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HIGHLY MAFIC AMPHIBOLITES IN THE MOLDANUBIAN ZONE OF THE BOHEMIAN-MORAVIAN HEIGHTS (ČESKOMORAVSKÁ VRCHOVINA)

VYSOCE MAFICKÉ AMFIBOLITY MOLDANUBIKA ČESKOMORAVSKÉ VRCHOVINY

DUŠAN NĚMEC

Abstract

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In the Chýnov zone which encompasses the area E of the town of Tábor and belongs to the Moldanubian Varied series, highly mafic amphibolites occur that are almost monomineral. They are associated with marginal-sea-type metasediments, forming there very long and narrow layers. Their chemistry points to an igneous rock which evidently was originally part of a volcanosedimentary complex. Their chemical composition recalls basaltic komatiites. However, other members of the komatiite series, particularly the peridotite metakomatiites, which are the parent rock of the komatiite series, are completely lacking in the Chýnov zone, the highly mafic amphibolites being in contrast associated there with metatholeiites. The content of femic minerals in the original igneous rock must have been higher than in primitive MORBs. Thus, they probably were olivine- and clinopyroxene-enriched accumulative magmas. This opinion is supported by the fact that several amphibolites of the Chýnov zone contain intercalations of olivine-chlorite-tremolite-actinolite schists which are assumed by MACHART (1984) to have been originally cogenetic olivine-pyroxene-plagioclase cumulates.

Key words: Amphibolites, parental magmas, genesis, Moldanubian Zone, Bohemian-Moravian Heights.

Dušan Němec, Institute of Mineralogy, Petrography and Geochemistry, Masaryk University, Kotlářská 2, 611 37, Czech Republic.

Introduction

Trace element investigations carried out on metavolcanic amphibolites from the Moldanubian Zone of the Bohemian-Moravian Heights (NĚMEC 1998) revealed a general increase in their Ni and Cr contents from the E, where they lie below 100 and 300 ppm, respectively, to the W, where they attain up to 300 and 600 ppm, respectively. This mafic trend in amphibolites is also confirmed by the fact that only in the W, in the Bohemian part of the Bohemian-Moravian Heights, amphibolites locally contain intercalations of ultramafic olivine-chlorite-tremolite-actinolite schists which are interpreted by MACHART (1984) as original olivine-pyroxene-plagioclase cumulates cogenetic with the parental basalts that were afterwards regionally metamorphosed along with their hosts under PT conditions of the amphibolite facies. In accordance with these observations also occurrences of so extremely mafic amphibolites that occasionally are completely devoid of feldspars (amphibolite schists) were reported only from this area. These rocks represent the magnesium-richest type among the Moldanubian amphibolites. They were petrographically described by ORLOV and VESELÝ (1931) and SUK (1977). The aim of the present paper is to elucidate their genesis and their setting within the family of the Moldanubian amphibolites.

The highly mafic amphibolites occur in the Chýnov zone (the area E of the town of Chýnov) which is part of the Moldanubian Varied series. Its rocks are consistent petrographically with those of the Sušice-Votice zone (ZOUBEK 1988), except for lower grade of their regional metamorphism (medium degrees of the amphibolite facies). Amphibolites are accumulated there in a rock series labelled by PLETÁNEK and SUK (1976) the Hořice series.

The bulk chemical analyses of the amphibolites used for the study include partly those published in the literature (ORLOV 1931, ORLOV and VESELÝ 1931, SUK 1971), partly original analyses performed by H. Červená in the former Geoindustria Laboratory in Jihlava. So far no source is given, the data presented in figures are own data of the present author. The analyses of minerals were performed by Mgr V. Vávra in the Department of Mineralogy, Petrography and Geochemistry of the Masaryk University in Brno, utilizing a CanScan 4 DV SEM, coupled with a Link 10.000 EDS analyser.

