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HIGH-PRESSURE METAMORPHISM AND P-T PATH OF THE METABASIC ROCKS IN THE BOREHOLE KOMJÁTI-11, BÓDVA VALLEY AREA, NE HUNGARY

P. HORVÁTH[1]

Department of Petrology and Geochemistry, Eötvös University, Budapest and
Laboratory for Geochemical Research, Hungarian Academy of Sciences

ABSTRACT

The Alpine, polyphase, regional metamorphic evolution was revealed by mineral paragenetic, mineral chemical and chlorite crystallinity studies carried out on a representative profile of the incomplete, dismembered ophiolite complex of the Bódva Valley area (Aggtelek-Rudabánya Mts., NE Hungary). This complex belongs to the South Gemer nappe system and represents a strongly tectonized part of the Mesozoic Vardar-Meliata oceanic branch of the Neotethys. On the basis of the first description of Na-amphiboles (ferro-glaucophane and riebeckite) and the discrimination of magmatic and metamorphic Ca-amphiboles, the P-T-relative time path of the metabasic rocks was reconstructed as follows. The most probably Middle Jurassic, subduction-related epidote-blueschist facies event (ca. 7 kbar, 300-350°C) was followed by a (probably Middle Cretaceous) greenschist facies regional metamorphism (ca. 4-5 kbar, 300°C). In contrast with the earlier studies (RÉTI, 1985) no signs of an ocean-floor hydrothermal event could be proved. Thus, the present study provides the first evidence of subduction-related high-pressure assemblages in the ophiolitic rocks from the Hungarian part of Meliaticum.

INTRODUCTION, GEOLOGICAL SETTING

Metamorphic features of ophiolites provide an effective tool for reconstructing the tectonic conditions of closure of paleo-oceanic branches. The aim of the present paper is to characterize the metamorphic evolution path of the Bódva Valley ophiolites on the basis of the metamorphic petrological results obtained from a representative section of these rocks cored by the borehole Komjáti-11. This borehole is located at the northern foot of the Rudabánya Mountains, NE Hungary (*Fig. 2*).

The dismembered, incomplete ophiolite complex of the Bódva Valley area is related to the Meliaticum, which represents the remnants of the Vardar (s.l.)-Meliata ocean of Triassic-Jurassic age in the Neotethyan realm (*Fig. 1*). The oceanic slivers of Meliaticum represent slices and small (from dm to 100 m in scale) fragments embedded in the ductile Upper Permian Perkupa Evaporite Formation found in the basal part of the non-metamorphic Silicicum, which forms the uppermost nappe in the area studied. The Silicicum is underlain by the intermediate-high pressure/low temperature metamorphic Tornaicum (ÁRKAI and KOVÁCS, 1986; KOVÁCS et al., in press). These nappes built up the South Gemer nappe system of the Gemer-Bükk units of the Pelsonia composite terrane

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[1] H-1112 Budapest, Budaörsi út 45., Hungary
E-mail: phorvath @sparc.core.hu

