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TARAMITE-BEARING METABASITES FROM RAKOVEC (GEMERIC UNIT, THE WESTERN CARPATHIANS)

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Abstract: The Rakovec Group, which forms a narrow belt along the northern and eastern boundaries of the Early Paleozoic of the Gemeric Unit, is represented mostly by greenschist-facies metabasites and phyllites. The metabasites usually contain albite, epidote, chlorite and actinolite. However some metamorphosed basaltic rocks near Rakovec, located in the western part of this Group, contain Al-rich Na-Ca and Ca amphiboles instead of actinolite. Compositionally, these amphiboles correspond to taramite and sodian ferropargasite and reveal textural equilibrium with albite, epidote, chlorite, Ca-garnet and biotite. The presence of taramite and sodian ferropargasite in metabasites are a result of relatively higher metamorphic pressures and temperatures than in other parts of the Gemeric Unit, but the influence of the whole-rock composition in favoring the appearance of greenish-blue amphiboles is also possible. Mineral zoning indicates a decrease of pressure and temperature during metamorphism. Regarding the metamorphic conditions of the Early Paleozoic sequences of the Gemeric Unit, the northern part, as represented by the Rakovec Group, underwent metamorphism in the high-pressure part of the greenschist facies.

Key words: Western Carpathians, Gemeric Unit, metamorphic pressures and temperatures, metabasalts, sodian ferropargasite, taramite.

Introduction

Prograde mineral assemblages involving Na-Ca and Ca amphiboles occur in metabasites of the Rakovec Group, situated along the northern and eastern boundary of the Early Paleozoic of the Gemeric Unit (Fig. 1). The Rakovec and the Gelnica Group rocks underwent Variscan greenschist-facies metamorphism. The most common metamorphic minerals of the metabasites are albite, epidote, chlorite, actinolite, titanite, occasionally also stilpnomelane and biotite (Faryad 1991). Metapelites and metapsammites adjacent to metabasites contain white mica, chlorite, quartz and rarely albite. Kyanite was found only in Al-rich rocks in the central part of the Gelnica Group (Faryad & Dianiška 1992). Biotite is usually present in some acidic metavolcanics which are frequent in the Gelnica Group.

Metabasalts forming pillow lavas and lava flows near Rakovec from the Rakovec Group were first described by Bajaník (1975, 1976). Hovorka et al. (1988) identified a Na-Ca amphibole in these rocks and consider two Variscan metamorphic events, the former (medium pressure) related to generation of Na-Ca amphibole and the latter (greenschist facies) producing actinolite. Since there are no geochronological data, Hovorka et al. (l.c.) do not exclude a possible relationship of Na-Ca amphibole formation to Alpine high-pressure metamorphism of the Meliata Unit for which Faryad (1995) estimated pressures of 7.5–12 kbar at 350–460 °C.

The aims of this work were to undertake petrological analysis by studying the textural and phase relations of the metabasites, and to estimate the P-T conditions of metamorphism. In order to evaluate the postulated medium-pressure event of the Rakovec Group, the estimated metamorphic conditions are interpreted in the context of mineral assemblages occurring in the Rakovec and Gelnica Groups.

Geological setting

Metabasites with greenish-blue taramite and sodian ferroparagasite, as described here, occur within an east–west-trending metabasite belt of the Rakovec Group of Bajaník et al. (1983), situated in the northern and eastern part of the Gelnica Group (Fig. 1). The metabasites are a part of the Sykava Formation that overlies the lower Smerčiny Formation, represented mostly by quartz phyllites (Fig. 1B). Following Grecula (1982), both the Rakovec and the Gelnica Groups actually correspond to the same lithostratigraphical unit and form a slice and nappe system overthrust to the north. The Rakovec and Gelnica Groups are characterized by Early Paleozoic volcano-sedimentary sequences, the former with abundant basaltic and the latter with abundant acidic to intermediate volcanic rocks. With respect to geochemical character of the metabasites, the Rakovec Group may be regarded as a remnant of the crust of a marginal part of a back-arc basin (Ivan 1994). Both the Gelnica and Rakovec Group rocks underwent Variscan greenschist-facies metamorphism. Small amounts of amphibolite-facies rocks (the so-called Gneiss-Amphibolite Complex), forming slices and tectonic blocks, occur in the northern and eastern parts of the Gemeric Unit. The greenschist- and amphibolite-facies rocks are in part covered by very low-grade Late Paleozoic sequences. From the south, the Late and Early Paleozoic rocks are tectonically overlain by the Meliata high-pressure/low-temperature rocks.

