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Coexisting Garnets and Amphiboles of Metabasites from Rudňany Area (the Paleozoic, the Spišsko-gemerské rudohorie Mts., the Western Carpathians)

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Pre-Variscan and Variscan events
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Сосуществующие гранаты и роговые обманки метабазитов района Рудняны (палеозой, Спишско-гемерские рудные горы, Западные Карпаты)

В метабазитах палеозоя района Рудняны авторы изучали химический состав гранатов и роговых обманок при помощи электронного микрозонда. Роговая обманка отвечает известковому типу (подгруппа магний-роговая обманка, Б. Е. Леаке 1978). Гранаты незональные с преобладанием алмандиновой молекулы. Химический состав особенно роговой обманки и подсчитаные коэфициенты распределения (магний, железо, кальций, манган) свидетельствуют о том, что возникновение указанных минералов происходило в условиях амфиболитовой фации, или „медиум граде“ метаморфизма баровианского типа.

Coexisting garnets and amphiboles of metabasites from Rudňany area (the Paleozoic, the Spišsko-gemerské Mts., the Western Carpathians)

Chemical composition of coexisting garnets and amphiboles in metabasites of Paleozoic age from Rudňany area has been investigated using EMA technique. The composition of amphiboles is that of calcic amphibole group (subgroup of magnesio-hornbiende) and garnets are not zonal containing maingly almandine but also considerable amounts of grossularite and pyrope molecule. Chemical composition of amphibole and calculated distribution coefficients (Mg, Ca, Fe, Mn and Ti) point to the generation of the assemblage under amphibolite facies conditions or under "medium grade" and low to moderate baric conditions of metamorphism.

Chemical composition of coexisting garnets and amphiboles was examined in the Paleozoic metabasites from Rudňany area with the aid of electron microprobe. Amphibole corresponds to calcic amphibole (sub-group Mg-hornblende, Leake 1978), garnets are not zonal, the almandine molecule is prevailing, the grossulare and pyrope molecules are of substantial occurrence. Chemical composition, mainly that of amphibole, and calculated distribution coefficients (Mg, Ca, Fe, Mn, Ti) of coexisting amphiboles, garnets and plagioclases suggest the mentioned minerals to have originated in conditions of amphibolite facies, and/or „medium grade" metamorphism of low/medium baric type.

Introduction

Complexes of metasediments and metaeruptives of the Gemerides, the southernmost tectonic unit of the Western Carpathians (or the Paleozoic of the Spišsko-gemerské rudohorie Mts.), are generally classified as metamorphites, which originated in green-schist facies conditions (Kamenický — Krist 1969, Kamenický 1969 in Mahel' et al. 1969, Varga 1973). In contrast to the majority of authors (l. c.) who considered the mineral assemblages of metasediments and metaeruptives to be the product of the Variscan metamorphic recrystallization, I. Varga (1973) ascribed only the folding effect to these processes. He assumed the origin of mineral assemblages of metamorphosed rocks (this author made also a map of the areal distribution of the individual assemblages) to be the consequence of the Alpine processes.

From the universally accepted scheme of intensity and type of the Gemeride Paleozoic metamorphism, the results obtained by L. Rozložník (1965) from the area of Dobšiná substantially differ. This author (l. c.) gave the description of the rock complexes of the amphibolite facies in the mentioned area and he considered them to be the local consequence of the penetrating "granitizing" components through the rocks of the Early Paleozoic Rakovec group. Among metamorphites of higher grade he introduced mainly various gneiss types and amphibolites.

In the course of recent years, the rocks of higher grade metamorphic recrystallization from the area of Rudňany were introduced by J. Popreňák et al. (1973). Their essential characteristics (composition and position) as well as arguments in favour of their metamorphic (not magmatic) origin can be found in D. Hovorka et al. (1979). Gneisses and amphibolites were described also from the area of Vyšný Klátov (Dianiška — Grecula 1979). In this way, the amphibolite facies metamorphites and/or the facies of epidote amphibolites) form the zone located along the northern margin of the Gemeride Paleozoic (the Volovec anticlinorium).

So far the whole number of studies concerned with metamorphites of higher metamorphic grade was based on field investigations as well as on discovered mineral assemblages examined by means of microscopic methods. Chemical composition of coexisting metabasite amphiboles and garnets was the objective of our study during the recent years. Chemical composition, mainly that of amphiboles, reflects the pressure-temperature conditions of their origin. If coexisting with other minerals of the rock under consideration, amphibole may provide helpful data to solve the conditions of its origin.

The analyses of garnets and amphiboles were carried out using the electron microprobe ARL — SEMQ at Central Geological Institute, Prague (we wish to express our gratitude to RNDr. P. Jakeš, CSc. for his suggestions and countless help) by RNDr. J. Krištín, CSc.

Occurrence and description of metabasites

Various types of amphibolites (the garnet and the augen ones, melaamphibolite and others), together with gneiss-type rocks, occur in the complex considered to be the Upper Carboniferous (on the basis of lithology and correlation considerations). Its position, the rock column and the essential characteristics of the mineral assemblages of the main rock types are dealt with in D. Hovorka (1977) and D. Hovorka et al. (1979). It seems necessary to put the emphasis on the fact that the generalized profile of the Upper Carboniferous Rudňany area follows like this: polymict conglomerates designated as conglomerates of "Bindt-Rudňany" type form the lowermost horizon. They are overlaid by the complex of dark-coloured schists and psammites with layers of green-coloured, locally also laminated metapyroclastics of basic volcanics. The "gneiss-amphibolite complex" of thickness 50—250 m is occurring above the mentioned beds. Its direct overlying rocks are graphitic schists which are replaced by the complex of schists and psammites in the lateral direction. The "intraformational conglomerates" are also included in the direct overlying rocks. These are distinguished from the conglomerates of "Bindt-Rudňany" type mainly by smaller size of pebbles, their lithological filling and/or higher metamorphic grade. The "intraformational conglomerates" are overlaid by the layer of brownish fine-grained psammites with rich remnants of flora. In the uppermost part of the Carboniferous the bed of dark-coloured schists, psammites and fine-grained green to grey-green metatuffs of basic volcanics is included. Mutual quantitative proportion of the mentioned rock types is strongly variable.

Amphibolites form concordant bodies of thickness most frequently to 1 m (bodies of thickness to 10 m were only seldom observed) in gneisses. The contact of amphibolites with gneisses appears to be mostly a sharp one (Fig. 1). In some cases, gradual transition of amphibolites into biotitic plagioclase (garnet-plagioclase) gneisses was observed. The transitional rock types are different types of gneisses with amphibole (amphibole-biotite, biotite-amphibole, amphibole). Amphibolites s. s. appear to be the essential and at the same time, the dominating type of amphibolites. They are mostly fine-grained, with areally parallel (Fig. 2) to massive structure. Higher content of pure-green amphiboles results in local presence of melaamphibolites. Garnet amphibolites (Fig. 3) form only layers

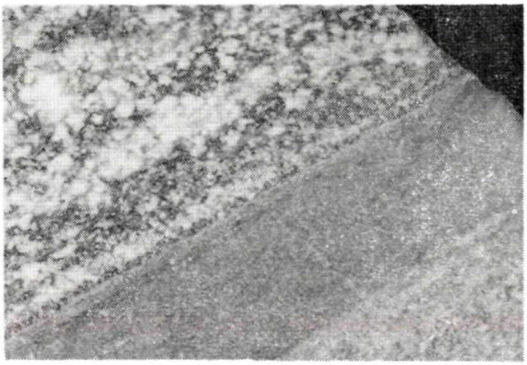


Fig. 1. Selective albitization of the original psammite layer. Concordant layer of primarily ash-like volcanic material has only been recrystallized during the development of fine-grained amphibolite. Ry-Z-60/55,60 m. Magn. 1,2×

