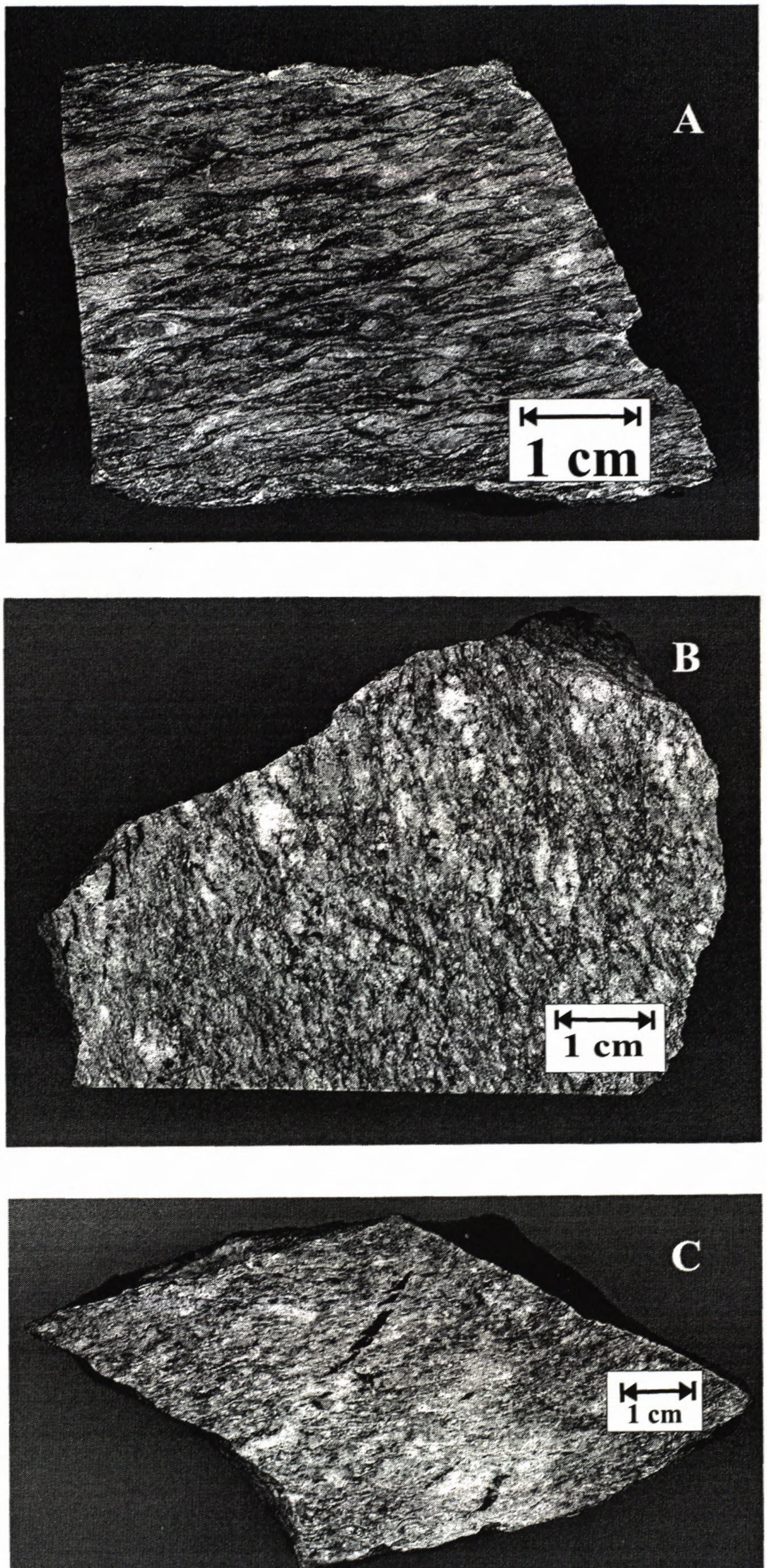

Fig. 2A – eyed fabric of the mylonite, the sample NTB – 3a, S-C fabric indicates crossing shear bands,
2B – indistinctive S-C fabric of mylonite, sample NTB-3b,
2C – extension veins filled with chlorite in ultramylonite of the sample NTB-1.