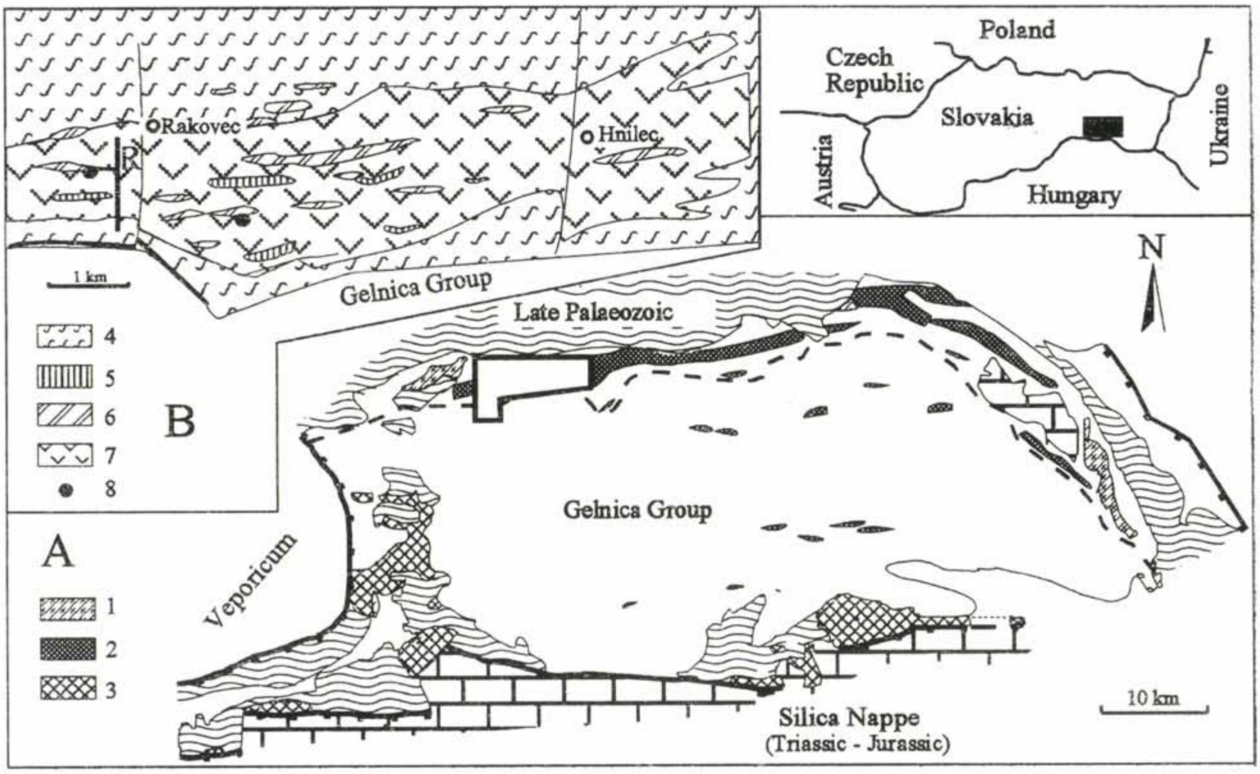

Fig. 1. Schematic geological map of the Gemeric Unit (Bajaník et al. 1984): **A** — the Early Paleozoic Rakovec (to the north) and Gelnica (to the south) Groups, separated by dashed line: 1 — Gneiss-Amphibolite Complex, 2 — metabasite occurrences within the Rakovec and Gelnica Groups, 3 — the Meliata blueschist facies rocks. **B** — geological sketch map of the study area near Rakovec and Hnilec: 4 — quartz phyllites of the lower Smerčiny Formation, 5 — chlorite phyllites, 6 — metabasalts, 7 — metamorphosed basaltic tuffs (5–7 the upper Sykava Formation), 8 — occurrence of taramite. R indicates position of geological profile in Fig. 2.

The detailed geological situation of metabasites containing taramite and sodian ferropargasite is shown in Fig 1B. The metabasalts, primarily representing lava flows and pillow lavas form east–west-trending lens-like bodies surrounded by metapyroclastics, partly also by phyllites (Bajaník 1975). Metabasalts usually show tectonic contacts with the foliated metabasites, mainly with phyllites, but all these rocks are considered to be a part of the Sykava Formation of the Rakovec Group.

Petrography

Metabasites near Rakovec were sampled along a south-north profile (Fig. 2) crossing lithologically different rocks. Well-developed greenish-blue taramite and sodian ferropargasite occur in metabasalts represented by pillows, lava flows, amygdaloidal and porphyric varieties. The pillows are rimmed by a fine-grained mass containing hematite and magnetite. In addition to pseudomorphs of albite after plagioclase, pyroxene phenocrysts are also present. Small amygdales in the rock are filled by chlorite, epidote, calcite and rarely also by albite. Metamorphic mineral assemblages occurring in massive pillows are greenish-blue amphibole, epidote, albite, chlorite, titanite (Tab. 1) and occasionally also calcite, biotite, Ca-garnet, quartz and actinolite. Some foliated metabasites contain elongated plagioclase phenocrysts (up to 1 cm in size) forming augen-like textures. The taramite and sodian ferropargasite crystals are partly replaced by chlorite in some samples. Representative chemical analyses of metabasites are given in Tab. 1. Metapyroclastics lack amphibole, and there are no relics or pseudomorphs after taramite or sodian ferropargasite. Both amphibole-bearing and amphibole-free assemblages can be observed in the same outcrop.

Greenish-blue amphibole is fine-grained (up to 0.1 mm) but some amphibole crystals have a length of 0.5 mm. It is intergrown with chlorite, biotite (Fig. 3) and forms inclusions in, or cross-cuts albite. Garnet with accessory amounts of epidote, chlorite, quartz and taramite and/or sodian ferropargasite were found in pseudomorphs of albite after phenocrysts of plagioclase (Fig. 4). Relic pyroxene is overgrown by greenish blue amphibole, chlorite and biotite. The presence of accessory actinolite forming individual crystals and rimming the Na-Ca amphibole was described also by Hovorka et al. (1988). These authors consider that actinolite was formed during the second, greenschist-facies metamorphism. In our case, rarely occurring actinolite reveals textural equilibrium with taramite or sodian ferropargasite. Calcite usually forms narrow veins crossing the foliation, but small amounts of calcite replacing plagioclase or filling amygdales indicate equilibrium with the above-mentioned mineral phases. Some calcite aggregates are cut by taramite or sodian ferropargasite. In addition to albite forming pseudomorphs after plagioclase or filling amygdales, narrow albite vein can be also observed.