Obr. 1. Selektívna albitizácia polohy pôvodného psamitu. Konformná poloha pôvodného popolovitého vulkanického materiálu je len rekryštalizovaná za vzniku jemnozrnného amfibolitu. Ry-Z-60/55,60 m. Zväčš. 1,2×

in amphibolites s. s. The garnet size is 1—7 mm. The centric texture of

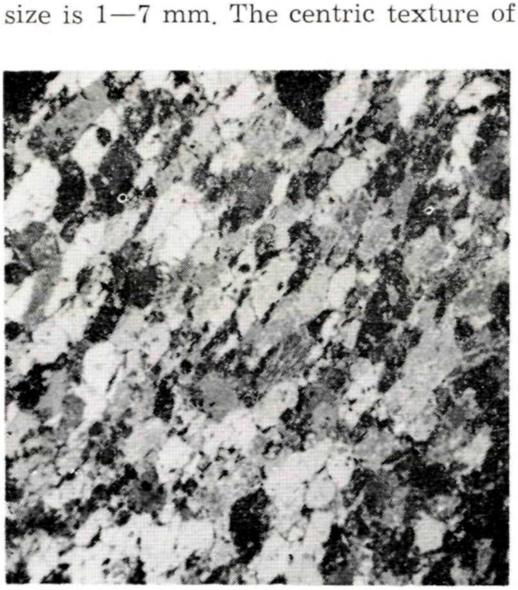


Fig. 2. Grano-nematoblastic texture of fine-grained melaaphibolite. Zl-II-36/38,10 m. Magn. 20×, × pol.
Obr. 2. Granonematoblastická štruktúra jemnozrnného melaamfibolitu. Zl-II-36/38,10 m. Zväčš. 20×, × pol.

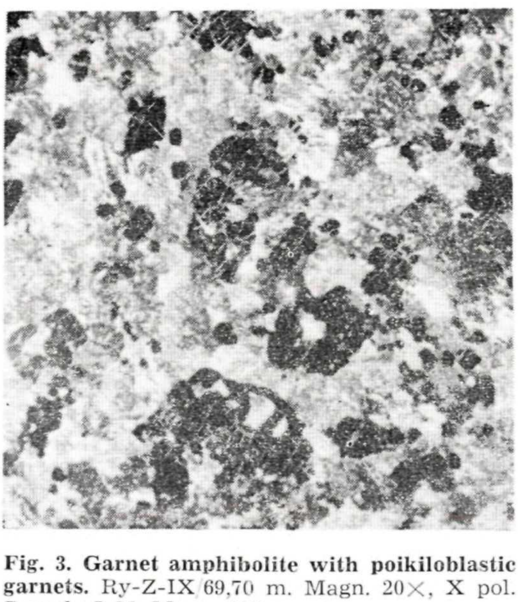


Fig. 3. Garnet amphibolite with poikiloblastic garnets. Ry-Z-IX/69,70 m. Magn. 20×, X pol. Sample I-26. Magn. 300×
Obr. 3. Granátický amfibolit s poikiloblastickými granátmi. Ry-Z-IX/69,70 m. Zväčš. 20×, × pol.

garnet amphibolites (Fig. 4) seems to be a characteristic one, i. e. already macroscopically observable concentration of light minerals in the surroundings of garnet porphyroblasts.

Fig. 4. Garnet amphibolite with pronounced centric structure. Ry-Z-61/54,70. Magn. 1,3×
Obr. 4. Granátický amfibolit s výrazne centrickou stavbou. Ry-Z-61/54,70. Zväčš. 1,3×

Garnets

Garnets of metabasites from Rudňany area exhibit red and pink colouring and pronounced idioblastic tendency of development. Their quantitative proportion in metabasites is of variable nature — it varies from accessory amounts up to 35 %. Garnets of 2—3 mm size in types in which they form substantial rockforming mineral, were examined.

The examination of the garnet composition provided evidences confirming their non-zonal composition (structure) — Figs. 5, 6. Numerous published works on the composition of garnets in various types of metamorphites offer sufficient data suggesting prevalency of zonal composition of metabasite and metapelite garnets which have originated in conditions of green-schist facies to low temperature areas of amphibolite facies, i. e. to temperatures of 600 °C (Woodsworth 1977, Avtchenko et al. 1980). Discovered non-zonal character of the metabasite garnet composition from Rudňany area confirms that they might have originated in conditions of medium to high temperature areas of amphibolite facies. This discovery corresponds to chemical composition of coexisting amphiboles and/or also to calculated temperatures of the origin of coexisting garnet—amphibole and amphibole—plagioclase pairs.

Projection points of analyzed metabasite garnets (Tab. 1) from Rudňany area are located in limited area, the biggest part of this area is overlapped by the area of projection points of metabasite garnet analyses of Moldanubicum (analyses in Suk 1979). Garnets under consideration are noted for only slight shift of projection points in the direction of lower pyrope molecule content.

On the plot with peaks MgO : MnO : FeO (Fig. 8), projection points of analyzed garnets show large scattering. In case of low, and on the whole, a little

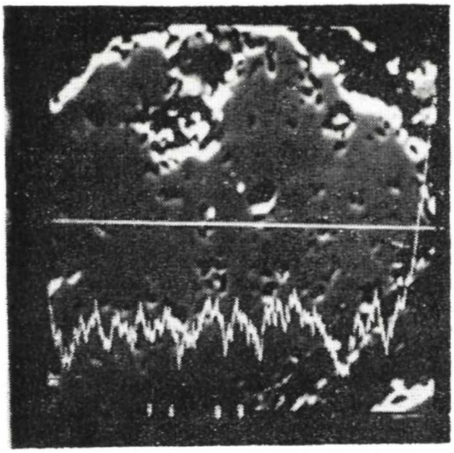


Fig. 5. Composition + line profile MnK$_\alpha$. Sample I126. Magn. 300×
Obr. 5. Kompozícia + líniový profil MnK$^\alpha$. Vzorka I-26. Zväčš. 300×

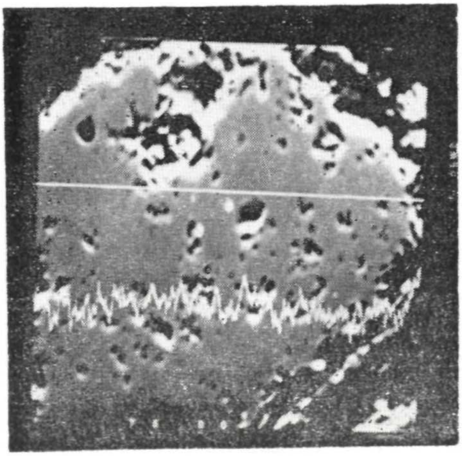


Fig. 6. Composition + line profile FeK$_\alpha$. Sample L-26. Magn. 300×
Obr. 6. Kompozícia + líniový profil FeK$_\alpha$. Vzorka L-26. Zväčš. 300×