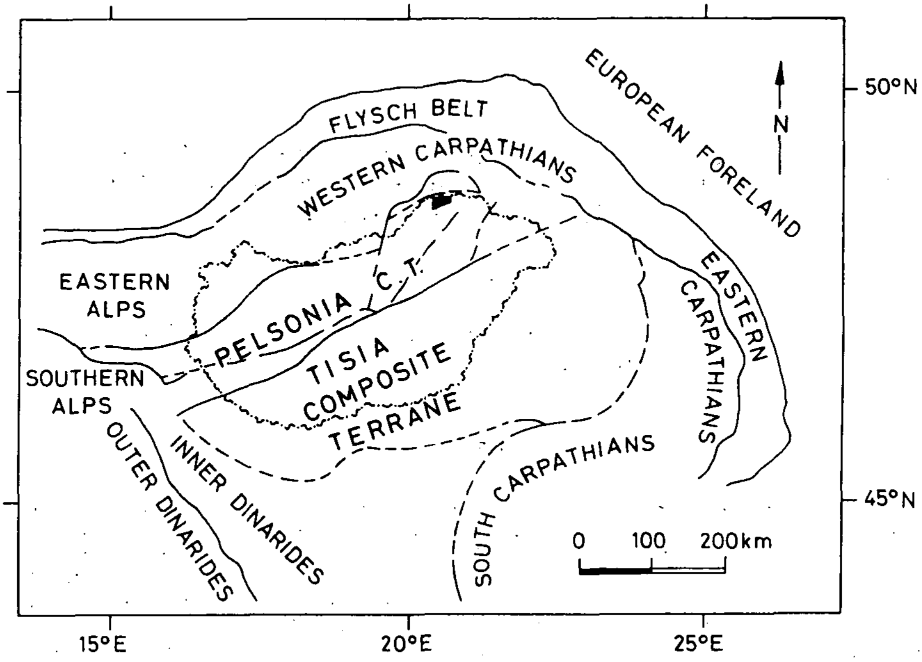

Figure 1 Tectonic scetch map of the Pannonian basin and the position of the examined area.

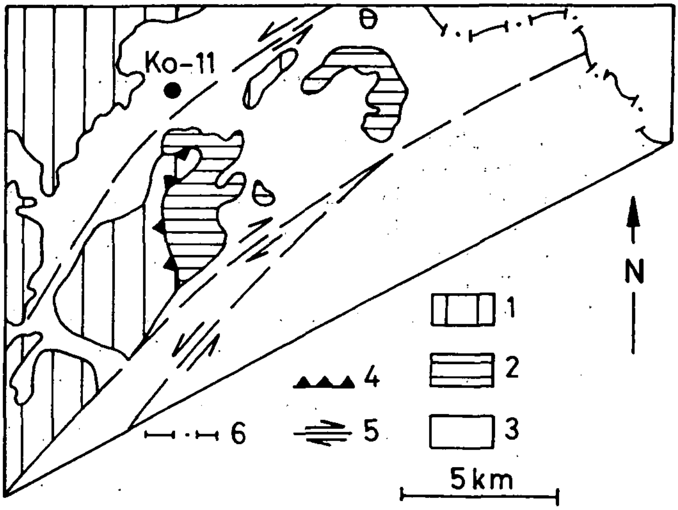

Figure 2 Simplified geological map of the examined area (enlarged from *Fig. 1*).
Legend: 1: Silicicum, 2: Tornaicum, 3: Tertiary and Quaternary, 4: nappe boundary, 5: transform faults, 6: state boundary. Black point shows the position of borehole Komjáti-11.

TABLE 1

Representative major and trace element analyses for the studied rock types of Komjáti-11. Major element analyses are from RÉTI (1985).

Sample	203m	232m	247m
SiO_2	46,20	41,30	41,20
TiO_2	2,51	3,84	3,93
Al_2O_3	14,50	10,60	11,10
Fe_2O_3	9,41	9,24	9,57
FeO	3,93	6,69	6,71
MnO	0,20	0,37	0,33
MgO	5,52	4,62	6,03
CaO	10,20	12,40	11,90
Na_2O	3,37	3,27	2,77
K_2O	0,23	0,48	0,40
P_2O_5	0,21	3,54	2,44
H_2O^+	2,81	1,93	2,47
H_2O^-	0,27	0,19	0,33
CO_2	1,39	0,72	0,45
Total	100,75	99,19	99,63

Ti (ppm)	20700	24770	24170
V	356	292	263
Ni	126	11	20
Sm	9,1	13,9	15,9
Ce	46,2	77,2	84,6
Lu	0,69	1	1,16
U	-	-	-
Th	-	0,89	1,09
Cr	158	-	-
Yb	4,9	7,71	8,06
Hf	6,48	8,9	9,6
La	18,65	32,6	33,8
Nd	25,5	42,9	48,2
Cs	1,75	-	-
Tb	1,89	2,67	2,44
Sc	32,5	44,5	28,3
Ta	0,87	1,41	1,53
Co	35	22	36,7
Eu	-	4,66	4,8
Y	98	150	106
Zr	288	395	302
Nb	8	13	10

TABLE 2

Representative analyses of amphiboles and their structural formulae. IMA names are after LEAKE, 1978.