The basaltic metapyroclastics are usually foliated and contain chlorite, epidote, albite, titanite, calcite and occasionally also actinolite (sample Fg-9/95 in Tab. 1). Phyllitic rocks adjacent to metabasites that are not the subject of this study are very fine-grained and contain white mica, quartz, chlorite and

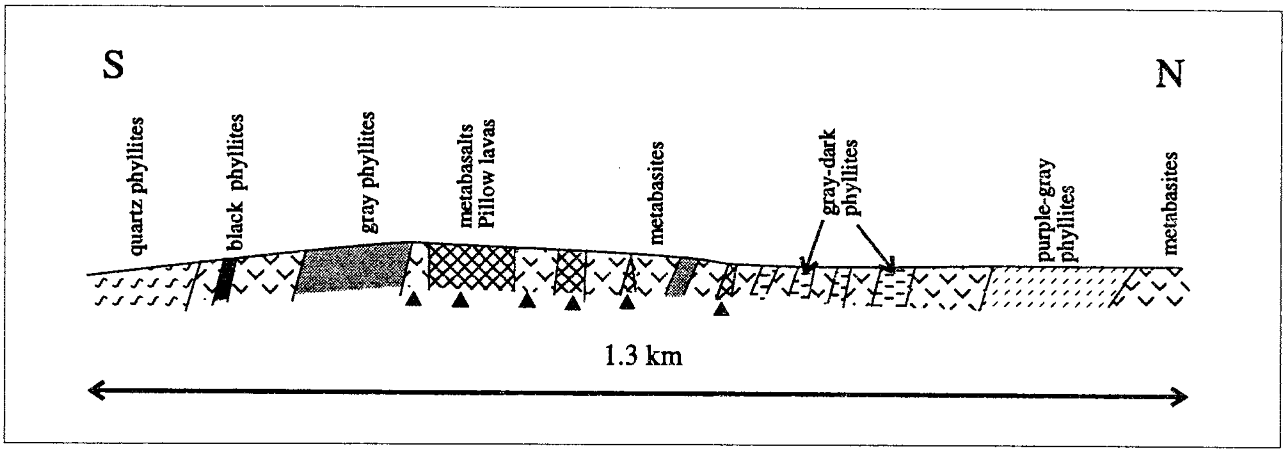

Fig. 2. Geological profile of metabasites and surrounding rocks near Rakovec (**R** in Fig. 1B). Filled triangles show occurrence of taramite in metabasalts.

Fig. 3. Photomicrograph of taramite intergrowing with and cross-cutting biotite. Plane polarized light.

Fig. 4. Phenocrysts of pyroxene (Px) and plagioclase, the latter replaced by albite (Ab) and garnet (Gr). Plane polarized light.

rutile. Some phyllites contain fine spot-like pseudomorphs of chlorite. Accessory amounts of green biotite were observed in quartz phyllite.

In order to compare mineral and chemical composition of taramite-bearing metabasalts with other mafic rocks of the Sykava Formation near to the studied area, some metamorphosed basalts and basaltic andesites outcropped at Hnilec were investigated. These rocks occur within metapyroclastics and contain albite, epidote, actinolite, chlorite and small amount of titanite and quartz (Tab. 1).

Mineral chemistry

Mineral analyses were carried out using a wavelength dispersive Cameca Camebax microprobe at the Institut für Mineralogie (Bochum). The standards used were pyrope, andradite-glass, jadeite, spessartine, TiO_2, K-silicate glass, Ba-silicate glass, topaz and NaCl. Operating voltage was 15 kV. Beam currents were 10 or 15 nA with 20 s counting time. All minerals were analyzed with a 2 µm beam diameter. The structural formulae and the Fe^{3+}/Fe^{2+} ratios were calculated based on the assumption of 13 cations (without K, Na and Ca) and 46 valencies for amphibole, 12 oxygens and using the equation $Al^{VI} + Cr + Ti + Fe^{3+} = 2$ for garnet.

Following Leake (1978), the Na-Ca and Ca amphiboles from Rakovec correspond to taramite and sodian ferropargasite in composition (Tab. 2, Figs. 5 and 6). The $X_{Mg} = Mg/(Mg + Fe^{2+})$ and Na^{M4} contents ranges between 0.36-0.45 and 0.5-0.8, respectively. Most amphibole analyses have (Na + K) > 0.5 (0.51-0.96) and Si < 6.4 (6.0-6.4 atoms per formula unit (a./f.u.)). Compositionally taramite is similar to that described by Linthout & Kieft (1970) from albite-bearing micaschists in the Sierra de los Filabres (SE Spain). Coarse grains of taramite are weakly zoned with a decrease of Al and an increase of Fe^{3+} from core to rim. Small amounts of actinolite occur in taramite-bearing rocks containing calcite.

Garnet usually occurs in pseudomorphs of albite after plagioclase (Fig. 4). It is rich in Ca, with an average composition of Grs_{73}, And_{18}, Sps_2, Alm_2, $Py_{0.2}$. Some garnet crystals show pronounced zoning; the grossularite content decreases and andradite increases from core (Grs_{72}, And_{20}) to rim (Grs_{44}, And_{54}) (Tab. 2). The maximum MgO content, analyzed in garnet core, was 0.6 wt. %.

The red-brown biotite forms aggregates consisting of small grains. Compared to the retrograde biotite occurring in greenschist-facies metabasites (Faryad 1991), it is rich in Mg with an X_{Mg} of about 0.47. Analyzed chlorite forms individual crystals in the rock and reveals textural equilibrium with taramite, biotite, garnet, albite and epidote. It has similar X_{Mg}

Table 1. Mineral modes and chemical composition of representative metabasite samples.