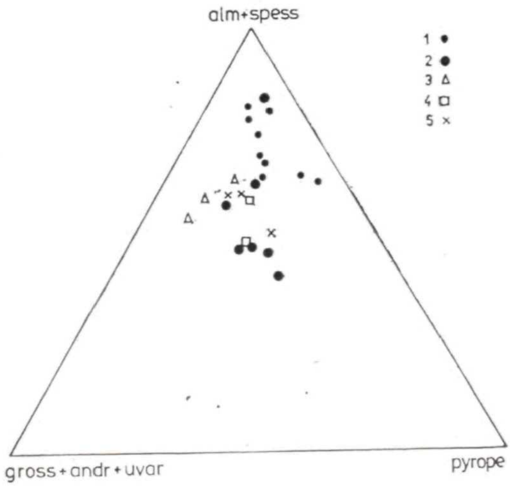


Fig. 7. 1 — garnets of Moldanubicum gneisses and migmatites, 2 — garnets of Moldanubicum amphibolites (1, 2 — data in Suk 1979), 3, 4, 5 — garnets of amphibolites from Rudňany area (3 — sample no. 1, 4 — sample no. II, 5 — sample no. V)

Obr. 7. 1 — granáty pararúl a migmatitov moldanubika; 2 — granáty amfibolitov moldanubika (1, 2 — údaje in Suk, 1979); 3, 4, 5 — granáty amfibolitov oblasti Rudnian (3 — vzorka č. I, 4 — vzorka č. II, 5 — vzorka č. V)

Chemical composition of garnets
Chemické zloženie granátov

Tab. 1

	I-26/1	I-26/2	I-16/1	I 26/3	II-16/3	II-16/1	II-36/1	V-16/1	V-16/2
TiO_2	0,12	0,10	0,12	0,13	0,00	0,14	0,08	0,15	0,19
MnO	2,15	2,21	1,47	3,21	0,45	0,40	0,10	0,20	0,27
SiO_2	38,44	37,02	38,14	37,08	39,30	39,21	37,37	37,67	37,29
FeO	23,88	26,69	22,61	22,68	26,56	21,57	26,85	26,24	25,77
MgO	2,50	3,17	2,26	2,03	4,88	5,84	4,13	3,62	7,85
CaO	10,06	6,72	11,97	10,25	7,11	9,54	7,45	8,53	8,05
Al_2O_3	21,27	21,10	21,16	20,58	22,02	21,68	21,61	21,62	21,38
total	98,43	97,01	97,74	95,97	100,32	98,40	97,59	98,04	100,80

Coefficients calculated according to Burri et al (1936)
Koeficienty — prepočet podľa C. Burri et al. (1936)

Ti	0,01	0,01	0,01	0,01	0,00	0,01	0,005	0,01	0,01
Mn	0,14	0,15	0,10	0,22	0,03	0,03	0,01	0,01	0,02
Si	3,06	3,01	3,05	3,04	3,04	3,05	3,00	3,01	2,89
Fe^{2+}	1,59	1,81	1,51	1,55	1,72	1,40	1,80	1,75	1,67
Mg	0,30	0,38	0,27	0,25	0,56	0,68	0,49	0,43	0,91
Ca	0,86	0,59	1,02	0,90	0,59	0,79	0,64	0,73	0,67
Al	1,99	2,02	1,99	1,99	2,01	1,99	2,04	2,03	1,95

End members (%)
Zastúpenie molekúl (%)

alm.	55,02	61,80	52,03	53,15	59,26	48,36	61,23	59,88	51,19
pyrope.	10,26	13,08	9,27	8,45	19,40	23,32	16,78	14,72	27,79
spes.	5,02	5,19	3,42	7,61	1,01	0,90	0,23	0,45	0,54
gros.	29,70	19,93	35,28	30,77	20,33	27,40	21,76	24,94	20,48
total	100,00	100,00	100,00	99,98	100,00	99,98	100,00	99,99	100,00

Sample localization
I — bore-hole Ry-Z-61/54,20 — garnet amphibolite
II — the coupling cross-cut between the veins Droždiak and Hrubá — Xth horizon, between the shafts 5 RP II and 5 RP I — breccia of garnet amphibolite
III — the shaft, XVIth horizon, gallery to Zlatník, sample XVI/X — amphibolite
IV — the shaft Zlatník, Xth horizon, 5 m northwards from the measuring point 11 — amphibolite
V — Zlatník II, bore-hole 39/22, 15; from XVIth horizon — garnet amphibolite
(localization of samples is valid also for Tables 2 and 3)

Lokalizácia vzoriek
I — vrt Ry-Z-61/54,20 — granátický amfibolit
II — spojovací prekop medzi žilami Droždiak a Hrubá — X. horizont — medzi šachtami 5 RP II—5 RP I — brekcia granatického amfibolitu
III — šachta Mier, XVI. horizont, smerná na Zlatník, vzorka XVI/X — amfibolit
IV — šachta Zlatník, X. horizont, 5 m na s.od m. b. 11 — amfibolit
V — Zlatník II, vrt 39/22,15 — zo XVI. obzoru — granátický amfibolit
(lokalizácia vzoriek platí aj pre tabuľky 2 a 3)

variable MnO content, garnets form elongated field in the direction of MgO and FeO peaks. This field overlaps the fields stated (Miyashiro — Kuculu, in Antipin 1977) for metamorphite garnets of various facies relevance. Projection points of analyses II and V fall within the metamorphite field of amphibolite,

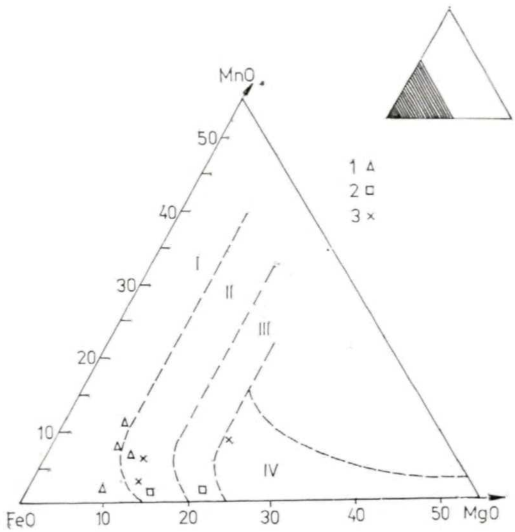


Fig. 8. I — garnets of green-schist facies and epidote amphibolite facies, II — garnets of epidote amphibolite facies and low-temperature subfacies of garnet amphibolite facies, III — garnets of amphibolite facies, IV — garnets of granulite facies (fields I—IV according to Miyashiro — Kuculu, in Antipin 1977), 1—3 garnets of amphibolites from Rudňany area (for sample numbering see Fig. 7)

Obr. 8. I — granáty fácie zelených bridlíc a fácie epidotických amfibolitov; II — granáty fácie epidotických amfibolitov a nízkoteplotnej subfácie fácie granátických amfibolitov; III — granáty amfibolitovej fácie; IV — granáty granulitovej fácie (polia I—IV podľa Miyashiro — Kuculu, in Antipin, 1977); 1—3 granáty amfibolitov oblasti Rudnian — (číslovanie vzoriek pozri obr. 7)

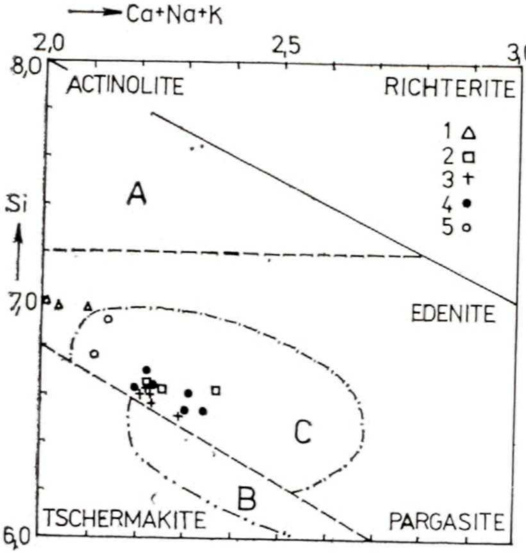
and/or epidote-amphibolite facies. Analyses of sample II resulted in projection points shifted towards lower MgO contents and they are located in the metamorphite field of epidote—amphibolite facies, and/or green-schist facies. This corresponds to other findings regarding their origin at lower temperatures.