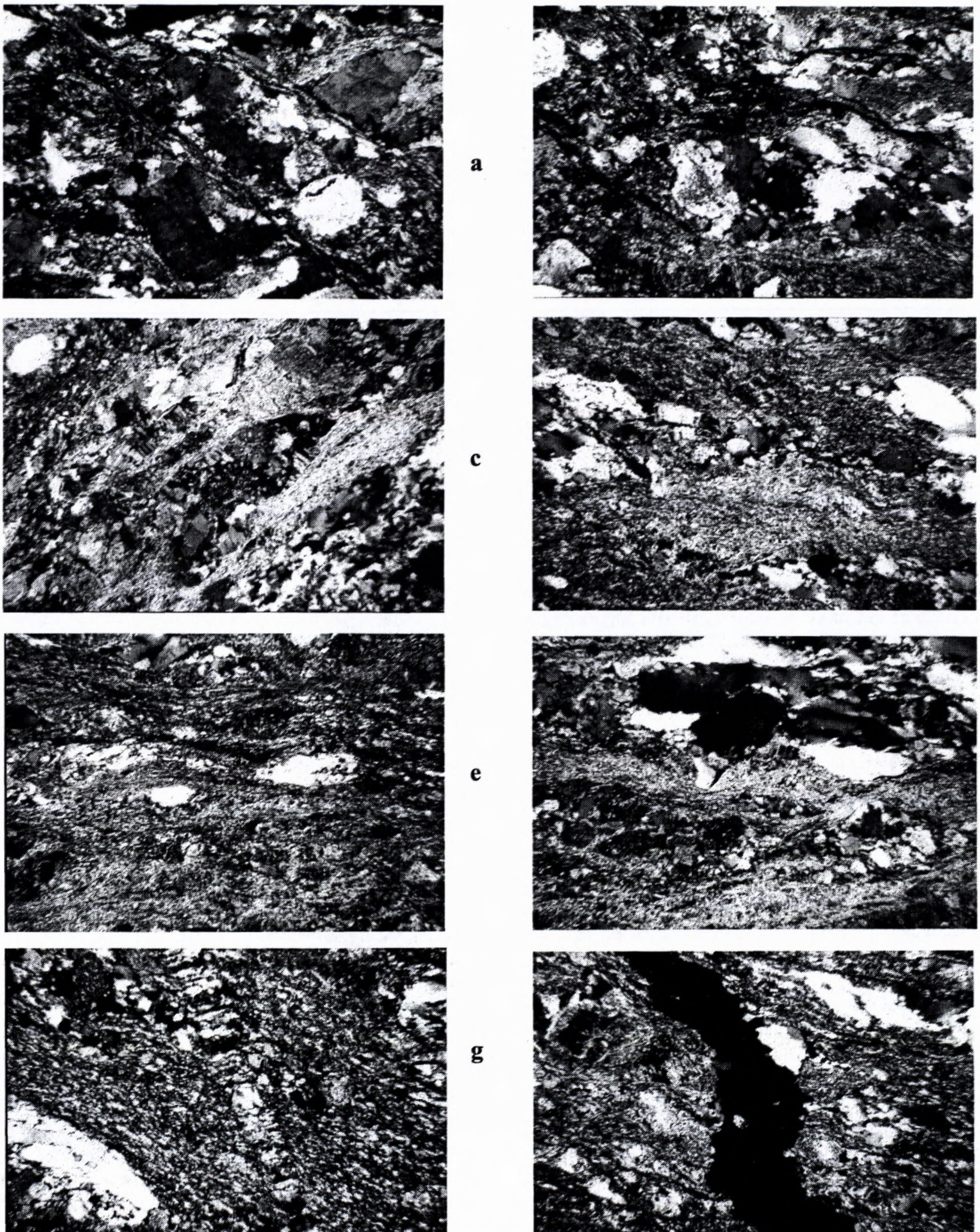

Fig. 3 Microphoto documenting growth of the progressive deformation from porphyroclastic structure – (3a) to ultramylonite structure (3e) in SDGM, 3g – extension vein filled with quartz, 3h – extension vein filled with chlorite. Crossed nicols. Width of the photo = 1.5 mm.

muscovite mica – sericite (phengite). Within the framework of the secondary minerals we observed also epidote, clinozoisite, chlorite (Fig. 3h), carbonates, titanite, ± garnet, rutile, ± bauerite and sagenite. Signs of the original magmatic – hypidiomorphic fabric is observed only in the greater „augen“ – porphyroclasts. The dominant fabric of this pressure – deformed rock is porphyroclastic, and/or mylonite fabric. The modal composition is given on table 1.

Based on the petrographic analysis, we identify this rock as *porphyroclastic (eye-shaped) granitic mylonites to ultramylonites*, or simply as **Sparistá dolina granitic mylonites (SDGM).** Our evaluation of these rocks is partly in agreement with identification according to Miko et al. (1982); however, we prefer the designation „mylonite" over granitoid, because this rock is more tectonically metamorphosed rock than is a magmatic rock in current form.

Tab. 1 The modal composition of the studied SDGM mylonites.

Mineral	NTB-1	NTB-2	NTB-3a	NTB-3b	NTB-8	NTB-9	NTB-10	NTB-11
Quartz	33,1	32,3	35,7	35,8	32,7	35,4	35,2	33,8
Plagioclase/Albite	24,9	25,4	23,5	25,7	24,1	26,2	24,4	22,7
K-feldspar	5,4	6,3	5,6	5,0	5,8	4,7	4,6	4,2
Biotite	3,6	2,3	1,5	1,2	3,1	1,3	2,2	3,8
Muscovite/Sericite	21,6	22,2	25,4	24,0	22,1	24,5	21,3	22,1
Epidote - Zoisite	4,3	5,2	3,9	3,6	5,5	3,2	5,6	5,2
Chlorite	2,4	1,6	0,8	1,1	1,8	0,9	1,7	1,9
Calcite	2,9	3,1	2,1	2,4	3,0	2,5	3,4	4,4
Accessories	1,8	1,6	1,5	1,2	1,9	1,3	1,6	1,9

Geochemical characteristics

The composition of the mylonites is shown on table 2. The table revealed that the rocks do not have economically interesting mineralization. The analytical values of the samples are in good agreement with the average content of the main and trace elements of the rocks of the upper part of the Earth´s crust and/or the granitic rocks according to Wedepohl (1969), Taylor and McLennan (1985). They are comparable with another nonmetallic (barren) granitic rocks of the Western Carpathians – more data can be found in the Geochemical Atlas - rocks of SR (Kohút in Marsina et al., 1999). Because these rocks are categorized into a group of tectonically deformed rocks, we compared the chemistry of the samples with analogues of the deformed rocks – orthogneisses from the Western Carpathians. The comparison was done with data from the rock catalogue (Marsina et al., l.c.), and also with newer data (Putiš et al., 1997). The particularity of the samples was recognized as a consequence of the high-grade (tectonic + metamorphic) strain deformation.

The rocks (SDGM) represent tectonically deformed analogues of magmatic – granitic rocks. Keeping in the mind the petrographic character of the rocks and the general rules of the changes that are observed during the deformation – metamorphic processes of similar rocks (Vrána, 1964; Kerrich et al., 1977, 1980; Marquer, 1989; and citations therein), and with respect to the chemical composition we do not infer a mantle origin of the magmatic precursor of these rocks. Most probably, the SDGM represent analogues of calk-alkaline magmatic rocks that originated from the hybrid crust/mantle types on the continental margins during the subduction processes (VAG, CAG). The SDGM chemically correspond to greywackes or recycled andesite rocks (basaltic andesite), from which biotite and amphibolite – biotite granodiorite to tonalite were formed. From the granitic rocks occurring in the Veporicum, tonalite of the Sihla type match this characteristic best.

However, for the possibility of tracing the changes in distribution of the individual elements during the deformation processes, we compared our values with an average composition of the relatively unstrained Sihla tonalite that, as we assume, was the precursor of these mylonites (Tab. 3). The average composition was obtained on the basis of published and archived sources (Broska and Petrík, 1993; Marsina et al., 1999). The graphic visualization of the distribution of the main and the most important trace elements of the SDGM compared to the average Sihla tonalite composition is shown in figure 4.