Petrography

Amphibolites of the Chýnov zone were already characterised in great details by ORLOV and VESELÝ (1931) and by SUK (1972). Both common feldspar-bearing amphibo-

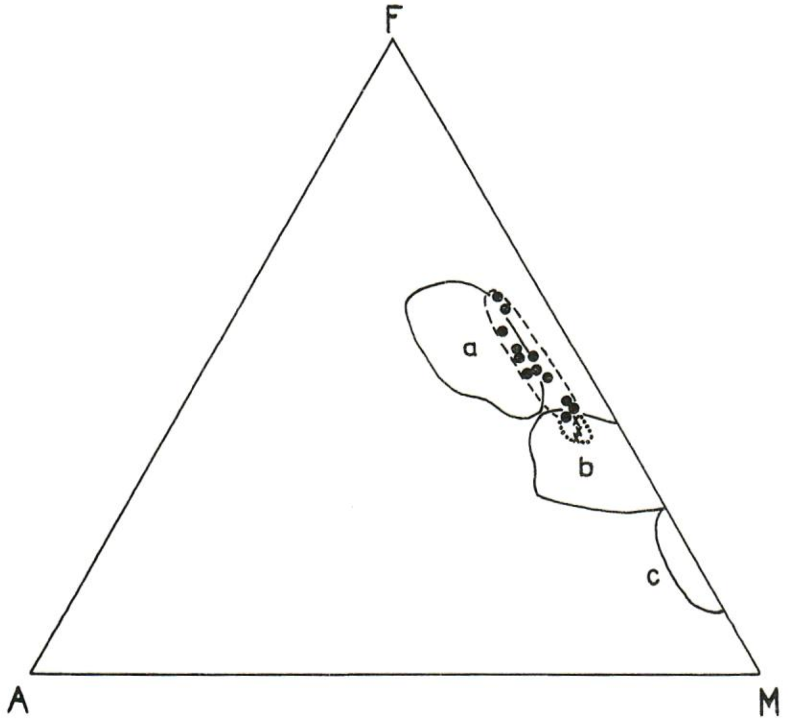

Fig. 1. AFM diagram showing fields of ophiolite volcanics (a), gabbros (b) and ultrabasics (c, according to ALLEMAN and PETERS 1972), and of komatiites (field enclosed by dotted line, according to COLEMAN 1977). Field of amphiboles from Moldanubian metavolcanic amphibolites (dots) is encircled by broken line. Crosses – highly mafic amphibolites of the Chýnov area.

Obr. 1. Diagram AFM ukazující pole ofiolitových vulkanitů (a), gaber (b) a ultrabasik (c), podle ALLEMAN a PETERS 1972), a komatiitů (pole ohraničené tečkovanou linií, podle COLEMAN 1977). Pole amfibolů z metavulkanických amfibolitů moldanubika (body) je ohraničeno čárkovanou linií. Křížky – silně mafické amfibolity chýnovské oblasti.

lites and highly mafic amphibolites occur there. The first type amphibolites form layers in gneisses as well as in marble. They mostly are consistent with the common amphibolite type found in the Moldanubian Zone. They are equigranular. Hornblende (pargasite in the classification of LEAKE et cons. 1997, Table 1) is their overwhelming constituent (up to 80 vol. %), clinopyroxene and biotite are their occasional minor constituents. Accessory ilmenite grains are jacketed with titanite rims. The ilmenite possesses enhanced V_2O_3 contents (Table 2) which are also inherited by the rim titanite. The amphibolites that exhibit elevated Fe_2O_3 contents (Nos 8–10, Table 3) carry accessory magnetite. Plagioclase is andesine which locally grades into both oligoclase and labradorite. The amphibolites are chemically throughout gabbroic, which points to their igneous origin. This is also confirmed by their geochemical signature (JANOUŠEK et al. 1997). The range of their mg numbers is broad (0.43–0.70), which proves their heterogenity. They are ol- and ne-normative (Table 3) and, consequently, silica-undersaturated. Only some feldspar-bearing amphibolites within the Chýnov marbles that accompany the highly mafic amphibolites are different, being chemically also gabbroic, but hypersthene-normative and highly magnesian (Table 3, No 3). These differences probably are due to different ages (proterozoic to early paleozoic) of individual amphibolite types, as was recently shown by geochronological measurements of JANOUŠEK et al. (1997).