Amphiboles

Not only do amphiboles represent one of the essential mineral phases of metabasites of different metamorphic grade recrystallization, but they appear to be of importance as an indicator of pressure-temperature conditions of their origin. Contemporary knowledge makes it possible to formulate general principles of their chemical composition. For example, the more the temperature of metamorphic recrystallization in amphiboles increases, the more the content of alkaline metals and titanium increases. At the same time, tetrahedraly coordinated Al increases, to the detriment of Al in octahedral coordination. Another principle may be gradual decrease of K content and others. Pronounced differences in Al distribution and content changes of other cations (particularly Ti) are manifested also by the change of pleochroic colours of amphiboles originated in various temperature (and/or pressure) conditions. The following change of pleochroic colours in metabasite amphiboles with increasing temperature is universally accepted (Miyashiro 1973): lightgreen, green and blue, blue—green—brown amphibole (according to Ng).

At this stage the focus of the study was mainly on amphiboles of green to brown pleochroic colours. Apart from these, the presence of lightgreen (mostly a younger one) actinolitic type amphibole was locally observed in metabasites. The analyses of amphiboles obtained by means of electron microprobe are given in Table 2.

The plot according to A. Miyashiro (1973 — Fig. 9) shows projection points of the most analyzed amphiboles located in the field C — that is, in the field of high temperature amphiboles. From the given set, analyses of amphiboles from sample I are quite different. Their projection points are very close to field C, yet their location outside the field A is obvious. The A field employs



low temperature amphiboles of green—blue colour, which are considered as belonging to the green-schist facies (on the basis of their conditions of origin).

In order to classify amphiboles, to give the genetic interpretation and to classify amphiboles of metabasites from

Fig. 9. Plot of dependence of Si : (Ca + Na + + K) of amphiboles (Miyashiro 1973). Ng pleochroic colours of amphiboles: A — field of actinolite, B — green to blue amphibole, C — green-brown to brown amphibole; 1—5 analyses of amphibolite amphiboles from Rudňany area (1 — I, 2 — II, 3 — III, 4 — IV, 5 — V)

Obr. 9. Diagram závislosti Si : (Ca + Na + K) amfibolov (Miyashiro 1973). Gama pleochroizmus amfibolov: A — pole aktinolitu, B — zelený až modrý amfibol, C — zelenohnedý až hnedý amfibol; 1—5 — analýzy amfibolov amfibolitov oblasti Rudnian (1 — I, 2 — II, 3 — III, 4 — IV, 5 — V)

Chemical composition of amphiboles
Chemické zloženie amfibolov

Tab. 2

		I-4A/1	I-4A/2	I-5A/1	II-4A/2	II-2A/1	II-2A/2	III-1A/1	III-1A/2	III-2A/1	III-2A/2
	TiO_2	1,55	1,53	1,72	0,49	1,55	1,19	2,03	1,85	1,95	2,19
	MnO	0,18	0,20	0,12	0,09	0,06	0,07	0,29	0,34	0,32	0,28
	SiO_2	45,77	45,81	46,45	44,47	44,59	44,88	43,99	43,46	42,40	42,84
	FeO	16,05	15,46	15,94	9,17	13,77	14,31	15,44	15,25	16,26	16,55
	K_2O	0,13	0,15	0,16	0,29	0,58	0,52	0,23	0,22	0,24	0,22
	Na_2O	1,23	1,31	1,36	1,93	1,74	1,81	1,77	1,72	1,74	1,71
	MgO	11,13	11,61	11,46	15,18	12,21	12,25	11,64	11,82	11,23	11,11
	CaO	9,80	10,38	9,98	10,91	10,21	10,01	10,28	10,15	10,40	10,34
	Al_2O_3	8,44	8,54	9,00	11,54	11,52	11,64	10,35	10,20	10,45	10,33
	Total	94,27	94,99	96,19	94,08	96,21	96,70	96,01	95,03	94,99	95,57
8	Si	6,985	6,937	6,937	6,633	6,633	6,649	6,625	6,615	6,509	6,537
	Al^{IV}	1,015	1,063	1,063	1,367	1,367	1,351	1,374	1,385	1,491	1,463
	Al^{VI}	0,503	0,462	0,522	0,662	0,652	0,682	0,464	0,446	0,402	0,395
	Ti	0,177	0,175	0,193	0,055	0,173	0,133	0,230	0,212	0,225	0,251
	Fe^{2+}	1,790	1,743	1,737	0,907	1,472	1,480	1,693	1,660	1,804	1,826
5	Mg	2,530	2,620	2,548	3,376	2,703	2,705	2,613	2,682	2,569	2,528
	Mn	—	—	—	—	—	—	—	—	—	—
	Fe^{3+}	0,257	0,214	0,255	0,238	0,242	0,293	0,253	0,281	0,184	0,285
2	Mn	0,023	0,025	0,014	0,012	0,007	0,009	0,037	0,044	0,041	0,037
	Ca	1,603	1,680	1,596	1,743	1,626	1,589	1,658	1,656	1,711	1,678
	Na	0,117	0,081	0,135	0,007	0,125	0,109	0,052	0,019	0,064	—
	K	0,246	0,303	0,258	0,552	0,376	0,411	0,463	0,489	0,456	0,506
	Ca	0,025	0,028	0,030	0,055	0,106	0,099	0,044	0,044	0,048	0,041
	Na	—	—	—	—	—	—	—	—	—	0,13
	$\frac{Mg}{Mg + Fe^{2+}}$	0,59	0,60	0,59	0,79	0,65	0,65	0,61	0,62	0,59	0,58

Tab. 2 (continued)