As we indicated from table 3 and figure 4, during the dynamic metamorphism that effected the hypothetical precursor of the SDGM – the Sihla tonalites, allochemical changes due to cataclasis and pressure solution (Kerrich et al., 1977), leaching and recrystallization of a new mineral assemblage have been occurred. A significant depletion (as much as 50%) occurred in the case of iron, strontium, barium and titanium. During the mylonitization, the original tonalite was depleted of as much as 25 % of its magnesium, calcium and zirconium content. In contrast, a 20 - 50 % content increases were registered in the case of potassium, rubidium and partly also of lithium. Also slightly increased are the contents of sodium and silica. A balanced distribution is the case of aluminum, which is in agreement with the generally accepted ideas about its limited mobility. All these chemical changes occurred due to mineral changes during recrystallization. The changes of the content of FeO^T, MgO, CaO and Ba reflects a destruction and the following recrystallization of biotite mica and plagioclase, which is also directly related to the main changes in content of alkalies (K_2O, Na_2O), Li and Rb, due to crystallization of sericite and albite. Other elements (Tab. 3), Ta, Co, Cr, U and V have balanced distributions, Nb, Y, Hf, Ni, Zn, Th and REE have decreasing contents. In contrast, Be, Pb and Cu have increasing contents. These rocks have record of REE identical with that of rocks melted in the active continental arc with a combined crust type – recycled continental with contribution of primitive mantle magma, melted in the lithospheric wedge. Assimilation-fractional processes most probably cause the intermediate character of the tonalite-granodiorite rocks. In the magmatic rocks the REE are preferably bonded with the accessory minerals (monazite, apatite, allanite, garnet, etc.). In the process of dynamic metamorphism these mineral forms were also attacked and broken-up (monazite, allanite), and instead of them mainly REE-rich epidote crystallized, which is in agreement with observations by Petrík et al. (1995) and Broska and Siman (1998). Titanites crystallizing at the expense of biotite micas and plagioclases contributed slightly in increasing of the HREE content (Fig. 5).

Tab. 2 The chemical composition of the studied rocks

Sample	NTB-1	NTB-2	NTB-3a	NTB-3b	NTB-8	NTB-9	NTB-10	NTB-11
SiO_2	68,08	68,33	68,46	67,21	68,22	68,59	69,69	69,09
TiO_2	0,45	0,43	0,32	0,37	0,41	0,35	0,39	0,33
Al_2O_3	15,15	14,47	14,43	16,18	15,08	14,98	13,97	15,07
Fe_2O_3	0,85	0,80	0,78	0,74	0,77	0,95	0,73	0,72
FeO	1,88	1,81	1,41	1,59	1,73	1,34	1,73	1,41
MnO	0,05	0,04	0,06	0,05	0,05	0,04	0,05	0,05
MgO	1,30	1,65	1,26	1,15	1,46	1,00	1,18	1,10
CaO	2,23	2,15	2,68	2,58	2,35	3,03	2,47	2,57
Na_2O	3,67	3,64	4,16	4,73	4,02	4,26	4,89	4,61
K_2O	3,71	3,91	3,30	3,21	3,74	3,31	2,43	2,96
P_2O_5	0,13	0,13	0,14	0,13	0,15	0,13	0,12	0,13
H_2O+	1,75	2,05	2,29	1,31	1,81	1,81	1,96	1,45
H_2O-	0,38	0,39	0,41	0,43	0,20	0,24	0,36	0,37
Total	99,63	99,80	99,70	99,68	99,99	100,03	99,97	99,86
B	7	9	9	11	10	7	9	10
Ba	460	229	236	402	385	315	301	381
Rb	116	136	125	78	124	98	90	96
Sr	249	177	197	457	268	338	354	337
Zr	157	150	123	120	141	154	143	125
Nb	8	7	7	5,3	7	6	0,7	6
Y	10	11	9	7	10	10	10	8
Hf	4	3	3	1	4	4	4	3
Ta	1	1	1	2	2	1	1	1
Be	2,6	2,5	3,7	2,4	2,8	2,6	2,6	2,6
Li	38	35	27	26	34	26	21	29
Co	6	5	4	6	5	5	5	5
Cr	30	27	15	18	25	18	20	19
Ni	10	10	1	8	8	2	3	1
Pb	5	7	5	21	6	20	9	18
Cu	13	8	12	8	11	108	28	9
V	49	43	34	34	44	46	46	42
Zn	45	41	23	58	43	52	52	54
Th	6	6	4	2	6	5	6	5
U	2	2	2	1	2	2	2	2
La	26,00	26,00	24,00	19,00	25,00	23,00	26,00	21,00
Ce	36,00	37,00	35,00	28,00	36,00	35,00	38,00	29,00
Nd	18,00	18,00	15,00	13,00	17,00	14,00	15,00	13,00
Sm	4,50	5,00	4,00	3,00	4,50	3,80	3,00	3,50
Eu	0,90	0,90	0,80	0,60	0,90	1,00	0,65	0,70
Gd	2,60	2,70	2,50	2,10	2,40	2,60	2,60	2,00
Tb	0,40	0,38	0,37	0,30	0,40	0,35	0,40	0,33
Tm	0,24	0,24	0,23	0,19	0,22	0,22	0,23	0,20
Yb	1,10	1,10	1,00	0,80	1,10	0,90	1,20	0,80
Lu	0,15	0,15	0,14	0,12	0,15	0,14	0,14	0,13

Tab. 3 Comparison of the average composition of the precursor – Sihla tonalites (Sihla T) vs. composition of the SDGM, (SDGM – average composition, Min – minimum values of the composition, Max – maximum values of the composition, St.Dev. – standard deviation).