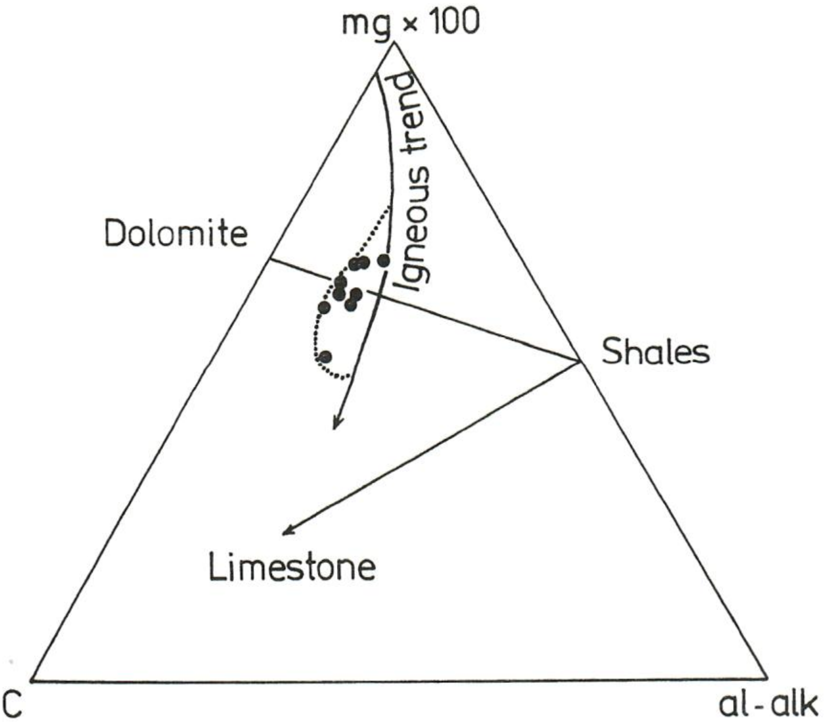

Fig. 2. Niggli c-mg-(al-alk) diagram (LEAKE 1964) for amphibolites (points) associated with marbles of the Chýnov zone. Dotted line encloses field of metatholeiitic basalts of the North Alabama Piedmont (according to STOW et al. 1984).

Obr. 2. Niggliho diagram c-mg-(al-alk) (LEAKE 1964) pro amfibolity (body) sdružené s chýnovskými mramory. Tečkované linie uzavírá pole metatoliitových basaltů předhůří severní Alabamy (podle STOW et al. 1984).

Table 1. Amphiboles, sample No 1. Formulae for T + C = 13 atoms
Tab. 1. Amfiboly, vz. č. 1. Formule pro T + C = 13 at

Amphibole No Amfibol č.	1	2	3
SiO_2	43.10	42.12	38.97
TiO_2	0.92	1.06	1.28
Al_2O_3	10.57	11.26	14.40
FeO_t	15.42	15.78	16.53
MnO	0.28	0.34	0.21
MgO	11.18	10.64	9.39
CaO	11.85	11.62	11.73
Na_2O	2.58	2.31	2.48
K_2O	0.67	0.72	1.16
Total	96.57	95.85	96.15
mg	0.56	0.54	0.48
$Fe^{3+}/Fe_t \times 100$	7	16	16
Si	6.51	6.40	5.97
Al^{IV}	1.49	1.60	2.03
Al^{VI}	0.39	0.42	0.56
Ti	0.11	0.12	0.15
Fe^{3+}	0.14	0.32	0.34
Fe^{2+}	1.81	1.69	1.78
Mn	0.04	0.05	0.03
Mg	2.51	2.41	2.14
Ca	1.92	1.89	1.92
Na	0.75	0.68	0.74
K	0.13	0.14	0.23

Fe^{3+} was computed according to SCHUMACHER (1997).
Fe^{3+} bylo počítáno podle SCHUMACHERA (1997).

Table 2. Microprobe analyses of ilmenite and titanite, sample No 10 (wt %). Formulae for 3 (ilmenite) and 5 (titanite) oxygen atoms.
Tab. 2. Mikrosondové analýzy ilmenitu a titanitu, vz. č. 10 (hm. %). Vzorec počítán na 3 (ilmenit) a 5 (titanit) at. kyslíku.

	Ilmenite	Titanite		Ilmenite	Titanite
SiO_2	0.28	30.95	Si	0.007	1.014
TiO_2	51.06	37.87	Ti	0.985	0.933
Al_2O_3	–	1.00	Al	–	0.039
V_2O_3	0.64	0.60	V	0.011	0.013
FeO_t	42.56	0.82	Fe^{3+}	–	0.022
MnO	3.04	–	Fe^{2+}	0.913	–
CaO	0.39	28.35	Mn	0.066	–
			Ca	0.011	0.995
Total	97.97	99.59	Total	1.993	3.016

Table 3. Selected chemical analyses of amphibolites, the Chýnov zone.
Tab. 3. Vybrané chemické analýzy amfibolitů, chýnovská zona.