		Na-amphibole				Ca-amphibole							
						magmatic				metamorphic			
SiO_2		54,24	53,81	53,58	53,37	43,65	42,91	44,49	43,59	56,71	49,62	54,62	54,87
TiO_2		-	-	-	-	4,13	4,36	3,64	4,23	-	-	-	-
Al_2O_3		4,48	4,14	1,13	1,13	9,34	10,12	8,60	9,71	1,43	6,47	1,24	1,78
FeO		23,42	23,65	27,90	27,59	14,84	14,01	15,06	13,94	10,30	11,41	13,62	15,92
MnO				1,13	0,83	0,00	0,00	0,00	0,00	-	-	-	-
MgO		7,34	7,40	6,08	6,32	11,94	12,01	11,97	11,96	17,58	16,87	14,84	13,66
CaO		0,99	2,68	2,46	2,41	11,14	11,06	11,17	11,08	12,99	10,08	11,54	9,93
Na_2O		5,46	5,18	5,34	5,08	3,06	3,22	2,79	3,44	-	2,34	1,69	2,30
K_2O		-	-	-	-	0,47	0,45	0,42	0,62	-	-	-	-
Total		95,93	96,86	97,62	96,73	98,57	98,14	98,14	98,57	99,01	96,79	97,55	98,46
		number of the cations on the basis of 23 (O)											
Si		8,001	7,881	7,937	7,979	6,451	6,359	6,588	6,462	7,909	7,017	7,925	7,869
Al^{IV}	T	-	0,119	0,063	0,021	1,549	1,641	1,412	1,538	0,091	0,983	0,075	0,131
Sum T		8,001	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Al^{VI}		0,778	0,596	0,135	0,178	0,076	0,125	0,087	0,157	0,144	0,094	0,137	0,170
Fe^{3+}		0,782	0,994	1,462	1,316	0,061	0,022	0,089	0,000	0,065	1,193	-	0,269
Fe^{2+}		1,826	1,795	1,995	2,098	1,773	1,714	1,775	1,728	1,136	0,156	1,653	1,640
Ti	C	-	-	-	-	0,459	0,486	0,405	0,472	-	-	-	-
Mg		1,614	1,616	1,343	1,409	2,631	2,653	2,642	2,643	3,655	3,556	3,210	2,921
Mn		-	-	0,066	-	-	-	-	-	-	-	-	-
Sum C		5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Fe^{2+}		0,281	0,108	-	0,036	-	-	-	-	-	-	-	-
Mn		-	-	0,076	0,105	-	-	-	-	-	-	-	-
Ca	B	0,156	0,421	0,390	0,386	1,764	1,756	1,772	1,760	1,941	1,527	1,794	1,526
Na		1,562	1,471	1,534	1,473	0,236	0,244	0,228	0,240	-	0,473	0,206	0,474
Sum B		1,999	2,000	2,000	2,000	2,000	2,000	2,000	2,000	1,941	2,000	2,000	2,000
Na		-	-	-	-	0,641	0,681	0,573	0,749	-	0,169	0,270	0,165
K	A	-	-	-	-	0,089	0,085	0,079	0,117	-	-	-	-
Sum A		-	-	-	-	0,729	0,766	0,652	0,866	-	0,169	0,270	0,165
Total		15,000	15,000	15,000	15,000	15,729	15,766	15,652	15,866	14,941	15,169	15,270	15,165
IMA name		crossite		riebeckite		ferroan pargasitic hornblende				hornblende		actinolite	

(KOVÁCS et al., in press), also known as the North Pannonian-Western Carpathian composite terrane (BALLA, 1982; CSONTOS et al. 1992). On the basis of biostratigraphic data (DOSZTÁLY and JÓZSA, 1992) and K-Ar dates (233 Ma on amphiboles, ÁRVA-SÓS et al., 1987) the age of the ophiolite complex is Middle Triassic. Under a ca. 150 m thick Tertiary and Quaternary cover the borehole Komjáti-11 crosscutted an approxiametely 200 m thick metamafic complex. The contact between this complex and the underlying Upper Permian Perkupa Evaporite is tectonic. The metamafic complex is cut by several, thin (ca. 30-50 cm thick) albitite veins and a 50 cm thick metabasalt vein. The complex is built up predominantly by metagabbro and its fine-grained variant (meta-microgabbro), described earlier by RÉTI (1985) as albite-gabbros and -dolerites. Major and new trace element analyses of representative samples listed in Table 1 and *Fig. 3* confirm the earlier statement of HARANGI et al. (1996) on the MORB character of the ophiolite complex in question (for details see HORVÁTH, 1997).