Locality	Rakovec							Hnilec
Rock type	metabasalt				metapyroclastics			metaandesite
Sample n.	Fg-10/91	Fg-6/91	Fg-9/91	Fg-4/91	Fg-22/95	Fg-13/95	Fg-9/95	Fg-27/95
Ab	xxxx	xxx	xxxx	xxx	xxxx	xxxx	xxxx	xxxx
Ep	xxx	xxx	xxx	xxxx	xxx	xxx	xxx	xx
Chl	xx	x	xxx	xxxx	xxxx	xxxx	xxx	xx
Tar-Prg	xxxx	xxx	xxx					
Act		x					xx	xx
Tnt	xxx	xx	xx	xx	x	xxx	xx	x
Bt	xx		x					
Gr	x							
Qtz	x	x	x	xx	xx		x	xxx
Cc		x	xx					
				wt. %				
SiO_2	44.00	46.47	42.90	45.50	48.10	47.72	47.90	54.30
TiO_2	4.47	1.00	0.6	1.20	0.08	0.08	0.12	0.00
Al_2O_3	14.80	16.14	19.1	16.82	24.98	20.13	20.90	17.07
Fe_2O_3	6.39	6.22	6.62	5.50	5.85	7.40	5.25	1.40
FeO	8.12	7.75	9.33	8.47	6.01	6.17	6.75	5.02
Mn	0.21	0.10	0.16	0.26	0.30	0.40	0.40	0.00
MgO	5.81	7.86	5.0	6.85	6.02	4.66	4.20	7.45
CaO	8.47	8.69	11.21	8.97	3.22	8.06	9.53	5.60
Na_2O	4.10	3.00	2.1	0.22	2.00	2.00	2.10	4.40
K_2O	0.60	0.56	0.20	0.10	0.20	0.20	0.20	0.80
P_2O_2	0.30	0.00	0.20	0.27	0.02	0.01	0.00	0.00
H_2O^+	3.27	2.55	2.90	5.42	2.20	2.64	2.04	3.48
H_2O^-	0.36	0.16	0.04	0.17	0.18	0.14	0.18	0.12
Total	100.90	99.75	100.36	99.75	99.55	100.18	99.57	99.64

Sample Fg-10/91, Fg-9/91 additionally contain pyroxene
xxxx > 20 % xxx > 5 %; xx > 1 %, x < 1 %

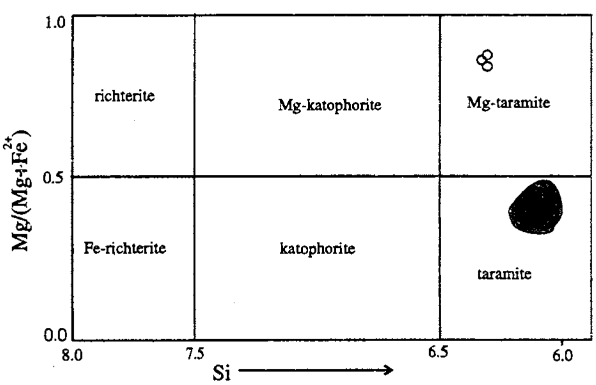

Fig. 5. The Si vs. $Mg/(Mg + Fe^{2+})$ diagram of Leake (1978) for amphiboles. Solid field represents taramite and sodian ferropargasite from Rakovec. Star corresponds to taramite from iron-rich albite-bearing micaschists in the Sierra de los Filabres (SE Spain) (Linthout & Kieft 1970); open circles are Mg-Al taramite from the Nybö eclogite in Norway (Ungaretti et al. 1981).

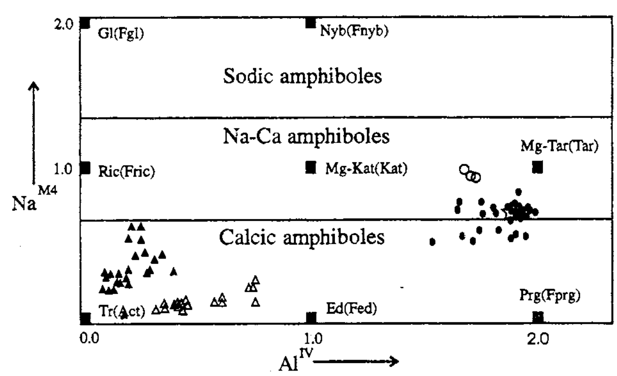

Fig. 6. Plot of the Na content at the M4 site (in atoms p.f.u.) vs. the tetrahedral aluminum content in studied Na-Ca amphiboles. Solid circles are taramite and sodian ferropargasite from the Rakovec. Solid triangles correspond to Na-rich actinolite in Hnilec. Open triangles represent actinolite from the Gelnica Group and eastern part of the Rakovec Group. Star and open circles are the same as in Fig. 5.

content to that in biotite (ca. 0.48). Some chlorite intergrown with biotite indicate relatively high K_2O contents and probably represent mixed layer crystals. Epidote corresponds to clinozoisite with $Fe^{3+}/(Al+Fe^{3+})$ ratio of about 0.24. Plagioclase is usually an albite with maximum CaO content of 0.8 wt. %.

Amphibole from the Hnilec basaltic metaandesites is an actinolite in composition. Compared to actinolite occurring in metabasalts and/or basaltic andesites in the Gelnica Group and in the eastern part of the Rakovec Group (Faryad 1991), it has higher Na_2O content (1.0-2.3 wt. %). Fig. 5 shows that some actinolite analyses plot close to the Na-Ca amphibole field. The Hnilec rocks are characterized by relatively high-Mg Chlorite (X_{Mg} = 0.6) and low-Al epidote ($Fe^{3+}/(Al+Fe^{3+})$ = 0.33) compare to that in the Rakovec.

Phase equilibria and metamorphic conditions

The presence of taramite within the Rakovec greenschist-facies belt is interesting, since this mineral is usually known from high-grade, high-pressure rocks. Ungaretti et al. (1981) described Mg-Al taramite (Fig. 5) from amphibolized eclogite in Nybö (Norway). They suggest that it was formed during a retrograde stage of metamorphism, but still at high pressure and high temperature (9-13 kbar and 650-720 °C). Taramite of composition similar to that described in this work was reported by Linthout & Kieft (1970) from iron-rich albite-bearing micaschists in the Sierra de los Filabres (SE Spain). The rocks adjacent to the albite-bearing mica schists are amphibolite, containing glaucophane-crossite and blue-green amphibole, but no metamorphic pressure and temperature were estimated for taramite formation. Ernst (1979) investigated Na-Ca amphibole of barroisite composition which compared to taramite has lower $(Na + K)_A$ (<0.5) and higher Si (6.5-7.5 a./f.u.) contents. He considered a P-T stability field ranging between 4-5 kbar at 350 °C and 5-7 kbar at 450 °C for barroisite. Ungaretti et al. (1983) supposed pressure higher than 8 kbar to be necessary for barroisitic amphibole described from the Sesia-Lanzo Zone in the Alps.