		III-3A/1	IV-1A/1	IV-1A/2	IV-2A/1	IV-2A/2	IV-3A/1	IV-3A/2	V-2A/1	V-4A/1	V-4A/2
	TiO_2	1,72	1,88	1,84	1,72	1,73	1,55	1,93	1,13	0,72	0,47
	MnO	0,25	0,24	0,24	0,26	0,27	0,18	0,22	0,13	0,11	0,18
	SiO_2	44,00	42,03	43,01	43,76	42,98	42,63	42,02	46,89	45,72	44,79
	FeO	15,98	16,24	16,21	17,26	17,31	16,24	16,36	14,90	14,34	13,62
	K_2O	0,28	0,67	0,66	0,58	0,63	0,62	0,68	0,21	0,12	0,18
	Na_2O	1,56	1,38	1,39	1,28	1,34	1,33	1,38	1,47	1,30	1,59
	MgO	11,32	9,88	10,02	9,77	9,40	9,92	9,55	12,53	11,78	12,46
	CaO	10,57	10,53	10,59	10,34	10,29	10,78	10,78	10,66	9,68	9,80
	Al_2O_3	10,61	11,22	10,96	10,23	10,86	10,72	11,17	10,90	9,50	9,24
8	Total	96,30	94,06	94,92	95,20	94,81	93,96	94,09	98,80	93,27	92,34
	Si	6,622	6,518	6,596	6,705	6,626	6,613	6,525	6,783	6,978	6,918
	Al^{IV}	1,328	1,482	1,404	1,295	1,374	1,387	1,475	1,217	1,022	1,082
	Al^{VI}	0,503	0,570	0,579	0,554	0,599	0,573	0,570	0,641	0,687	0,602
5	Ti	0,196	0,219	0,212	0,198	0,200	0,182	0,225	0,122	0,083	0,055
	Fe^{2+}	1,762	1,927	1,920	2,015	2,041	1,952	1,995	1,534	1,550	1,475
	Mg	2,539	2,284	2,289	2,233	2,160	2,293	2,210	2,703	2,680	2,868
	Mn	—	—	—	—	—	—	—	—	—	—
	Fe^{3+}	0,251	0,180	0,159	0,195	0,190	0,155	0,130	0,269	0,281	0,285
	Mn	0,032	0,032	0,030	0,035	0,037	0,023	0,028	0,016	0,014	0,023
	Ca	1,704	1,750	1,739	1,697	1,700	1,789	1,794	1,651	1,585	1,622
2	Na	0,013	0,038	0,072	0,073	0,073	0,033	0,048	0,064	0,120	0,070
	Na	0,442	0,376	0,342	0,307	0,327	0,365	0,368	0,348	0,264	0,406
	K	0,055	0,133	0,129	0,115	0,124	0,122	0,133	0,039	0,025	0,035
	Ca	—	—	—	—	—	—	—	—	—	—
	$\frac{Mg}{Mg + Fe^{2+}}$	0,59	0,54	0,54	0,53	0,51	0,54	0,53	0,64	0,63	0,66

Rudňany area, Leake's classification (1978) was applied. Analyzed amphiboles belong to the group of calcic amphiboles. Their projection points fall within fields VII, VIII and XVII (Fig. 10). The $Mg/Mg + Fe^{+2} = 0{,}5—0{,}7$ ratio is characteristic for all analyzed amphiboles. On the partial plot A, which includes analyses with the ratio $(Na + K)_A < 0{,}5$, analyses of amphiboles from Rudňany area are projected into the field "Mg-hornblende". The "ferrohornblende" field contains only one amphibole sample. The projection point of this sample is located near the dividing line of the mentioned fields.

Criterion for classification of amphiboles into partial plots A or B, appears to be the sum of alkalies $(Na + K)_A =$ 0,5. For analyzed amphiboles the sum $(Na + K)_A$ similar to 0,5 is characteristic and projection points of amphiboles fall into both partial plots.

The $Al^{VI} : Al^{VI}$ ratio and its relation to Si provided the basis for classification of essential Ca-amphibole types according to E. Wenk et al. (1974), Figs. 11a, 11b. Projection points of amphiboles under consideration fall mostly into the field of amphibolite amphiboles, characteristic for the Lepontine Alps amphibolite facies (Wenk et al. 1974). A part of analyzed amphiboles falls into the actinolitic (common hornblende) amphibole field. This position, mainly in the case of sample I is common in all other presented plots.

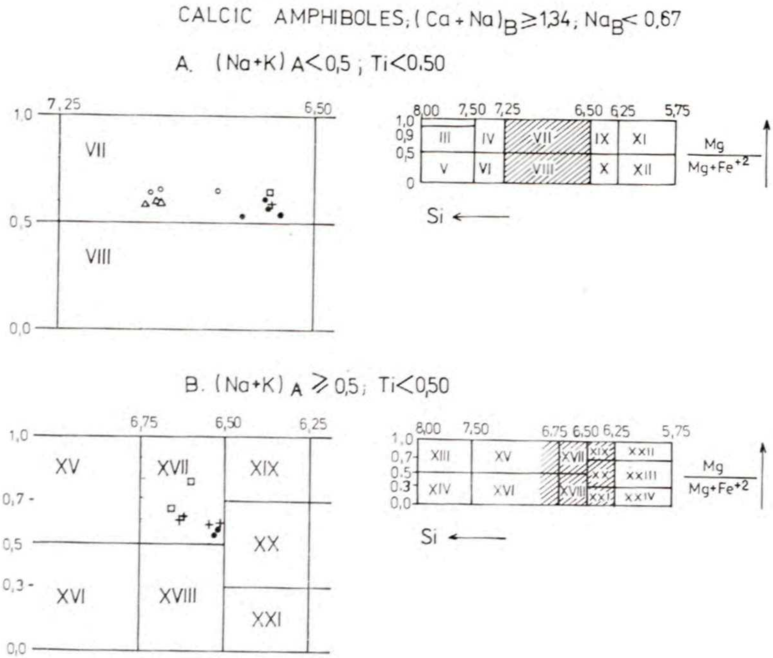


Fig. 10. Classificational diagram of amphiboles (Leake 1978). VII — Mg-hornblende, VIII — ferrohornblende, XVII — edenitic hornblende; explanations as in Fig. 9

Obr. 10. Klasifikačný diagram amfibolov (Leake 1978); VII — Mg-amfibol, VIII — železnatý amfibol, XVII — edentický amfibol; vysvetlivky ako pri obr. 9

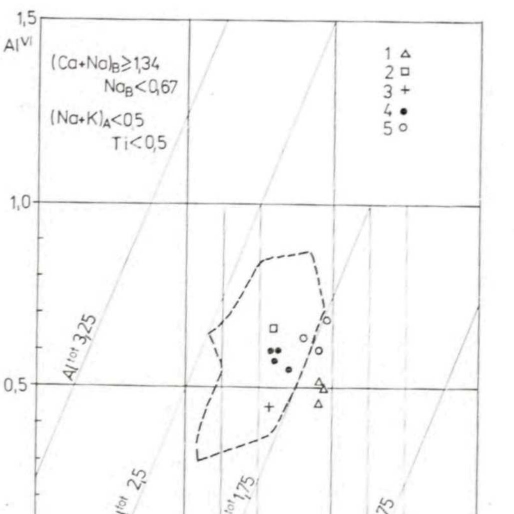


Fig. 11a. Classificational diagram of calcic amphiboles (Wenk et al. 1974). I — tschermakite, II — tschermakitic hornblende, III — Mg—Fe hornblende, IV — actinolitic hornblende, V — tremolite, actinolite; A — tschermakitic hornblende, B — Mg—Fe hornblende, C — arctinolitic hornblende, D — actinolite, tremolite; 1 — 5: see Fig. 9. Field designated by dashes corresponds to amphibolite amphiboles of the Lepontine Alps (Wenk et al. 1974)

Obr. 11a. Klasifikačný diagram vápenatých amfibolov (Wenk et al. 1974); I — tschermakit, II — tschermakitický amfibol, III — Mg—Fe amfibol, IV — aktinolitický amfibol, V — tremolit, aktinolit; A — tschermakitický amfibol, B — Mg—Fe amfibol, C — aktinolitický amfibol, D — aktinolit, tremolit; 1—5: pozri obr. 9. Čiarkovane ohraničené pole — odpovedá amfibolom amfibolitov Lepontských Álp (Wenk et al., 1974)

Plots of Ti content (Fig. 12) range analyzed amphiboles to high—temperature part of amphibolite facies. Ti contents in sample I can be used as a criterion for determining its formation in conditions of epidote amphibolite facies and in lower—temperature parts of amphibolite facies, respectively.