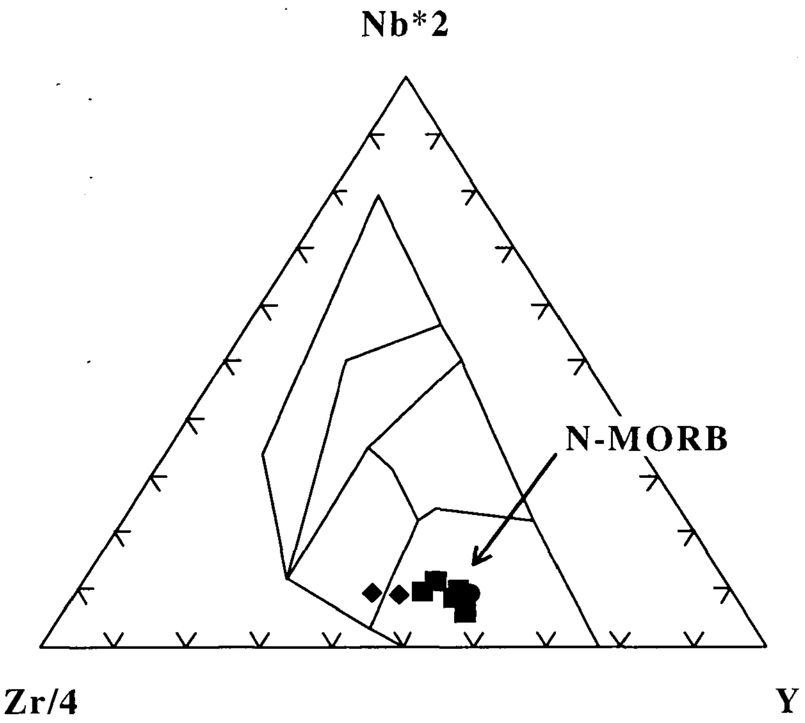

Figure 3 Zr-Nb-Y discrimination diagram for the studied rocks (after MESCHEDE, 1986). Diamonds represent the albitites, circles the metagabbros, and squares for the meta-microgabbros.

PETROGRAPHY

Thin section studies reveal that despite the metamorphic effects the rocks preserved their original magmatic texture. The prevailing mineral assemblages of the metabasic rocks consist of Na-amphibole, actinolite, hornblende, epidote, albite, chlorite and Fe-Ti-oxides. Na-amphibole shows blue-violet pleochroism, usually rims the hornblende and occurs also as fissure fillings. Actinolite is abundant and rims both the hornblende and the Na-amphibole and contains them as relics as well. Epidote is also abundant and shows euhedral and subhedral forms. Albite commonly displays subhedral forms and is twinned occasionally. Chlorite is found in the matrix and forms pseudomorphs after clinopyroxene. In the albitite veins white mica and only in one case, chloritoid were also found.