Sample No Vzorek č.	1	2	3	4	5	6	7	8	9	10
SiO_2	45.85	46.06	46.85	43.90	45.96	45.39	47.73	47.63	47.77	48.17
TiO_2	0.84	0.82	1.39	1.26	1.25	1.94	1.25	2.23	2.34	1.40
Al_2O_3	13.01	13.02	17.44	16.09	13.37	14.09	15.15	14.61	16.36	17.16
Fe_2O_3	1.53	1.98	1.13	3.89	2.70	2.15	2.58	4.03	4.94	4.39
FeO	7.57	7.96	7.79	9.01	7.82	9.39	7.10	7.30	6.23	5.38
MnO	0.06	0.06	0.07	0.08	0.08	0.16	0.13	0.12	0.12	0.16
MgO	13.04	13.10	11.47	10.17	10.30	9.05	8.32	7.48	4.55	6.49
CaO	10.99	10.90	8.52	11.32	15.36	12.24	11.43	9.70	11.36	10.00
Na_2O	1.05	1.08	2.42	2.07	1.82	2.30	3.43	4.18	3.98	3.95
K_2O	0.43	0.45	0.48	0.39	0.40	0.36	0.48	0.24	0.70	0.63
P_2O_5	0.09	0.10	0.28	0.30	0.11	0.19	0.10	0.31	0.32	0.09
CO_2	1.02	1.08	–	–	–	0.13	–	–	–	0.46
H_2O^+	4.28	3.18	1.82	1.39	1.01	1.59	1.42	1.22	1.00	1.13
H_2O^-	0.16	0.12	0.09	0.18	0.08	0.13	0.11	0.16	0.21	0.23
Total	99.99	99.97	99.93	100.05	100.26	99.11	99.36	99.21	99.88	99.64
Fe_2O_3 (%of tot. FeO)	15	18	12	28	26	17	25	33	42	42
FeO_t	8.95	9.74	8.81	12.51	10.52	11.32	9.42	10.93	10.68	9.33
mg	0.72	0.70	0.70	0.59	0.64	0.58	0.61	0.55	0.43	0.55
an	29.5	29.5	35.3	33.6	27.2	27.0	24.7	20.3	24.7	27.0
or	2.8	2.8	2.8	2.2	2.2	2.2	2.8	1.7	3.9	3.9
ab	8.9	8.9	20.4	15.7	7.8	16.5	22.5	31.2	28.3	29.3
ne	–	–	–	0.8	4.0	1.6	3.4	2.1	2.8	2.3
di	18.8	18.6	3.9	16.0	37.4	25.7	24.2	20.1	23.1	17.3
hy	19.6	20.1	10.0	–	–	–	–	–	–	–
ol	10.8	11.1	22.2	21.4	13.8	17.2	13.7	11.7	3.5	9.0
il	1.7	1.5	2.6	2.4	2.4	3.6	2.4	4.3	4.4	2.7
mt	2.3	2.8	1.6	5.6	3.9	3.0	3.7	5.8	7.2	6.3
ap	0.3	0.3	0.6	0.6	0.3	0.3	0.3	0.6	0.6	0.2

Sample location: 1 Pacova hora hill at Chýnov (highly mafic amphibolite, SUK 1971); 2 the same; 3 Pacova hora hill at Chýnov (ORLOV and VESELÝ 1931); 4 Kladrubská hora hill at Chýnov (ORLOV and VESELÝ 1931); 5 Věžná at Obrataň (ORLOV 1931); 6 Věžná at Obrataň (clinopyroxene amphibolite); 7 Oblajovice (clinopyroxene amphibolite); 8 Dolní Hořice; 9 Lejčkov (clinopyroxene amphibolite).
Lokalizace vzorků: 1 Pacov a hora u Chýnova (silně mafický amfibolit, SUK 1971); 2 totéž; 3 Pacova hora u Chýnova (ORLOV a VESELÝ 1931); 4 Kladrubská hora u Chýnova (ORLOV a VESELÝ (1931); 5 Věžná u Obrataně (ORLOV 1931); 6 Věžná u Obrataně (klinopyroxenový amfibolit); 7 Oblajovice (klinopyroxenový amfibolit); 8 Dolní Hořice; 9 Lejčkov (klinopyroxenový amfibolit).