The Al^{VI}: Si ratio was used by P. Raase (1974) to define metabasite amphibole fields of high and low—pressure metamorphism (Fig. 13). The majority of analyzed amphibole projection points is placed into the field A, near the dividing line (= 500 MPa). A position like that suggests their low to medium—pressure metamorphism origin.

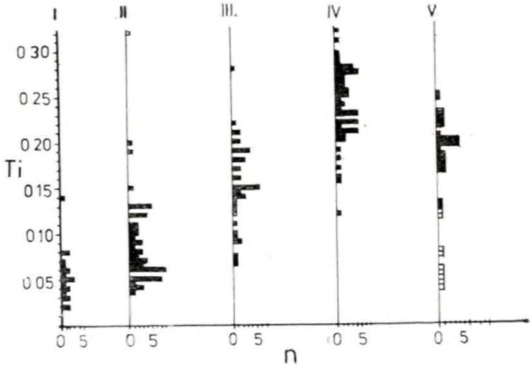


Fig. 12. Histogram of Ti distribution in metabasite amphiboles belonging to different facies (Raase 1974). I — green-schist facies, II — low-temperature subfacies of amphibolite facies, III — high-temperature subfacies of amphibolite facies, IV — amphibole-granulite facies, V — histogram of Ti distribution in metabasite amphiboles from Rudňany area (n — number of analyses)

Obr. 12. Histogram distribúcie Ti v amfiboloch metabazitov rôznej faciálnej príslušnosti (Raase 1974). I — fácia zelených bridlíc, II — nízkoteplotné subfácie amfibolitovej fácie, III — vysokoteplotné subfácie amfibolitovej fácie, IV — amfibolitovo-granulitová fácia, V — histogram distribúcie Ti v amfiboloch metabazitov oblasti Rudnian (n — počet analýz)

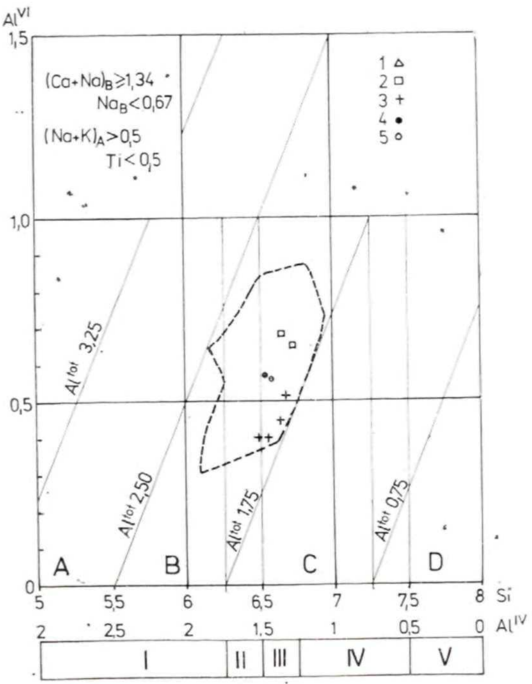


Fig. 11b. Classificational diagram of calcic amphiboles (Wenk et al. 1974). I — pargasite, II — pargasitic hornblende, III — edenitic hornblende, IV — edenite, V — silicic edenite; A—D: see Fig. 11a

Obr. 11b. Klasifikačný diagram vápenatých amfibolov (Wenk et al. 1974). I — pargasit, II — pargasitický amfibol, III — edenitický amfibol, IV — edenit, V — kremitý edenit; A—D: pozri obr. 11a

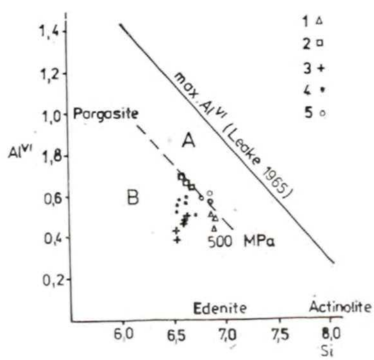


Fig. 13. Plot of Al^{VI} : Si dependence (Raase 1974); A — high-pressure metamorphism, B — low-pressure metamorphism

Obr. 13. Diagram závislosti Al^{VI} : Si (Raase 1974); A — vysokotlaková metamorfóza, B — nízkotlaková metamorfóza

Distribution coefficients

To collect the information on the origin conditions of coexisting garnets and amphiboles, the distribution of some elements in these minerals was also employed. The distribution of Mg, Fe, Mn, Ti and Ca between garnet and amphibole, and/or amphibole and plagioclase (Pertchuk 1970, Matkovskiy 1978) was calculated. For calculation of distribution coefficients the average contents of the mentioned cations in the individual samples were taken into consideration. Since the results are almost identical, only some of them are presented (Table 3).

S a m p l e 1 : From the whole series, the lowest origin temperatures (510—520 °C) were calculated in the couples garnet—amphibole and amphibole—plagioclase. These ones correspond to the transitional temperatures between the green-schist facies and the low—temperature area of the amphibolite facies. According to different classifying schemes of the metamorphic facies (Eskola 1939, Turner 1968, Winkler 1967 and others) the given mineral pairs originated in the highest temperature subfacies conditions of the green-schist facies, and/or in conditions of epidote amphibolite facies to conditions of the lowest temperature subfacies of the amphibolite facies. In concordance with the present tendency of classifying the metamorphic complexes into 4 main groups (very low, low, medium and high-grade — Winkler 1979), the minerals originated in "medium grade metamorphism" conditions. At the same time, it is characteristic that in com-

Distribution coefficients
Distribučné koeficienty

Tab. 3

	Sample I	
$X_{hbl}^{Mg} = 5,56$	$T_x = 510$ °C	$X_{gar}^{Mg} = 0,14$
$X_{hbl}^{Ca} = 0,80$	$T_x = 520$ °C	$X_{plag}^{Ca} = 0,32$
	Sample II	
a) $X_{hbl}^{Mg} = 0,68$	$T_x = 580$ °C	$X_{gar}^{Mg} = 0,38$
b) $X_{hbl}^{Mg} = 0,61$	$T_x = 600$ °C	$X_{gar}^{Mg} = 0,36$
	Sample V	
$X_{hbl}^{Mg} = 0,61$	$T_x = 620$ °C	$X_{gar}^{Mg} = 0,28$

Explanations:

$$X_{hbl}^{Mg} = \frac{Mg}{Mg + Fe + Mn}; \qquad X_{hbl}^{Ca} = \frac{Mg}{Mg + Fe + Mn};$$

$$X_{gar}^{Mg} = \frac{Ca}{Ca + Na + K}; \qquad X_{plag}^{Ca} = \frac{}{Ca + Na + K};$$

parison with the other analyzed amphiboles, the same lowest temperature conditions of origin were exhibited also by projections of analyzed amphiboles in diagrams with different coordinates (Figs. 8, 9, 11, 12).