	Sihla T	SDGM	Min	Max	St.Dev.
SiO_2	64,95	68,46	67,21	69,69	0,73
TiO_2	0,81	0,38	0,32	0,45	0,05
Al_2O_3	15,72	14,92	13,97	16,18	0,66
Fe_2O_3	2,05	0,79	0,72	0,95	0,08
FeO	2,53	1,61	1,34	1,88	0,21
MnO	0,07	0,05	0,04	0,06	0,01
MgO	1,76	1,26	1	1,65	0,21
CaO	3,25	2,51	2,15	3,03	0,28
Na_2O	4,01	4,25	3,64	4,89	0,47
K_2O	2,52	3,32	2,43	3,91	0,48
P_2O_5	0,36	0,13	0,12	0,15	0,01
H_2O+	1,45	1,80	1,31	2,29	0,31
H_2O-	0,22	0,35	0,2	0,43	0,08
Total	99,7	99,83	99,63	100,03	0,15
B	4	9,00	7	11	1,41
Ba	640	338,63	229	460	82,13
Rb	71	107,88	78	136	20,22
Sr	541	297,13	177	457	92,33
Zr	174	139,13	120	157	14,65
Nb	11	5,88	0,7	8	2,25
Y	16	9,38	7	11	1,30
Hf	7	3,25	1	4	1,04
Ta	1	1,25	1	2	0,46
Be	2	2,73	2,4	3,7	0,41
Li	26	29,50	21	38	5,68
Co	6	5,13	4	6	0,64
Cr	20	21,50	15	30	5,21
Ni	10	5,38	1	10	4,00
Pb	8	11,38	5	21	7,03
Cu	5	24,63	8	108	34,31
V	48	42,25	34	49	5,52
Zn	70	46,00	23	58	10,98
Th	8	5,00	2	6	1,41
U	2	1,88	1	2	0,35
La	46	23,75	19	26	2,60
Ce	91	34,25	28	38	3,69
Nd	39	15,38	13	18	2,07
Sm	6,5	3,91	3	5	0,73
Eu	1,6	0,81	0,6	1	0,14
Gd	4,9	2,44	2	2,7	0,26
Tb	0,6	0,37	0,3	0,4	0,04
Yb	1,5	1,00	0,8	1,2	0,15
Tm	0,23	0,22	0,19	0,24	0,02
Lu	0,21	0,14	0,12	0,15	0,01

The tectonic-deformation processes, and with them connected allochemical changes, lead to recrystallization of the new mineral assemblage under changed pressure-thermal conditions. During these processes circulation of fluids occurred, not only within the framework of the granitic rocks itself, but also in surrounding metamorphic complexes. The yield of individual components within the granitic rocks and their diffusive transportation in the form of metamorphic fluids had to lead, on the other hand, toward their concentration at another place. Preliminary, within the Sparistá dolina granitic mylonites we have registered only the extension veins filled with silica – albite – chlorite mineral assemblage, which documents the migration of lithophile (Si, Na), as well as

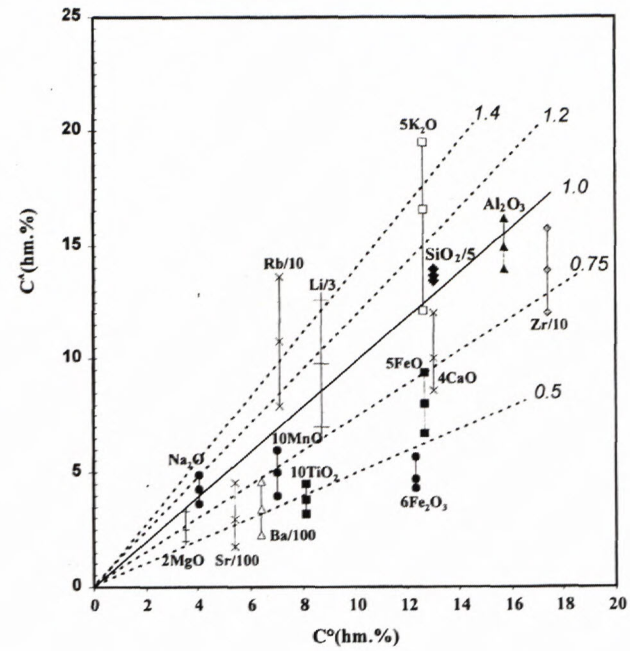

Fig. 4 Relationship between chemical composition of the SDGM (C^A) and composition of the precursor – the Sihla type tonalite (C°) from Tab. 3 (the composition of the main elements is in wt.%, the trace elements in ppm) in the isocone diagram according to Grant (1986). The composition of the SDGM mylonites is shown by the interval between minimal and maximal content, as well as by their average composition.

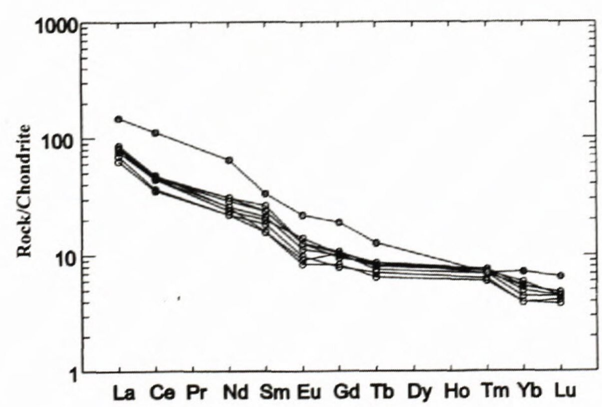

Fig. 5 Diagram of chondrite normalized contents of REE in the studied rocks. Symbols: empty circle - SDGM, filled circle – average composition of the Sihla type tonalite, table 3.

siderophile (Fe, Mg) elements. Since this deformation occurred in the extreme depths (>20 km), we assume only limited influence by external fluids, which would be facilitated the shear deformation of the former granitic rocks and its strain for SDGM.

Metamorphic Conditions

Whereas the petrographic studies clearly proved the penetration character of the deformation changes, as well as the metamorphic character of these rocks in the present state, we tried to identify the degree of metamorphism and the overall metamorphic conditions of the origin of these mylonitic rocks. We determined the thermal-pressure conditions of the deformation on the basis of the structural-deformational criteria and mineralogical-petrological conditions. For these purposes it was necessary to know the composition of the mineral phases contributing to the fabric of the mylonites, because during the crystallization they recorded pressure-thermal conditions of closing the crystallization lattice. The chemical composition of the analyzed mineral phases is shown on tables 4 – 6.

Tab. 4 The representative chemical composition of the feldspars (a – plagioclase, o – K-feldspar) from the SDGM. The recalculation is based on 8 oxygens.