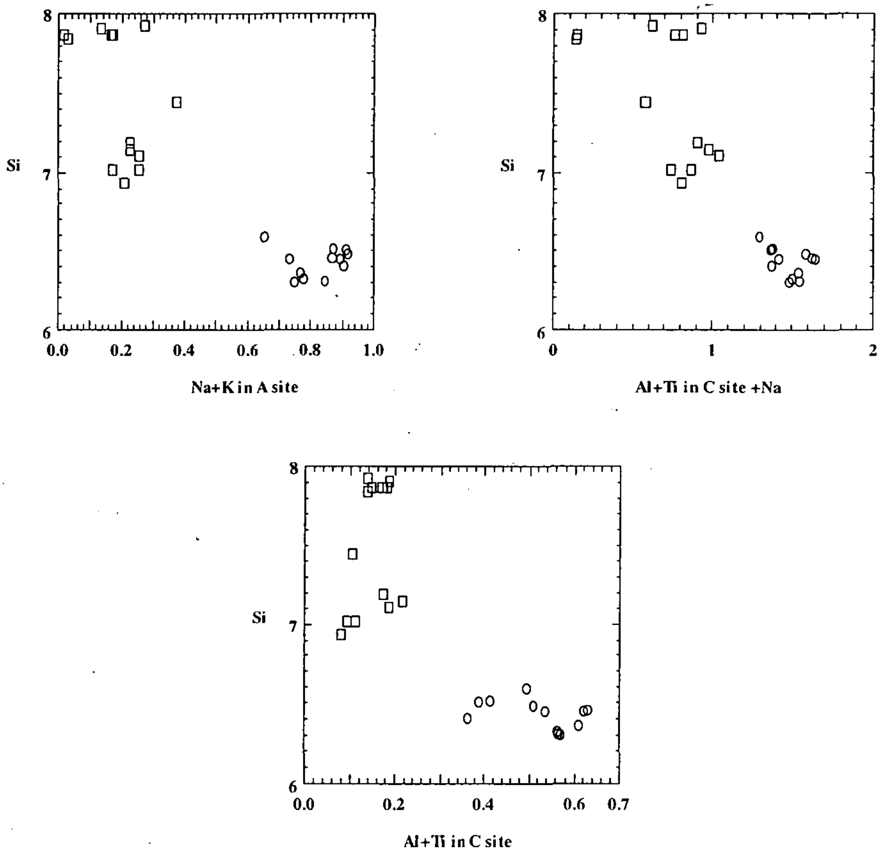

Figure 4 The subdivision of Ca-amphiboles. Circles represent the magmatic, and squares the metamorphic Ca-amphiboles.

MINERAL CHEMISTRY

Mineral analyses were performed at the Department of Petrology and Geochemistry of the Eötvös University, Budapest, using an AMRAY 1830 I/T6 scanning electron microscope, under operating conditions of 15 kV accelarating voltage and 1-2 nA specimen current. Analyses of amphiboles and their structural formulae are listed in Table 2. The calculations of cation numbers follow the scheme of ROBINSON et al. (1982). The Na-amphiboles are ferro-glaucophanes [or crossites, using the nomenclature of LEAKE (1978)] and riebeckites (see LEAKE et al., 1997). The Ca-amphiboles vary widely in their chemical compositions, forming two groups: a magmatic and a metamorphic one (*Fig. 4*). The subdivision of Ca-amphiboles is based on the fact that magmatic Ca-amphiboles are enriched in Ti, Al and Na, and depleted in Si as compared to metamorphic amphiboles (MÉVEL, 1988; SADEK GHABRIAL et al., 1996). Table 3 shows the differences in concentrations of various elements between magmatic and metamorphic Ca-amphiboles in the studied rocks. The magmatic amphiboles are pargasites and magnesio-hastingsites (LEAKE et al., 1997) or ferroan pargasitic hornblendes using the nomenclature of LEAKE (1978), while the metamorphic Ca-amphiboles fall into the actinolite and hornblende fields (LEAKE, 1978 and LEAKE et al., 1997).

TABLE 3
Differences in concentrations of various elements between the magmatic and the metamorphic Ca-amphiboles in the studied rocks. Legend: mag.: magmatic, met.: metamorphic).

	Si		Al^{VI}		Ti	
	mag	met	mag	met	mag	met
Mean	6,430	7,590	0,115	0,111	0,406	0,028
St. Dev.	0,091	0,384	0,044	0,063	0,114	0,069
Num. of cases	12	21	12	21	12	21

Representative analyses of epidote, albite and chloritoid are given in Table 4. The Ps component of epidote varies between 20-30%, which is characteristic of metabasic rocks from other occurences described by EVANS (1990) and BALTATZIS (1996), who have found no significant difference in compositions of epidotes from blueschist and from greenschist facies rocks. Albites are always pure Ab_{100}. Chloritoid was found in association with Mg-bearing calcite. They may represent eventual alteration products of pumpellyite.