Textural relations in the Rakovec metabasites, mainly intergrowth of taramite + biotite, taramite + chlorite or of biotite + chlorite, as well as taramite forming inclusions in and cross-cutting pseudomorphs of albite after plagioclase, indicate the possible equilibrium coexistence of taramite in this assemblage. The appearance of taramite replacing pyroxene was favored by introduction of Na from plagioclase. The presence of Ca-rich garnet in pseudomorphs of albite after plagioclase suggests its formation by a local equilibrium of plagioclase replacement. In addition to garnet, accessory amounts of taramite and epidote also occur in these pseudomorphs.

To estimate the P-T conditions of the metabasites of this study, we used available thermodynamic data and empirical

Table 2. Representative microprobe analyses of minerals from metabasalts in Rakovec and Hnilec.

	Greenish-blue amphiboles					Actinolite				Pyroxene	
sp. n.	Fg-10/91			Fg-15/95		Fg-9/95		Fg-27/95		Fg-10/91	
	rim	core	rim								
SiO_2	39.94	39.64	39.96	39.72	43.51	52.84	52.88	53.62	54.94	50.62	50.68
TiO_2	0.40	0.40	0.25	0.14	0.31	0.00	0.01	0.04	0.01	1.05	1.02
Al_2O_3	15.74	16.11	13.02	13.74	14.82	1.67	1.72	2.32	0.86	2.35	2.38
Fe_2O_3	6.51	5.72	8.72	7.52	4.79	0.24	3.75	6.25	3.97	-	-
FeO	15.69	15.95	14.99	15.65	15.25	16.68	13.48	12.36	10.36	7.67	7.79
MnO	0.28	0.27	0.31	0.25	0.22	0.36	0.24	0.22	0.30	0.17	0.21
MgO	5.39	5.12	6.36	6.24	6.21	12.60	13.42	12.42	15.32	15.31	15.34
CaO	7.67	7.43	8.34	8.91	7.56	12.38	11.21	8.95	10.88	21.37	21.42
Na_2O	5.01	5.15	4.51	4.17	4.28	0.46	1.41	2.36	1.16	0.24	0.26
K_2O	0.64	0.64	0.71	0.74	0.63	0.16	0.07	0.13	0.07	0.02	0.00
F	0.00	0.00	0.07	0.06	0.03	0.10	0.02	0.15	0.13	-	-
Cl	0.02	0.00	0.02	0.02	0.00	0.02	0.01	0.00	0.02	-	-
Total	96.65	95.87	96.41	99.07	97.13	97.51	97.38	98.23	97.61	99.36	99.21
Ox.basis	23									6	
Si	6.103	6.102	6.160	6.127	6.499	7.800	7.716	7.732	7.875	1.904	1.903
Al^{IV}	1.897	1.897	1.839	1.873	1.501	0.199	0.284	0.267	0.125	0.096	0.097
ΣT	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	2.000	2.000
Al^{VI}	.937	1.026	0.525	0.626	1.110	0.090	0.012	0.127	0.021	0.008	0.007
Ti	0.046	0.047	0.029	0.016	0.034	0.000	0.001	0.004	0.000	0.029	0.028
Fe^{3+}	0.749	0.667	1.011	0.873	0.536	0.026	0.413	0.678	0.428	-	-
Fe^{2+}	2.004	2.054	1.932	2.019	1.905	2.059	1.651	1.490	1.242	00.241	0.244
Mn	0.037	0.035	0.040	0.032	0.027	0.044	0.020	0.027	0.036	0.005	0.006
Mg	1.227	1.176	1.460	1.434	1.383	2.772	2.929	2.669	3.273	0.858	0.858
ΣC	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000		
Ca	1.255	1.226	1.377	1.473	1.210	1.957	1.758	1.383	1.671	0.861	0.861
Na^{M4}	0.745	0.744	0.623	0.527	0.790	0.130	0.242	0.659	0.321	0.017	0.018
ΣB	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	1.99	-	-
Na^{A}	0.739	0.792	0.726	0.721	0.549	0.088	0.158	0.042	0.000	-	-
K	0.125	0.126	0.138	0.146	0.120	0.030	0.013	0.024	0.013	0.000	0.000
ΣA	0.864	0.918	0.865	0.867	0.669	0.119	0.241	0.066	0.010	-	-
F	0.000	0.000	0.033	0.027	0.014	0.045	0.009	0.069	0.058	-	-
Cl	0.006	0.000	0.006	0.000	0.000	0.006	0.003	0.000	0.005	-	-