	NTB-3/1a	NTB-3/3a	NTB-2/3a	NTB-2/5a	NTB-10/3a	NTB-1/1a	NTB-1/4a	NTB-3/2o	NTB-2/1o	NTB-1/3o	NTB-1/4o
Na_2O	11,35	11,18	11,45	11,08	11,36	11,36	11,70	0,00	0,00	0,21	0,10
Al_2O_3	19,64	20,14	19,99	19,98	20,05	19,89	19,57	18,17	18,38	18,35	18,62
SiO_2	67,92	68,42	67,76	67,68	67,41	68,79	68,54	64,83	65,05	64,55	65,06
K_2O	0,16	0,16	0,11	0,11	0,18	0,00	0,00	16,48	16,77	16,64	16,46
CaO	0,08	0,14	0,18	0,17	0,41	0,16	0,13	0,00	0,00	0,00	0,00
FeO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,19	0,27	0,00
Total	99,15	100,04	99,49	99,02	99,41	100,20	99,94	99,48	100,39	100,02	100,24
Na	0,97	0,95	0,97	0,95	0,97	0,96	0,99	0,00	0,00	0,02	0,01
Al	1,02	1,04	1,03	1,04	1,04	1,02	1,01	0,99	1,00	1,00	1,01
Si	2,99	2,98	2,97	2,98	2,97	2,99	2,99	3,01	3,00	2,99	3,00
K	0,01	0,01	0,01	0,01	0,01	0,00	0,00	0,98	0,99	0,98	0,97
Ca	0,01	0,01	0,01	0,01	0,02	0,01	0,01	0,00	0,00	0,00	0,00
Fe	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00
Sum	5,00	4,99	4,99	4,99	5,01	4,98	5,00	4,98	5,00	5,00	4,99

As can be seen in table 4, most of the plagioclases have decreasing CaO content, which is a consequence of the decalcification connected with the crystallization of the carbonate within the rock during the deformation processes. Due to their chemical composition, they are classified as albite to acid oligoclase (An 7 – 12). Phengite as a middle member of the muscovite-celadonite mineral group of white micas, reflects very well through its compositions the changes of the P-T conditions during its origin. The mineral assemblage phengite – biotite – K-feldspar – quartz has became the basis for the phengite barometer in sense of Velde (1965, 1967), later improved by Massonne and Schreyer (1987). Just such a mineral assemblage is typical for the mylonitized granitic rocks in the Veporicum. We have observed it in the Sparistá dolina granitic mylonites as well as. The barometer is based on the Si parameter value within a structural formula. The Si parameter values in the samples are within the range of 6.39 –7.10 pfu, which reveals a pressure of 400 - 1200 MPa (4 – 12 kbar) (Tab. 5 and Fig. 6). It is interesting that in the more deformed ultramylonites we have identified phengites with greater Si parameter value (6.65 – 7.10), which corresponds to a pressure of 800 - 1200 MPa and in mylonites only Si = 6.39 – 6.61, which indicates pressures of 400 – 750 MPa. Similarly, Hraško (1998) observed the wide range of phengite Si parameter values in the central and southeastern parts of the Vepor massif. Preliminary we assume that the deformation of the original granitic rocks (granodiorite to tonalite) happened in two phases. The maximum pressure was recorded by the ultramylonites in the first phase during the deepest burial of the complex within the compressional phase of the Alpine Orogeny. During this progressive phase, the pressure may have reach 12 kbar, which is in accordance with Plašienka et al. (1999). Based on the phengite component, we assume the average pressure of 9 kbar (Fig. 6) for this first stage. The mylonites were created during the retrograde phase of the orogeny, after the thermal relaxation due to extension. The identified average pressure in the mylonites – about 6 kbar is more likely a reflection of the second phase, in the consequence rapid unroofing connected with pressure changes (Fig. 6).

The composition of biotite undergoes the greatest changes during the dynamo-metamorphic processes, because this phyllosilicate is composed of several unstable elements (Ti, Fe, Mg, Ca, K), and undertakes various changes (chloritization, baueritization etc.). The secondary minerals as chlorite, ilmenite, rutile, titanite, magnetite,

Tab. 5 The representative chemical composition of the white micas from the SDGM. The recalculation is based on 22 oxygens.

	NTB-3/1	NTB-3/2	NTB-3/4	NTB-3/8	NTB-2/3	NTB-2/6	NTB-10/2	NTB-1/1	NTB-1/4	NTB-1/6	NTB-1/9
SiO_2	48,34	46,43	47,37	48,06	48,48	47,84	52,50	53,40	50,63	50,41	49,57
TiO_2	0,00	0,00	0,57	0,00	0,38	0,56	0,00	0,18	0,15	0,26	0,21
Al_2O_3	29,65	29,94	29,15	31,17	25,88	26,14	30,38	25,27	28,15	27,47	28,04
FeO	3,89	2,74	3,98	2,50	5,92	5,22	1,48	2,70	2,58	2,67	2,58
MnO	0,00	0,00	0,00	0,00	0,10	0,04	0,25	0,42	0,36	0,42	0,00
MgO	2,93	2,77	2,79	2,10	2,50	2,67	1,19	2,65	2,28	2,50	2,43
CaO	0,00	0,00	0,00	0,00	0,16	0,08	0,00	0,00	0,00	0,00	0,00
Na_2O	0,17	0,21	0,17	0,26	0,12	0,12	0,00	0,00	0,00	0,11	0,00
K_2O	11,37	11,72	11,20	11,57	11,14	11,04	9,19	10,44	10,57	10,83	10,64
Cr_2O_3	0,00	0,00	0,00	0,00	0,00	0,00	0,34	0,40	0,22	0,22	0,36
Total	96,35	93,81	95,23	95,66	94,68	93,71	95,33	95,46	94,94	94,89	93,83
Si	6,48	6,39	6,51	6,44	6,66	6,65	6,87	7,10	6,78	6,79	6,73
Ti	0,00	0,00	0,04	0,00	0,04	0,05	0,00	0,02	0,02	0,03	0,02
Al	4,68	4,86	4,66	4,93	4,24	4,22	4,68	3,96	4,45	4,36	4,49
Fe	0,44	0,31	0,43	0,28	0,69	0,64	0,16	0,30	0,29	0,30	0,29
Mn	0,00	0,00	0,00	0,00	0,01	0,01	0,03	0,05	0,04	0,05	0,00
Mg	0,59	0,57	0,56	0,42	0,51	0,55	0,23	0,53	0,46	0,50	0,49
Ca	0,00	0,00	0,00	0,00	0,03	0,01	0,00	0,00	0,00	0,00	0,00
Na	0,04	0,06	0,04	0,07	0,03	0,03	0,00	0,00	0,00	0,03	0,00
K	1,94	2,06	2,00	1,98	1,99	2,01	1,53	1,77	1,81	1,86	1,84
Cr	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,04	0,02	0,02	0,04
Sum	14,17	14,25	14,24	14,12	14,20	14,17	13,54	13,77	13,87	13,94	13,90

Tab. 6 The representative chemical composition of the biotite micas of the studied rocks. The recalculation is based on 22 oxygens.