THERMOBAROMETRY AND P-T PATH OF THE METABASIC ROCKS

In the studied rocks a stable mineral assemblage of Na-amphibole + epidote + albite has been recognized. For neither jadeitic pyroxene nor lawsonite have been found in these rocks, this assemblage is indicative of the albite-bearing region of the epidote-blueschist facies. *Figure 5* shows the mineral reaction boundaries defining the stability field of the epidote-blueschist facies (EVANS, 1990, chemical composition N.6) and the P-T path of the studied rocks. In the investigated complex the epidote-blueschist facies assemblage was transformed into a greenschist facies assemblage, which is represented by the

TABLE 4

Representative analyses of epidote, albite and chloritoid.

	epidote					plagioclase					chloritoid		
SiO_2	37,77	37,56	38,03	37,38	37,47		68,98	68,52	68,83	69,16	27,78	27,56	27,32
Al_2O_3	20,68	24,04	24,07	21,01	21,11		19,55	19,58	19,10	19,66	21,70	21,53	21,43
FeO	-	-	-	-	-		-	-	-	-	34,19	34,04	34,13
Fe_2O_3	15,15	10,86	11,35	15,14	14,76		-	-	-	-	-	-	-
MgO	-	-	-	-	-		-	-	-	-	8,08	8,16	7,98
CaO	23,59	24,29	23,68	23,91	23,69		-	-	-	-	-	-	0,44
Na_2O	-	-	-	-	-		11,95	11,78	11,83	12,08	-	-	-
Total	97,19	96,75	97,13	97,44	97,03		100,48	99,88	99,76	100,90	91,75	91,29	91,30
	number of the cations on the basis of 25 (O)					number of the cations on the basis of 8 (O)					n. of cat. on the basis of 12 (O)		
Si	6,112	6,023	6,063	6,044	6,071		2,997	2,994	3,011	2,994	1,981	1,978	1,966
Al	3,941	4,540	4,519	4,001	4,028		1,000	1,008	0,984	1,002	1,823	1,819	1,816
Fe^{2+}	-	-	-	-	-		-	-	-	-	2,040	2,042	2,053
Fe^{3+}	1,843	1,309	1,360	1,840	1,798		-	-	-	-	-	-	-
Mg	-	-	-	-	-		-	-	-	-	0,859	0,872	-
Ca	4,090	4,173	4,045	4,142	4,112		-	-	-	-	-	-	0,034
Na	-	-	-	-	-		1,007	0,998	1,003	1,014	-	-	-
Total	15,986	16,022	15,987	16,027	16,009		5,004	5,000	4,998	5,010	6,703	6,712	6,724
Ps (%)	30	20	20	30	30	Ab (%)	100	100	100	100	-	-	-