Table 2 continued

sp. n.	Biotite		Chlorite						Garnet	
	Fg-10/91				Fg-9/95		Fg-27/95		Fg-10/91	
									rim	core
SiO_2	36.60	36.38	25.66	25.47	26.02	26.02	26.86	26.61	37.16	38.18
TiO_2	0.54	0.52	0.08	0.05	0.02	0.02	0.00	0.05	0.07	0.03
Al_2O_3	14.04	13.99	19.34	19.48	18.80	18.80	19.34	19.26	13.53	17.91
Fe_2O_3	-	-	-	-	-	-	-	-	12.72	6.84
FeO	22.32	22.19	26.48	27.02	29.11	29.11	21.31	20.61	0.21	1.36
MnO	0.27	0.27	0.49	0.51	0.39	0.39	0.52	0.39	1.23	1.36
MgO	11.23	11.07	14.28	13.99	13.92	13.92	19.29	19.20	0.01	0.67
CaO	0.06	0.02	0.05	0.05	0.06	0.06	0.03	0.01	34.27	33.24
Na_2O	0.05	0.02	0.00	0.00	0.01	0.01	0.00	0.00	-	-
K_2O	9.39	9.35	0.17	0.36	0.00	0.00	0.03	0.01	-	-
F	0.01	0.02	0.08	0.00	0.07	0.04	0.11	0.12	-	-
Cl	0.22	0.00	0.00	0.00	0.01	0.01	0.00	0.00	-	-
Total	94.03	96.63	86.93	86.36	88.45	88.42	87.58	86.35	99.29	99.93
Ox. basis	22		28						12	
Si	5.802	5.804	5.543	5.502	5.570	5.570	5.568	5.576	2.961	2.961
Al^{IV}	2.198	2.195	2.457	2.498	2.430	2.430	2.432	2.424	0.038	0.038
Al^{VI}	0.427	.438	2.468	2.460	2.311	2.311	2.295	2.333	1.232	1.599
Ti	0.064	.062	.012	.008	.003	0.003	0.000	0.007	0.004	0.001
Fe^{3+}	-	-	-	-	-	-	-	-	0.762	0.399
Fe^{2+}	2.963	2.965	4.784	4.881	5.211	5.211	3.694	3.611	0.014	0.088
Mn	0.035	0.037	0.090	0.092	0.070	0.070	0.092	0.069	0.082	0.089
Mg	2.656	2.636	4.596	4.503	4.441	4.441	5.959	5.997	0.000	0.077
Ca	0.010	0.003	0.011	0.011	0.014	0.014	0.007	0.002	2.926	2.762
Na	0.013	0.005	0.046	0.099	0.000	0.000	0.007	0.003	-	-
K	1.901	1.906	0.000	0.001	0.004	0.004	0.001	0.000	-	-
F	0.003	0.005	0.053	0.000	0.047	0.025	0.075	0.078	-	-
Cl	0.000	0.001	0.000	0.000	0.004	0.004	0.001	0.001	-	-

sp. n.	Epidote				Albite						
	Fg-10/91		Fg-9/95	Fg-27/95	Fg-10/91			Fg-9/95		Fg-27/95	
SiO_2	37.24	37.43	37.29	36.55	68.61	68.43	68.36	67.25	68.68	67.69	67.94
TiO_2	0.06	0.06	0.13	0.06	-	-	-	-	-	-	-
Al_2O_3	24.71	24.37	21.99	20.98	19.36	19.15	19.44	20.38	19.68	19.88	19.90
Fe_2O_3	12.01	12.06	15.02	16.44	0.11	0.14	0.22	0.13	0.02	0.06	0.05
MnO	0.03	0.05	0.09	0.12	-	-	-	-	-	-	-
MgO	0.08	0.00	0.00	0.00	-	-	-	-	-	-	-
CaO	23.52	23.63	23.25	23.30	0.16	0.47	0.81	0.81	0.04	0.21	0.05
Na_2O	-	-	-	-	11.69	11.52	11.04	11.16	11.56	11.96	11.65
K_2O	-	-	-	-	0.03	0.020	0.00	0.05	0.03	0.05	0.06
Total	97.85	97.70	97.85	97.84	99.96	99.73	99.93	99.85	100.01	99.89	99.74
Ox. basis	12.5				8						
Si	2.961	2.979	2.996	2.961	2.998	2.999	2.998	2.949	2.995	2.968	2.977
Al	2.315	2.285	2.082	2.003	0.997	0.989	0.998	1.053	1.011	1.027	1.028
Ti	0.003	0.003	0.008	0.0038	-	-	-	-	-	-	-
Fe^{3+}	0.718	0.722	0.908	1.002	0.003	0.004	0.008	0.004	0.000	0.001	0.001
Mn	0.001	0.003	0.006	0.008	-	-	-	-	-	-	-
Mg	0.009	0.000	0.000	0.000	-	-	-	-	-	-	-
Ca	2.004	2.015	2.000	2.022	0.007	0.022	0.038	0.038	0.002	0.010	0.002
Na	-	-	-	-	0.990	0.978	0.962	0.949	0.978	1.016	0.989
K	-	-	-	-	0.001	0.001	0.000	0.002	0.001	0.002	0.003

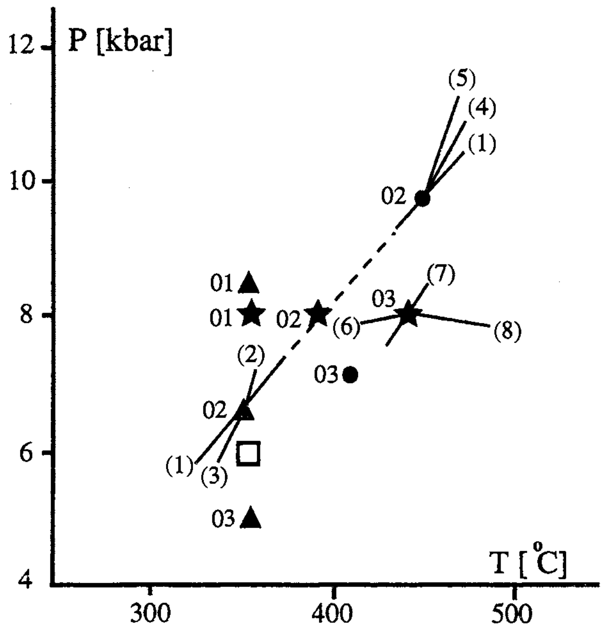

Fig. 7. Intersections of some representative equilibrium curves, obtained for metabasalts in Rakovec and Hnilec. Triangles and circles are intersections of the reactions (1-3) and (1, 4 & 5), obtained using datasets of Holland & Powell (1990). Stars are intersections of reactions (6-8) calculated using dataset of Berman (1988) and the latest version of GeO-Calc program (Brown et al. 1989). Numbers in brackets are reactions:
(1) 4 Cz + Qtz = Grs + 5 An + 2 W
(2) 4 Chl + 18 Cz + 5 Ab + Qtz = 5 Prg + 26 An + 20 W
(3) 9 Grs + 8 Chl + 10 Ab = 10 Prg + 7 Qtz + 7 An + 22 W
(4) Gl + Chl + 6 Cz = 2 Prg + 8 An + Qtz + 6 W
(5) Gl + Chl + 10 Cz = Grs + 2 Prg + 13 An + 8 W
(6) 6 Tr + 9 Chl + 50 Ab = 25 Gl + 6 Cz + 7 Qtz + 14 W
(7) Chl + 6 Cz + 7 Qtz = Tr + 10 An + W
(8) Tr + 2 Chl + 10 Ab = 5 Gl + 2 An + 4 W
Numbers 01, 02, 03 indicate anorthite contents in plagioclase that correspond to $Ab_{99}An_{01}$, $Ab_{98}An_{02}$, $Ab_{97}An_{03}$, respectively. Square indicates temperature and pressure obtained using geothermobarometer of Triboulet (1992) for actinolite-bearing metabasalts in Hnilec.