S a m p l e 2 : In two of the coexisting garnet and amphibole couples the distribution coefficient offered the temperatures of the origin 580 and 600 °C. Temperatures like that are characteristic for "medium grade metamorphism" (Winkler 1979).

S a m p l e s 5 : Calculated distribution coefficients between garnet and amphibole of this sample indicate also "medium grade metamorphism" conditions (620 °C).

Discussion

Considering the metamorphic history of the Paleozoic rocks in the area of Rudňany, designated as the "gneiss — amphibolite complex" (Hovorka et al. 1979), their genesis may be presented in the following ways:

a) The classic concept of the "regional" progressive metamorphism due to considerable effect of stress and elevated temperature is not likely because of limited thickness of the studied complex of amphibolite facies metamorphites occurring in metamorphites of green-schist facies.

b) Mineral assemblages under consideration may also have originated via the overheating of the studied rock complex due to the effect of the Variscan plutonite intrusions. This type of genesis is in contradiction with the following facts:

i) transitions into the surrounding rocks, i. e. metamorphites of green—schist facies can be traced locally towards the overlying and underlying rocks (in the case of appropriate lithology of the surrounding rocks);

i) metamorphite mineral assemblages of amphibolite facies (paragneisses and amphibolites) are continually appearing within the whole area (the length of the gneiss-amphibolite complex is about 3 km!) as well as in the cross profile of their occurrence. No features of zonal distribution of critical minerals conditioned by thermic effect of intrusion have been observed;

i) metamorphites under consideration have mostly areally parallel textures which would not be so definite in the case of rocks originated in the exocontact of the intrusion.

c) The presence of gneiss-amphibolite type metamorphites within the metamorphites of considerably lower metamorphic grade (green-schist facies) in so far known occurences (Dobšiná—Rudňany—Vyšný Klátov) enables to interpret their origin as the consequence of tectonic — recrystallization processes in the zone of crustal subduction of the Gemeride block under the northern Tatraveporide block. These occurrences are parallel with the contact of the Gemeride block (of the Volovec zone) with the Veporide — Sľubica crystalline complex along the Margecany—Ľubeník lineament. However, this way of gneiss--amphibolite type metamorphite origin is opposed mainly by the structures of blasthesis of gneiss and amphibolite mineral assemblage in quasi—static conditions (i. e. weak pressure phenomena at the origin of given mineral assemblages).

d) Mineral assemblages under consideration originated most probably as the product of recrystallization of original mineral assemblage of metapsammites and metapyroclastics of the green-schist facies (chlorite + albite + quartz ± carbonate ± actinolitic amphibole) in the zone of elevated heat flow (a weakened tectonized belt). In this type of metamorphic recrystallization an important part was played by the heat effect; the pressure effect was not of such importance. According to this interpretation, areally parallel textures of gneisses and amphibolites represent the product of overprinting metamorphic recrystallization of originally directed mineral aggregate. This interpretation of the genesis of amphibolite facies metamorphites is supported by the following lines of evidence:

1) concordant, generally plate to lenticular — longitudinal shape of gneiss and amphibolite complex (Hovorka et al. 1979) in the lower grade metamorphic metamorphites;

2) in the case that in the overlying and underlying rocks of the gneiss—amphibolite complex (originally microscopic-grained psammites of graywacke type with layers of fine—grained volcanoclastics of basic volcanics) the graphitic schists of the Carboniferous occur, their mutual contact is a sharp one; in the case that in direct environment of the discussed metamorphites other rock types are occurring (conglomerates with sand matrix, pebbles), the effects of thermal recrystallization were observed in these rocks. Transitions from the gneiss—amphibolite complex into the surrounding rocks are in these cases the gradual ones.

3) within the complex of gneisses and amphibolites the albitized types were discovered, i. e. migration of mainly alkaline metals appeared locally. In the essential rock types this process is documented by the origin of pronounced porphyroblasts of albite, veinlets (locally oriented in oblique and perpendicular direction toward the foliation of the rock) with monomineral albite filling. The mentioned processes are most probably appearing in tectonically prepared zone with presence of elevated heat flow.

4) Discovered simple (not zonal) structure of metabasite garnets is the most probable consequence of rapid overheating of the complex under static conditions.

In the course of recent years (Cambel 1980, Kantor 1980) the age of amphibolite facies metamorphites of the northern margin of the gemeride block (Dobšiná, Rudňany, Vyšný Klátov) has been stated. The following data of the metamorphite age were discovered with the use of Ar/K method.

Paragneisses: Rudňany — 286,5 $\pm$ my; Dedinky — 272,5 my; Dobšiná — 258 $\pm$ 25 my; Amphibolites: (amphiboles of amphibolites were analyzed): Dobšiná—Langenberg — 357,7 $\pm$ 15,6 my; Dobšiná—Gugl — 338,5 $\pm$ 15,5 my; Vyšný Klátov — 362,5 $\pm$ 1,4 my (all data in B. Cambel 1980); Vyšný Klátov 391 $\pm$ 18 my; Vyšný Klátov — 448 $\pm$ 23 my, Košická Belá — 337 $\pm$ 16 my (data in Kantor 1980).

These data provide the information that the age of the amphibolite amphibole genesis is considerably higher than that of mineral assemblages of gneisses. They correspond to the ages on the boundary of the Upper Devonian — the Lower Carboniferous, while the paragneisses originated within the Upper Carboniferous — the Permian. It is necessary to emphasize the fact that the positions of gneisses and amphibolites in all the mentioned localities belong to one and the same complex of metamorphites with multiple interstratifying of gneisses and amphibolites in the vertical section of the given metamorphosed complexes, their origin is definitely a syngenetic one according to the geological criteria.

The problem of stratigraphic identification of the gneiss—amphibolite complexes of the gemeride Paleozoic still remains a crucial issue. Whilst in the area of Dobšiná (Rozložník 1965) and Vyšný Klátov (Dianiška — Grecula

1979) the complexes are considered to be a part of the Early Paleozoic Rakovec group, discontinuous transitions of gneiss—amphibolite complex in Rudňany into psammites regarded definitely as the Upper Carboniferous express the urgent need to solve the problem of the stratigraphy of the rock complexes regarded as the Lower Paleozoic (the Rakovec group), and/or the Upper Carboniferous.

Conclusions

i) Examination of chemical composition of coexisting garnets and amphiboles of metabasites from Rudňany area enables to state that the mentioned rock types definitely belong to metamorphites of amphibolite, and/or epidote—amphibolite facies. In concordance with contemporary trend of classifying metamorphite complexes (Winkler 1979), examined metamorphites belong to the group "medium grade metamorphites".

i) Chemical composition of garnets corresponds to the type with prevailing almandine and substantial presence of pyrope and grossulare molecules. Garnets have a simple (not zonal) structure, which is conditioned by probable consequence of their origin under static conditions. Amphiboles belong to the group of calcic amphiboles (Leake 1978), while most of analyzed grains belong to the subgroup of Mg-hornblende. On the basis of Al^{VI}/Si ratio in amphiboles, according to the criteria of P. Raase (1954) they have originated in low to medium — pressure metamorphic conditions.

i) Calculated distribution coefficients, mainly Mg_{hbl}^{gr} and Ca_{hbl}^{plag} prove that these minerals originated at temperature within the range 500—600 °C. The lowest calculated temperatures (500, 510 °C) are those of garnets, amphiboles and plagioclases from sample I. Amphiboles and garnets from this sample originated at lower temperatures also according to their chemical composition in comparison with others.

i) On the basis of occurrence, textural features and composition of coexisting garnets and amphiboles, the most likely seems to be the origin of amphibolites under consideration (and in this way also the origin of surrounding gneisses) in tectonically suitable zone of considerably elevated heat flow, while the graphitic schists played the role of heat barrier.