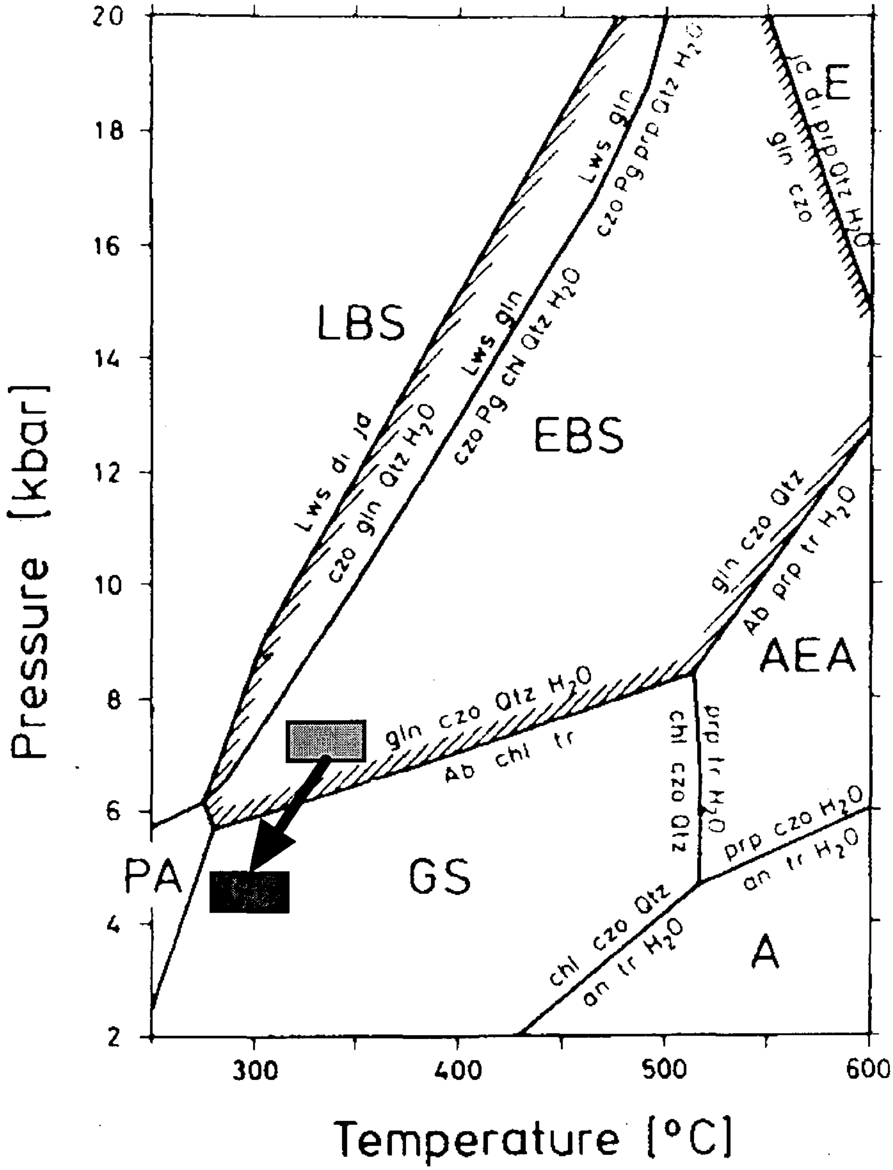

Figure 5 P-T stability field for epidote-blueschists (EVANS, 1990, chemical composition N.6.) and P-T path for the studied rocks. Legend: EBS: epidote-blueschists, LBS: lawsonite-blueschists, AEA: albite-epidote-amphibolite facies, A: amphibolite facies, E: eclogite facies, G: greenschist facies, PA: pumpellyite-actinolite facies. Mineral abbrevations are from KRETZ (1983).