Table 4. Trace element contents in amphibolite from Věžná near Tábor (sample No 6 in Table 3), ppm
Tab. 4. Obsahy stopových prvků v amfibolitu z Věžné u Tábora (vz. č. 6 v tab. 3), ppm

Ni	185	Zr	108
Co	51	Y	29
Cr	475	Sr	239
V	396	Rb	7
Nb	5		

The highly mafic amphibolites are limited with their occurrence to the Chýnov marbles where they form cm to m thick slabs (compare their photos in ORLOV and VESELÝ 1931 and SUK 1972). They were strongly affected by tectonism, which occasionally made them to boudins. They consist of hornblende, accompanied locally by accessory biotite, plagioclase and quartz. The almost monomineral character of these rocks is also documented by Fig. 1, where the field covered by their points adjoin and partly overlap the field of amphiboles derived from common Moldanubian amphibolites. Due to their almost monomineral compositions the analyses of the rocks can be easily computed to crystal formulae of amphiboles:

$$Na_{0.30}K_{0.09}Ca_{1.70}Fe^{2+}{}_{0.97}Mg_{2.79}Fe^{3+}{}_{0.21}Ti_{0.09}Al_{0.95}(Si_{6.71}Al_{1.29})O_{23}$$

In the classification of LEAKE et cons. (1997) it corresponds to magnesio-hornblende. Igneous rocks with similar chemistry are rare, being represented, for instance, by melanocratic clinopyroxene- and olivine-rich gabbros, formally termed tylaites according to their type locality in the Ural (compare ZAVARITSKII 1955, for their petrography, and SOLOVEV 1970, for their chemistry). Almost monomineral amphibolites of similar chemistry were also described, for instance, from Tamil Nadu in India (RAJASEKARAN and RAM MOHAN 1985).

Protoliths

The amphibolites of the Chýnov zone are of igneous origin. This is documented by Fig. 2. They obviously display an igneous trend and their points plot, for instance, into the field taken by metatholeiitic basalts of the North Alabama Piedmont (STOW et al. 1984). The feldspar-bearing amphibolites of the Chýnov Zone are partly MORB-type metavolcanics which represent the by far most common type of amphibolites found in the Moldanubian Zone of the Bohemian-Moravian Heights (NĚMEC 1997a, in print a, b). In the case of the Chýnov zone it is documented by Figs. 3 and 4. Fig. 3 shows simultaneously that points of the highly mafic amphibolites cluster outside the field of the mid-ocean ridge basalts (MORB) due to their picritic affinity manifested especially by their high mg numbers (0.70–0.72). In Figs. 1 and 5 their points lie within the field of komatiitic basalts. In spite of it these rocks cannot be classified as pristine komatiites. Komatiites have relatively restricted temporal distribution being abundant only in Archaic terranes (compare MÍSAŘ 1980), whereas dating of the amphibolites of the Chýnov zone by use of the Nd method yielded ages ranging from upper Algonkian to lower Paleozoicum (JANOUŠEK et al. 1997). Further-

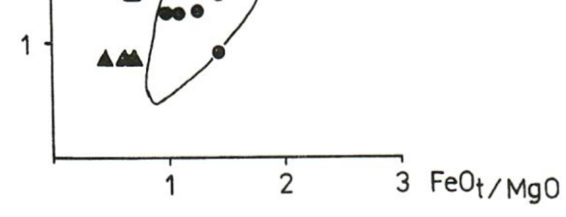

Fig. 3. TiO_2 contents (wt %) vs FeO_t/MgO ratio of tholeiitic (dots) and highly mafic (triangles) amphibolites of the Chýnov zone. Field of Atlantic MORBs (after LE ROEX et al. 1983) is enclosed by full line.

Obr. 3. Obsahy TiO_2 (váh. %) vs FeO_t/MgO tholeiitových (body) a silně mafických (trojúhelníky) amfibolitů chýnovské zóny. Pole atlantických MORB (podle LE ROEX et al. 1983) je omezeno plnou čarou.

more, according to ARNDT et al. (1977), presence of rocks of the whole komatiite series in an area is crucial. However, metabasites exhibiting the chemistry of peridotite komatiites, from which all the other komatiite types can be derived by crystal fractionation or accumulation, are fully lacking in the Chýnov zone. In contrast, a linkage of the highly mafic amphibolites to the metabasites of the magnesian tholeiite type is there conspicuous (Fig. 5). Some ophiolite gabbros are chemically also close to the highly mafic amphibolites (Fig. 1), but the geological setting of the latter excludes such a provenience. Their association with marbles and graphitic quartzites testifies to an originally volcanosedimentary formation. Moreover, very large areal extension of the metavolcanic layers as well as their small thicknesses suggest an originally volcanic extrusion. All authors who examined them recently (ZEMÁNEK 1967, SUK 1977, JANOUŠEK et al. 1997) hold them for metavolcanics, too.