Translated by Hana Budajová

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Koexistujúce granáty a amfiboly metabazitov oblasti Rudnian

DUŠAN HOVORKA — JÁN SPIŠIAK

V metabazitoch komplexu hornín zaraďovaných do vrchného karbónu, ktoré sa v minulosti interpretovali ako intruzíva (Mandáková et al., 1971), resp. ako metamorfity amfibolitovej fácie (Hovorka et al., 1979), sme pomocou elektrónového mikroanalyzátora bádali chemické zloženie koexistujúcich granátov a amfibolov. Výsledky výskumu priniesli jednoznačné dôkazy o vzniku tejto minerálnej asociácie pri metamorfóze v podmienkach amfibolitovej fácie, resp. metamorfózy „medium grade" (v zmysle Winklera, 1979). Súčasne prebiehajúce prieskumné banské práce priniesli ďalšie dôkazy o vystupovaní „rulovo-amfibolitového komplexu" (Hovorka et al., l. c.) v horninách, ktoré sa zaraďujú do vrchného karbónu, pričom inkriminovaný komplex eruptív (metamorfitov) má tvar ložnej polohy až pretiahnutej šošovky s postupným vykliňovaním v smere Z—V (Kusák, ústna informácia). Nateraz známe rozšírenie komplexu je v dĺžke väčšej ako 3 km. Jeho hranice s nadložnými a podložnými (karbónskymi ?) horninami sú ostré (v prípade grafitických bridlíc) alebo pozvoľné (v prípade psamitov a jemnozrnných extruzív bázických vulkanitov).

Chemické zloženie granátov metabazitov zodpovedá typu s prevládajúcou almandínovou a podstatne zastúpenou pyropovou a grossulárovou molekulou. Majú jednoduchú (nezonálnu) stavbu, čo je pravdepodobne výsledok ich vzniku za vyššej teploty. Amfiboly metabazitov patria do skupiny vápenatých amfibolov, pričom väčšina analyzovaných zŕn patrí do podskupiny Mg amfibolov (Leake, 1978). Na základe pomeru Al^{VI} a Si v štruktúre amfiboly podľa kritérií P. Raasa (1974) vznikli v nízkotlakových, resp. až v strednotlakových metamorfných podmienkach.

Vznik analyzovaných amfibolov v podmienkach amfibolovej fácie dokumentuje aj vysoký obsah Ti (obr. 13), pomer Al^{VI} : Al^{IV} a ich vzťah k Si — týmto vzťahom mnohí autori prisudzujú zásadný klasifikačný aj genetický význam (obr. 11a, 11b), ale aj zelenohnedý (gama) pleochroizmus amfibolov a i. Pritom uvedené stanovenia korelujú so zisteným chemickým zložením koexistujúcich granátov aj s celkovou minerálnou asociáciou amfibolitov (chýbanie koexistujúceho chloritu ako typického reprezentanta fácie zelených bridlíc, ale aj iba lokálna prítomnosť pravdepodobne naloženého epidotu — bazicita plagioklasu, obsah An vyše 26 %, a i.).

Vypočítané distribučné koeficienty najmä Mg_{amf}^{gr} a Ca_{amf}^{plag} dokumentujú teplotu vzniku týchto minerálov od 500 do 600 °C (Perčuk, 1970, Matkovskij, 1978). Pritom najnižšia vypočítaná teplota (500, 510 °C) patrí granátom, amfibolom a plagioklasom zo vzorky I. Amfiboly a granáty aj podľa chemického zloženia v porovnaní s ostatnými vznikli pri nižšej teplote.

Podľa geologickej pozície komplexu rúl a amfibolitov, textúrnych znakov základných horninových typov a ich mnohonásobného striedania, ale aj zloženia skúmaných koexistujúcich granátov a amfibolov metabazitov je najpravdepodobnejšie, že študované horniny (amfibolity, ale aj okolné ruly) vznikli v tektonicky predisponovanej zóne výrazne zvýšeného tepelného toku. Grafitické bridlice v okolí tejto zóny sa miestami uplatnili ako výrazná teplotná bariéra. Rozpornosť vo vystupovaní a zaraďovaní litologicky celkove podobných komplexov v oblasti Dobšinej, Rudnian a Vyšného Klátova (staršie paleozoikum: karbón) nastoľujú nevyhnutnosť prehodnotiť stratigrafickú príslušnosť metasedimentov a metaeruptív severného okraja gemerika, ktoré sa súčasne zaraďujú do rakoveckej série a vrchného karbónu.

RECENZIA

I. F. Zubkov: **Problém geologickej formy pohybu hmoty.** 1. vyd. Bratislava, Pravda 1981. 272 s.

Recenzovaná monografia je prekladom z ruštiny (Problema geologičeskoj formy dviženija materii. Moskva, Nauka 1979. Preložil M. Řehák) a zaoberá sa jedným z najzávažnejších problémov geológie — geologickou formou pohybu hmoty, ako aj s ním súvisiacimi filozoficko-metodologickými otázkami tejto vedy.

Geologická forma pohybu hmoty sa dostala do centra pozornosti filozofov i geológov v súvislosti s vymedzovaním objektu bádania geológie, ale najmä jej miesta v systematike prírodných vied. Materialistické klasifikačné systémy, ako je známe, vychádzajú pri klasifikácii vied z ich vzťahu k formám pohybu hmoty. Problémy vznikli tým, že F. Engels pri vymedzovaní základných foriem pohybu hmoty geologickú formu neuvádza, a pretože podľa neho a ďalších filozofov každá veda sa zaoberá istou formou pohybu hmoty, vznikali spory o tom, do akej miery je geológia samostatnou vedou, ako aj o tom, čo treba rozumieť pod formou pohybu hmoty vôbec.

Spomenuté a mnohé ďalšie otázky z rozličných aspektov analyzuje Zubkovova monografia. V sovietskej literatúre sa týmto problémom venovalo veľa autorov a ich publikácie sú prístupné aj našim čitateľom, ale aj tak po rusky písaná filozofická literatúra kladie najmä na „nefilozofov" vysoké nároky. Preto treba vrele privítať počin nakladateľstva Pravda vydať recenzovanú publikáciu v slovenčine, a tak sprístupniť širokej verejnosti, osobitne geologickej, riešenie filozofických problémov geológie.

Popri základných otázkach formy pohybu hmoty a geologickej formy pohybu hmoty osobitne, ich vzťahu k iným formám pohybu hmoty atď. nájde čitateľ v práci aj riešenie radu filozofických otázok geológie a geologických vied, ako aj predmet a objekt geológie a jej vedných disciplín, vzťah dialektiky a geológie ako systému, problémy formovania teoretickej geológie, zákony geológie z filozofického pohľadu, teoretické členenie geologických a príbuzných vied a pod.

Monografia I. F. Zubkova nastoľuje aj niektoré teoretické otázky geológie a aj z tohto hľadiska by mala patriť do základného knižného fondu nielen filozofov, ale najmä geológov.

J. Babčan