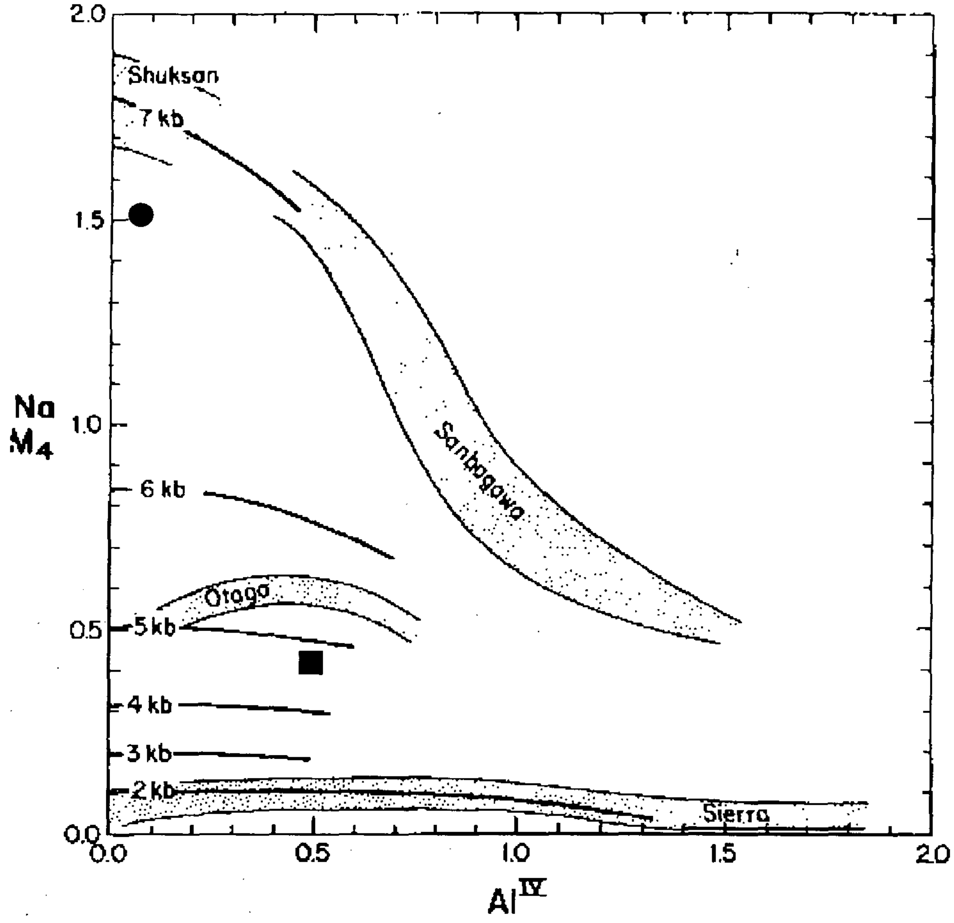

Figure 6 Relationship between the pressure value of metamorphism and the NaM_4 content of Ca-amphiboles (after BROWN, 1977). Circle represents the average NaM_4 content of the Na-amphiboles and square the average NaM_4 content of the metamorphic Ca-amphiboles.

association of actinolite + chlorite + epidote + albite. The pressure values of the epidote-blueschist facies and the greenschist facies metamorphic events were calculated using the geobarometer of BROWN (1977), which is based on the NaM_4 content of the Ca-amphiboles in a limiting mineral assemblage (*Fig. 6*). This value is ca. 7 kbar for the former, and ca. 4-5 kbar for the latter event. Using the reaction isograde scheme of EVANS (1990) the temperature of the epidote-blueschist facies metamorphism might be between 300 and 350°C (*Fig. 5*). On the basis of chlorite crystallinity (ChC) and chlorite-Al^{IV} thermometric data (Table 5, for details see HORVÁTH, 1997) the temperature of the greenschist facies overprint may be put around 300°C.

TABLE 5

Average chlorite crystallinity (ChC) and chlorite-Al^{IV} thermometry data for the studied metabasic rocks of borehole Komjáti-11.

ChC (001)		ChC (002)		Al^{IV}	Temperature (°C)
2°/min	1/2°/min	2°/min	1/2°/min		Cathelineau (1988)
0,309	0,2705	0,279	0,2385	1,088	285-290

DISCUSSION AND CONCLUSIONS

The metamorphic evolution path of a Triassic, dismembered, incomplete ophiolite complex of the Aggtelek-Rudabánya Mountains cored by the borehole Komjáti-11 was determined using metamorphic petrological (mineral paragenetic), mineral chemical (electron microprobe) and X-ray diffractometric (chlorite crystallinity) results. In the last phase of magmatic crystallization amphiboles formed instead of magmatic pyroxenes. The magmatic amphiboles are pargasites and magnesio-hastingsites according to the new nomenclature of LEAKE et al. (1997) or ferroan pargasitic hornblendes, using the nomenclature of LEAKE (1978). In contrast to the earlier statements of RÉTI (1985) no signs of an eventual ocean floor hydrothermal event could be evidenced in the sample series investigated. The observable first metamorphic event proved to be a subduction-related one, as evidenced by the Na-amphibole, epidote and albite assemblage. To our knowledge our results constitute the first demonstration of Na-amphiboles indicative of high-pressure metamorphism in the Hungarian part of the South Gemer nappe system. Metabasic rocks containing blue amphiboles have already been known for some time from the Slovakian part of Meliaticum, namely in the SE part of Slovakia (KAMENICKY, 1957, REICHWALDER, 1973 and FARYAD, 1995). The age of the subduction-related metamorphism is Middle Jurassic (150-165 Ma, K-Ar and ^{40}Ar-^{39}Ar ages on phengite from the Slovakian part of Meliaticum, see MALUSKI et al., 1993, FARYAD and HENJES-KUNST, 1995). The same HP/LT metamorphic event was reported from the Slovakian part of Meliaticum by FARYAD (1995) and from the Fruska Gora in the Inner Dinarides (MILOVANOVIC et al., 1995), but the age of the metamorphism in the latter case is Lower Cretaceous (123 Ma, K-Ar age on crossite, MILOVANOVIC et al., 1995). The HP/LT assemblage of the metabasic rocks from the borehole Komjáti-11 was overprinted by a greenschist facies event, characterized by the assemblage of actinolite + chlorite + epidote + albite. On the basis of the presumed analogies with the metamorphic evolution of the

Bükkium (see ÁRKAI et al., 1995), the age of this event is most probably Middle Cretaceous (Austrian phase).

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