	NTB-3/2	NTB-3/3	NTB-3/7	NTB-2/3	NTB-2/6	NTB-8/1	NTB-10/2	NTB-1/3	NTB-1/4	NTB-1/5
SiO_2	34,76	34,47	35,31	35,30	35,17	35,24	35,93	36,12	34,31	35,75
TiO_2	2,68	3,31	2,49	2,04	2,30	2,66	2,96	2,61	3,45	2,08
Al_2O_3	17,41	15,83	14,97	15,49	14,47	16,26	15,70	15,88	15,40	16,76
FeO	22,80	23,34	24,30	24,74	23,87	21,69	20,80	20,45	23,34	20,87
MnO	0,00	0,00	0,00	0,00	0,00	0,57	0,94	0,80	0,79	0,78
MgO	8,38	8,02	8,49	9,07	8,56	8,44	8,71	8,72	7,39	8,36
CaO	0,00	0,00	0,19	0,00	0,00	0,15	0,27	0,51	0,21	0,00
K_2O	8,98	9,83	9,03	8,70	9,78	9,92	9,79	9,85	9,62	10,08
Cl	0,00	0,00	0,00	0,05	0,00	0,00	0,00	0,00	0,00	0,00
Cr_2O_3	0,00	0,00	0,13	0,10	0,00	0,47	0,30	0,34	0,41	0,41
Total	95,01	94,80	94,91	95,49	94,15	95,40	95,40	95,28	94,92	95,09
Si	5,40	5,43	5,55	5,51	5,59	5,48	5,56	5,59	5,43	5,55
Ti	0,31	0,39	0,29	0,24	0,27	0,31	0,34	0,30	0,41	0,24
Al	3,19	2,94	2,77	2,85	2,71	2,98	2,86	2,89	2,87	3,07
Fe	2,96	3,08	3,20	3,23	3,17	2,82	2,69	2,64	3,09	2,71
Mn	0,00	0,00	0,00	0	0,00	0,07	0,12	0,11	0,11	0,10
Mg	1,94	1,88	1,99	2,11	2,03	1,96	2,01	2,01	1,74	1,93
Ca	0,00	0,00	0,03	0,00	0,00	0,02	0,04	0,09	0,04	0,00
K	1,78	1,97	1,81	1,73	1,98	1,97	1,93	1,94	1,94	1,99
Cl	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Cr	0,00	0,00	0,02	0,01	0,00	0,06	0,04	0,04	0,05	0,05
Sum	15,58	15,69	15,66	15,69	15,75	15,67	15,59	15,61	15,68	15,64

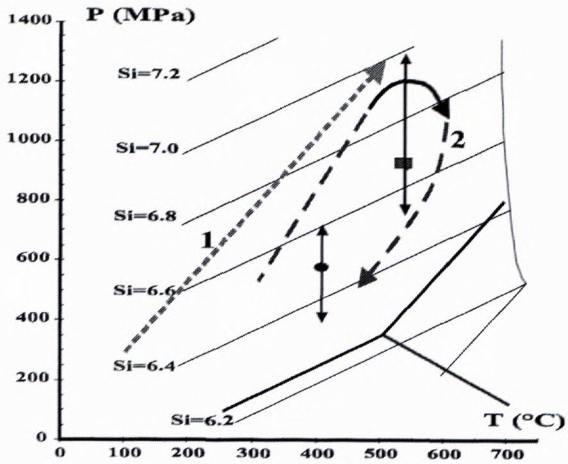

Fig. 6 P – T diagram based on the Si content in the muscovite mica – phengite (Massone and Schreyer, 1987) SDGM. The filled circle represents the average composition of the white micas (Si – component) of mylonites, filled box represents average composition of the white micas in ultramylonites. 1 – the path of the Alpine metamorphism according to Mazzoli et al., 1992, 2 – P-T path of the Alpine metamorphism according to Plašienka et al., 1999.

epidote, eventually also muscovite (bauerite) and phengite can be created. All this is reflected in the composition of the biotite (Table 6). Although we tried to analyze the non-altered phases, the migration of the individual elements within the studied sample is evident.

We also tried to make the temperature estimation on the basis of the mineral changes. The maximum tempeperature ?500°C indicates the origin of myrmekitic textures in K-feldspar (Bell and Johnson, 1989). In contrast to this, the minimum temperature of ?340°C is indicated by the change of biotite to chlorite (Eggleton and Banfield, 1985) in the granitic rocks. This temperature is in accordance with the minimum blocking temperature of the phengitic muscovite (350°C) in the K-Ar or Ar-Ar isotopic system (Purdy and Jäger, 1976), when the mineral lattice is finally closed, the diffusion of argon is stopped and the „isotopic clock“ is set off. The high-pressure conditions in the Alpine deformation is also well documented by the formation of clinozoisite and epidote at the expense of plagioclase at pressures of 8 – 12 kbar (Singh and Johannes, 1996). The deducted thermal (350 – 550 °C) and pressure (4 – 10 kbar) parameters are typical for the continental orogenic zones, as the Alpine Orogeny in the Western Carpathians certainly was.

Geochronology

In order to have an idea about the age of the host rock environment and of the migration of the fluids within the SDGM, as well as about possible relationship with potential ore mineralization, we decided to date these processes by the $^{40}Ar/^{39}Ar$ isotopic method. So far we obtained only one reliable age value from our samples, namely from the sericite sample NTB-3. The results of the measurements are shown on table 7 and their plot is shown in figure 7.