geothermobarometers. Since thermodynamic data for Na-Ca amphibole are not available, using thermodynamic datasets of Holland & Powell (1990) we calculated equilibrium curves for pargasite-bearing assemblage in the system NCMASH. Activities of minerals used in these calculations were obtained by the methods outlined in Will & Powell (1990) and Guiraud et al. (1990). Position of invariant point of the equilibrium curves (reaction 1-3, Fig. 7) depends on plagioclase composition. For plagioclase of Ab_{98}, An_{02} the curves intersect at 6.8 kbar and 350 °C. Higher pressure of 8.3 kbar at 350 °C was obtained for Ab_{99}, An_{01} and lower pressure of 5 kbar at 350 °C for Ab_{97}, An_{03}. Assuming the taramite as a solution of its two essential end-member components (glaucophane and pargasite), the curves of sliding reactions (4 & 5), calculated for Ab_{97}, An_{03} (Fig. 7), intersect the reaction (1) at 7 kbar and 400 °C. Similar to reactions (1-3), the intersection of these curves moves with decrease of anorthite content in plagioclase to higher pressures (10 kbar at 450 °C for Ab_{97}, An_{03}) For Ab_{99}, An_{01} it gives pressure much higher (out of the selected range in Fig. 7).

In order to confirm or otherwise the above obtained P-T conditions for taramite-bearing rocks, thermodynamic dataset of Berman (1988) and the latest version of GeO-Calc program (Brown et al. 1989) were used. Activity models for amphiboles were taken from Evans (1990). Intersection of the equilibrium curves of reactions, involving albite, anorthite, chlorite, epidote, quartz and tremolite- and glaucophane- end-members (6-8) is strongly controlled by the plagioclase composition. It moves from low temperature of 350 °C/ 8 kbar for Ab_{99}, An_{01} through 380 °C (Ab_{98}, An_{02}) to 440 °C/ 8 kbar for Ab_{97}, An_{03} (Fig. 7). We also used the geothermobarometer of Triboulet (1992), proposed for Na-Ca amphibole coexisting with albite, chlorite, epidote and quartz, but for the studied assemblage this gave very high lnKds (lnKEd-Tr = 2.2-4 and lnKd (Prg/Has)-Tr = 1.1-2.6) that are out of the Kd range given by Triboulet (-7 to 2 and -9 to 2.5). This geothermobarometer, however gave pressures of 6 kbar at 350 °C for basaltic metaandesites with Na-rich actinolite in Hnilec (Fig. 7). Considering metamorphic mineral assemblages in phyllitic rocks (quartz + white mica + chlorite and rarely green biotite) adjacent to both taramite-bearing metabasites in Rakovec, metamorphic temperatures were not higher than 400-420 °C.

To examine possible relationship between taramite formation and bulk rock composition, we compare taramite-bearing metabasites from Rakovec with those containing actinolite from both the Rakovec and Gelnica Groups. Compared to Gelnica and the Rakovec Group, the metabasites in Rakovec generally have low X_{Mg} and high Al contents. To describe these variations an Al_2-Fe-Mg diagram (Fig. 8) was selected. The whole-rock and mineral analyses were projected from H_2O, SiO_2, hematite, epidote and albite on to the Al_2-Fe-Mg plane. In the presence of titanite, biotite and pyroxene in analysed samples, the major oxide contents were modified according to modal amounts and average composition of these phases. Metabasites from Rakovec plot generally on Fe^{2+}—

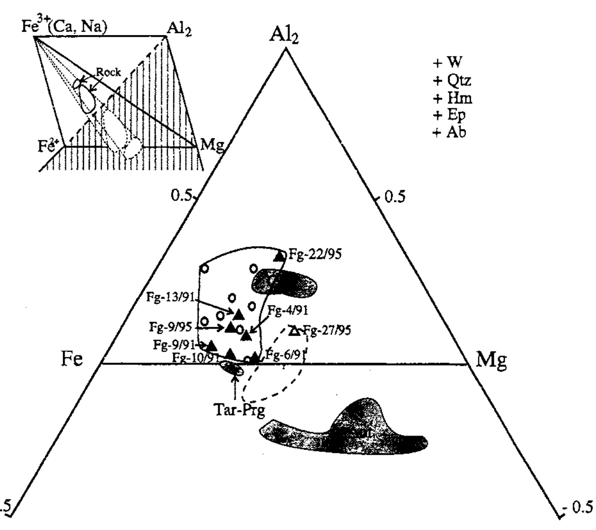

Fig. 8. Al_2:Fe:Mg diagram for metabasites of the Early Paleozoic of the Gemeric Unit. Mineral and whole rock analyses are projected from H_2O, SiO_2, hematite, epidote and albite. Solid envelop encompasses all analyses from metabasites near Rakovec (solid triangles correspond to the whole rock analyses listed in Tab. 1). Open circles are the whole rock analyses given by Bajaník (1976). Dashed envelop shows actinolite-bearing metabasites from the Rakovec and Gelnica Groups.

and some samples also on Al-side in Fig. 8. From actinolite-bearing basaltic metaandesites in Hnilec (Fg-27/95, Tab. 1, Fig. 8), they distinguish by low X_{Mg}, and high Fe^{3+} contents. As described in the petrographic section, taramite usually occur in metabasalts. The lack of this mineral in some basaltic rocks from the same outcrop (compare sample Fg-10/91 and Fg-4/91 in Tab. 1) was resulted from low Na content in the rock.