As is possible to state from the table 7 and figure 7, the sericite sample from the mylonite of the Sparistá dolina type – NTB - 3 has an outstandingly smooth spectrum of apparent ages of 76 - 79 Ma. It is equivalent of 96 % of the volume of the total amount of the degassed ^{39}Ar. Only in the first step does it show an apparent age slightly younger that the value of 67 Ma, which is common for similar samples. There were no relict cores of older muscovites in the sample, and it also does not show any signs of disturbances of the Ar/Ar isotope system in the consequent younger periods. Noteworthy is, that none high-pressure phengites were identified in this mylonite, only forms with Si = 6.39 – 6.61 pfu, corresponding to a pressure of about 6 kbar. As can be seen from the data, the sample attracts attention by its perfect match between the „total gas age“ calculated from the total amount of degassed ^{39}Ar and the weighted arithmetic mean of ages from the concordant steps of $^{40}Ar/^{39}Ar$ spectrum (plateau age). Thus, the interpreted age 78 ±1.3 Ma certainly represents the age of the creation and/or closing of the muscovite – sericite lattice during cooling under blocking temperature (Tc = 400 ±25 °C, respectively 350 °C), Purdy and Jäger (1976). More about blocking temperatures can be found in the work by Kohút et al. (1998).

Tab. 7 $^{40}Ar/^{39}Ar$ analytical data from the sericite sample NTB-3a.

Step	T(°C)	%^{39}Ar	40* (mV)	%^{40}Ar	39/37	%^{36}Ca	^{40}Ar*/^{39}Ar (%)	Apparent age (Ma)
1	650	4.3	25.63	90.9	2	4.07	11.05 ±2.1	67.0 ±1.4
2	720	5.3	37.09	99.0	2	31.24	12.97 ±0.7	78.4 ±0.6
3	790	13.2	91.94	96.1	8	2.43	12.86 ±1.0	77.7 ±0.8
4	850	45.6	322.75	97.8	5	6.84	13.04 ±1.2	78.8 ±1.0
5	1000	18.5	126.16	95.5	3	4.99	12.54 ±0.6	75.9 ±0.4
6	1250	13.2	93.37	92.9	5	2.10	13.06 ±2.0	78.9 ±1.6
J = 0.003274 ±0.4%							**Total gas age:**	**77.6 ±1.4**
						96%	**Plateau age**	**78.1 ±1.3**

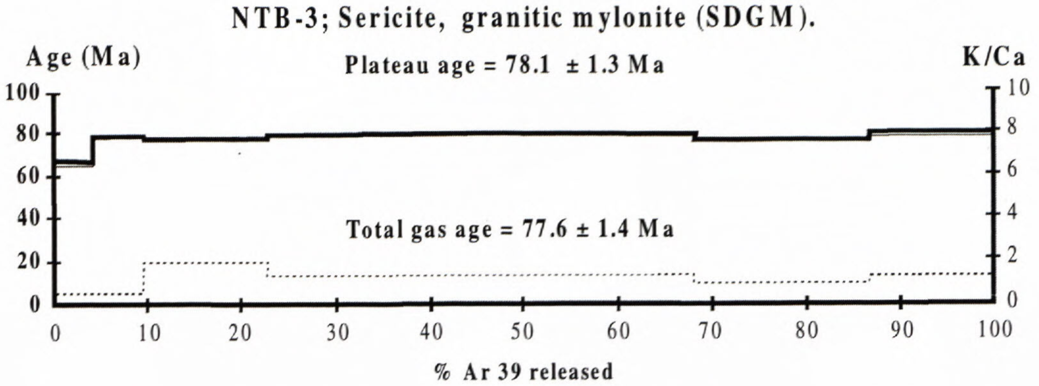

Fig. 7 The diagram of $^{40}Ar/^{39}Ar$ apparent age spectrums of sericite from the sample NTB-3a. The lower spectrum represents the changes of ratio K/Ca in the individual thermal steps.

Discussion and Conclusion

The complex research of the SDGM mylonites did not confirm potential ore mineralization of this rock type; however, at the recent level of knowledge we cannot reject the existence of the hypothetical occurrences of the economic mineral resources.

Based on the petrologic analysis we can confirm that the deformed granitic rocks north of the Bacúch site represents dynamo-metamorphosed, originally magmatic rocks, which is in agreement with previous findings (Miko, 1981; Miko et al., 1982). However, on the base of existing data we cannot confirm the affinity of these original igneous rocks to an early orogenic gabbro – plagiogranite formation in sense of these authors. We assume their origin from the combined crustal type within the active volcanic arch of „Andean type“, where they represented medium-potassium, calk-alkaline series. The Middle Paleozoic – Late Devonian age (370 Ma) of these original magmatitic rocks were proven by the U-Pb dating of zircons (Cambel et al., 1977).

The tectonic-deformation processes during the Alpine Orogeny when shearing and recrystallization of these rocks took place, were connected with allochemical changes. The original mineral assemblage: plagioclase, quartz, biotite, K-feldspar, ± muscovite + accessories was replaced by a new assemblage: quartz, plagioclase (albite), sericite (phengite), K-feldspar, carbonate (calcite), minerals of epidote – zoizite group, ± biotite, titanite, ± garnet, chlorite, muscovite (bauerite), rutile, ilmenite, magnetite and accessories.

Based on the study of the element distribution, the mobility of the majority of the elements during the deformation process was confirmed, either in a form of gain or loss into the composition of these mylonites. This is in accordance with observations by Miko et al. (1982) from this area, and by Putiš et al. (1997) from the central part of the Veporicum part of the Slovak Rudohorie Mts., or by Kolaříková et al. (1985; 1994) from the eastern part of the Czech Massif and by Marquer et al. (1985; 1994) from the Alps.

The identified thermal-pressure conditions (350–550 °C and 4 – 10 kbar), which are responsible for the total strain and recrystallization of originally granitic rocks, as well as the character of this dynamic and/or dynamic-thermal metamorphism is typical for the orogenic zones along convergent plate margins (Spear, 1995). It is important to emphasize that the metamorphism (deformation) in these rocks – SDGM has a penetrative character and that it is not bounded only to narrow, several-meter-thick mylonite shear zones. The maximum thickness of the „body“ in the Krškova and Bacúšska dolina Valleys reaches 200 m, with the foliation inclined 30 – 50° southwesternward; however, the maximum thickness can be as much as 500 m. Although within the body we observed zones with relatively lower degree of deformation assigned as porphyroclastic eye-shaped granitic mylonites with significant twin-cleavage S-C fabric, in many places there are also zones of fine-grained ultramylonites, where shear bands were gradually transformed into a single foliation fabric. The degree of metamorphism reached the balance level of biotite and garnet zone and/or boundary between greenschist facies and epidote amphibolite facies. A brittle-ductile character of porphyroclastic mylonites and ductile character of ultramylonites also refer to it. Interesting is the fact that deformation-metamorphic character of the SDGM is identical with the deformation of the Veporicum basement in the contact zone of the Veporicum and Gemericum (Plašienka et al., 1999).

The assumed metamorphic condition of the studied area (ca. 400 °C and 6 kbar) most probably represents a retrograde phase of the Alpine type of metamorphism after the climax of the progressive burial of the Veporicum block of the crystalline complex with its envelope under the overthrusting Gemericum from the southeast during the Jurassic – Cretaceous subduction – collision processes. However, there remains the unsolved problem: how and when the SDGM experienced by significant Alpine dynamo-thermal deformation and metamorphism, got into the Variscan low metamorphosed rock complex (Janov grúň formation) (Miko, 1981; Sassi and Vozárová, 1992). This requires detailed, mainly structural, research.

The Alpine metamorphism of the Veporicum is a problem that has long been discussed in the Western Carpathian literature, since the times of Zoubek (1936), who first identified this problem. Vrána (1966; 1980) later discussed this problem. He emphasized that the degree of the Alpine metamorphism of the granitic rocks is directly dependent upon the degree of tectonic deformation and intensity of the metamorphism. The author determined 5 types of D-R granitoids (deformed – recrystallized), from massive metagranites to blastomylonites. Vozárová (1990), Méreš and Hovorka (1991) and Hovorka and Méreš (1997) estimated the temperature and pressure of the Alpine metamorphism of the southwestern part of the Veporicum to 550 °C and 5–8 kbar. Mazzoli et al. (1992) deduced conspicuous pressure character of the Alpine metamorphism (12 kbar) on the basis of b_0 parameters of muscovites changed by the Alpine recrystallization. Korikovsky et al. (1997) determined the conditions of the Alpine metamorphism to about 500 °C and 7–9 kbar. Contrary to this, Kováčik et al. (1997) published temperatures of 350–500 °C and pressures of only 2 – 4 kbar, the obtained higher values of the pressure they explain by fluid influx. Although Kováčik (1998), basing on complex geothermobarometry, admits maximum temperatures of 550–580 °C and pressures of 8–10 kbar, in his model, on the basis of the geological situation, he prefers half-size lower pressures during the overthrusting of the southeastern Veporicum basement with a maximum 12-km-thick hangingwall (4 kbar). Based on structural relationships and geothermobarometric calculations by means of the Alpine mineral assemblage, Plašienka et al. (1999) set the peak of the metamorphism for the deeper parts of the Veporicum crystalline complex at their conception at 550 –600 °C and 8–12 kbar, which indicates burial of the Veporicum basement to a depth of 30–40 km.

The dating of the Alpine orogenic processes in Veporicum has started already by the first K-Ar dating that determined the age of biotite from the southeastern crystalline complex to 106–75 Ma (Kantora, 1960). The age of the Alpine deformation of granitic rocks from the Bacúch area was proven also by Bagdasarjanov et al. (1977) with the K-Ar method to 104–97 Ma. Another dating by Ar-Ar method (Dallmeyer et al., 1996; Maluski et al., 1993 and Kováčik et al., 1996) proved that the main period of the Alpine deformation of the Veporicum crystalline complex took place before 88–84 Ma.

Taking in to account all the above mentioned facts, as well as the present geological situation and position of individual tectonic elements within the Veporicum – Gemericum boundary, based on analogy with another Alpine type continental subduction-collision orogenic mountain ranges (Himalayas, Alps, and Pyrenees), we favor the model of the Veporicum area development in sense of Plašienka (1997) and Plašienka et al. (1999).

During the period between Jurassic and Cretaceous, after the closing of the Meliata ocean, the Meliata accretion complex started to overthrust from southeast over the passive margin of the Central Western Carpathians – Gemericum. The gradual shortening due to compression subsequently caused the overthrusting of the Gemericum with Meliaticum unit upon the Veporicum. The result of the intracratonic crustal shortening was a thickening of the crust, which involved the gravitational instability and rapid exhumation of the Veporicum basement, which was accompanied by east vergent extensive unroofing (Hók et al., 1993). Although partly problematic there remains the question of thickness of the tectonic overburden (roof). Beside the lithostatic pressure during such dynamometamorphic processes significant role plays also high strain rate and deviatoric stress, which magnify effect of the lithostatic pressure during collision and tectonic processes.

The SDGM studied by us are indicators of the Alpine tectonic processes. Their deformation reflects probably two tectonic events. The older high-pressure deformation originated as a consequence of maximum burial (P_{MAX} = 8–12 kbar, T = 550–600 °C in the time period before t = 110 Ma?) is overlapped by a younger event. The second episode took place during the retrograde phase of the orogeny and recorded rapid uplift of this crystalline complex block. This was caused by the reduction of thickness of the crust, thickened by the collision, and within the framework of extensive unroofing of overlapping Veporicum complexes at P = 6 kbar, T = 400 °C and in period before t = 78 Ma.

Acknowledgement

We thank Dr. I. Broska and Dr. J. Hók for their peer review of this paper and the suggestions improving its original version. Our gratitude belongs to Dr. J. Kráľ for his help with Ar/Ar dating, as well as for valuable advice improving this work. We owe our gratitude to Mr. D. Zaťovič for his precise mineral separation needed for the isotope dating. Accurate English style brushing by Dr. H. Drewes (US GS) is greatly appreciated.

P.S.: The first author (M.K.) discovered identical mylonitic rocks directly related to granitic rocks of the Nízke Tatry Mts.- Tatricum unit, at the southern slope of mountain range, during field season 2000 work. This finding can significantly changed tectonic interpretation of the SDGM in the future.

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Sample locations

NTB-1/98 – natural outcrop, crest toward Janov grúň, alt.- 825 m,
NTB-2/98 – outcrop in the road cut, Bacúšska valley, alt.- 855 m,
NTB-3a/98 – outcrop by old exploration gallery, Krškova valley, alt.- 770 m,
NTB-3b/98 – rocky outcrop, the slope opposite to 3a, in the Krškova v., alt.- 800 m,
NTB-8/98 – natural outcrop, in the Kriváň valley, alt.-755 m,
NTB-9/98 – rocky outcrop, above road, in the Leňušská valley, alt.- 1080 m,
NTB-10/98 – rocky outcrop, in the Zamrzlá valley, alt.- 1050 m,
NTB-11/98 – rocky outcrop, above a forest road, Sparistá dolina valley, alt.- 800 m.