Taking into account phase relations and calculated P-T condition, the presence of taramite and sodian ferropargasite in Rakovec was a result from combination of heterogeneous rock composition and P-T conditions of metamorphism. The estimated pressure and temperatures are comparable with some experimentally established stability field or boundary reaction for calcic and sodic amphiboles (Fig. 9). Since some amphibole analyses have Si = 6.49 and $(Na + K)_A = 0.66$ a./f.u. close to that in barroisite, pressures higher than 4.5 kbar can be assumed by the stability field of barroisite proposed by Ernst (1979). Following the actinolite-blue amphibole boundary reaction, experimentally investigated by Maruyama et al. (1986), the lack of glaucophane suggests pressures lower than 8 kbar. Pressure of 7.5-8.5 kbar at 400 °C are possible according to the petrogentic grid of Evans (1990). For a system with relatively high Fe^{3+} contents, the boundary reactions of the albite-epidote amphibolite facies, where Ca-Na amphibole can appear, moves to lower temperatures and pressures.

The estimated metamorphic condition confirm the postulated medium-pressure metamorphism of the Rakovec metabasites (Hovorka et al. 1988). However, pressure conditions were rather lower than that in Alpine Meliata Unit (Fig. 9). Some actinolite could appear after attainment of peak metamorphic condition, but most amounts of actinolite were formed during the same metamorphic event as that resulted in formation of taramite in the Rakovec. Considering the P-T conditions of the Variscan metamorphism estimated for the Gelnica and Rakovec Groups (300-430 °C, 4-5 kbar, Faryad 1991), the presence of taramite in Rakovec and Na-rich actinolite in Hnilec suggests relatively higher pressures for the northern part of the Gemeric Unit. The increase of andradite component in garnet from taramite-bearing rocks is considered to be a result of an X_{CO_2}-increase in the metamorphic fluid (Taylor & Liou 1978) or decrease of temperature. A decrease of metamorphic temperature can be assumed also by the decrease of Al content in the Na-Ca amphibole. Latter (Alpine ?) events resulted in the replacement of both taramite and actinolite or actinolite in the Rakovec- and Gelnica-Group metabasites.

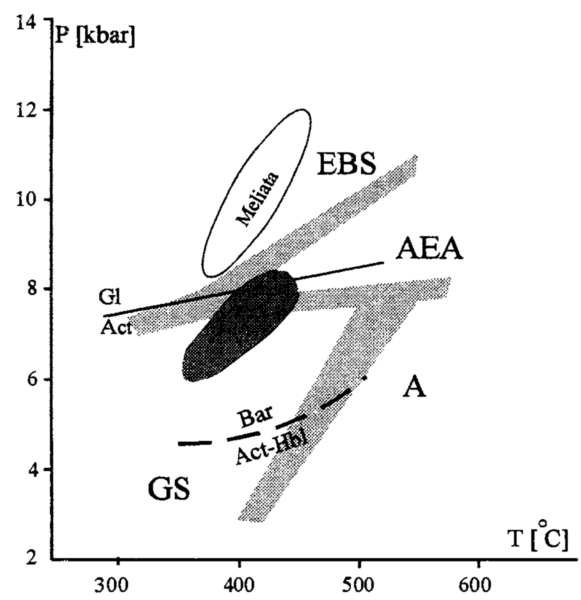

Fig. 9. Probable P-T conditions of metamorphism for metabasites from the Rakovec and Hnilec. Thick dashed curve corresponds to the Ca-amphibole and Na-Ca amphibole boundary (Ernst 1979). Gl/Act — glaucophane-actinolite boundary reaction (reaction 6 in Fig. 7) from Maruyama et al. (1986). The petrogenetic grid separating epidote blueschists(EBS), albite epidote-amphibolites (AEA), greenschists (GS) and amphibolites (A) is after Evans (1990).

Conclusions

Textural and phase relations discussed in metabasites from Rakovec suggest equilibrium conditions of taramite and sodian pargasite with albite, epidote, chlorite, garnet and biotite. P-T conditions of metamorphism assumed for the generation of Na-Ca amphibole were about 6-8 kbar at 480-440 °C. The presence of taramite was a result of a combination of P-T conditions (relatively higher than that considered for actinolite-bearing metabasites of the Gelnica Group and eastern part of the Rakovec Group) as well as of heterogeneous rock composition. Compared to the metamorphic conditions suggested for Mg-Al taramite in Nybö (Ungaretti et al. 1981), the lower P-T value estimated for taramite from Rakovec are due to relatively higher iron content in this mineral. Taking into account the presence of kyanite in metapelites (Faryad & Dianiška 1992), taramite in metabasites from Rakovec Na-rich actinolite in Hnilec, the Variscan metamorphism in the Gemeric Unit exhibits a medium-pressure rather than low-pressure greenschist-facies character. The appearance of taramite in metabasites in the northern part of the Gemeric Unit suggests that the Rakovec Group, i.e. mainly its western part, was underthrust to depths appropriate to the higher PT part of the greenschist-facies metamorphism.

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***Appendix:** Mineral abbreviations:*

Ab	albite	Gl	glaucophane
Act	actinolite	Gr	garnet
An	anorthite	Grs	grossularite
Bar	barroisite	Hm	hematite
Cc	calcite	Kat	katoforite
Chl	chlorite	Nyb	nyböite
Cz	clinozoisite	Prg	pargasite
Chl	chlorite	Prp	pyrope
Ed	edenite	Ric	richterite
Ep	epidote	Qtz	quartz
Fed	ferroedenite	Tnt	titanite
Fgl	ferroglaucophane	Tar	taramite
Fnyb	ferronyböite	Tr	tremolite
Fprg	ferropargasite	W	water
Fric	ferrorichterite		

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