Metamorphism

The Chýnov zone has a special position within the Moldanubian Zone in the territory of the Bohemian-Moravian Heights. It shows metamorphism of lower grade than other parts of the region. This metamorphism corresponds to the staurolite-kyanite type and is of medium pressures and temperatures. It manifests petrographically especially by wide occurrence of muscovite, in particular in two-mica gneisses which represent the most abundant rock type occurring in the area.

As to amphibolites, they show assemblages characteristic for the higher T part of the medium- and higher-grade amphibolite facies. So far the rock chemistry it allows, they contain abundant clinopyroxene (Lejčkov, Oblajovice, Věžná). Temperature of metamorphism of the amphibolites can be estimated according to O'BRIEN et al. (1992), who utilized the temperature dependence of hornblende Ti-content, as it was deduced from the experimental data of HELZ (1973). This method was applied to hornblende of the amphibolite sample No 10 (Table 3). The rock contains abundantly accessory ilmenite, which warrants saturation of the hornblende by Ti. The temperatures found mostly range between 670 and 690 °C.

As already JANOUŠEK et al. (1997) have mentioned, the amphibolites of the Chýnov zone are characterized by significant heterogenity of the oxidation grade of iron. This is also documented by the bulk rock analyses listed in Table 3. Hornblende of the rocks ex-

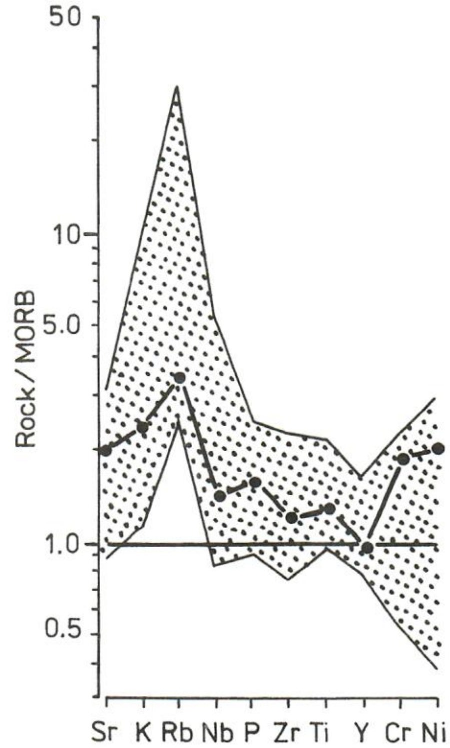

Fig. 4. MORB-normalized contents of minor and trace elements in the Věžná metatholeiitic amphibolite (dots) and in 15 metatholeiitic Moldanubian amphibolites of the Bohemian-Moravian Heights (dotted area). Normalizing values after PEARCE (1982).

Obr. 4. Obsahy minoritních a stopových prvků normalizované na MORB v metatholeiitovém amfibolitu od Věžné (body) a v 15 metatholeiitových moldanubických amfibolitech Českomoravské vrchoviny (tečkované pole). Normalizační hodnoty podle PEARCE (1982).

hibits low Fe^{3+}/Fe^{2+} ratios (only 7–16 % of total iron is trivalent, Table 1). If total iron found in ilmenite is computed as bivalent (Table 2), the $(R^{3+}+R^{4+})/R^{2+}$ ratio equals precisely to one, which points to total absence of Fe^{3+} and, consequently, to the absence of the haematite component in the mineral. On the other hand, in some samples (Nos 8–10, Table 3) accessory magnetite is copious, which evidently results in enhanced bulk Fe_2O_3 content of the rocks. Thus, it is uneasy to estimate f_{O_2} during metamorphism of the amphibolites.

Type of the parental magma

In Fig. 6, amphibolites of the Moldanubian Zone in the Bohemian-Moravian Heights are plotted in terms of their TiO_2 and MgO contents which both highly sensitively trace variational trends of basic igneous rocks. In Fig. 6 metavolcanics and metagabbros (distinguished according to NĚMEC 1997a, b, 1998) are plotted by different symbols. The major clusters of metavolcanics coincide with the line that traces the variational trend of mid-Atlantic ridge basalts (MARB) within its FAMOUS section (BRYAN 1979). This trend is also typical for other MARBs (ROCHETTE et al. 1991) and was also

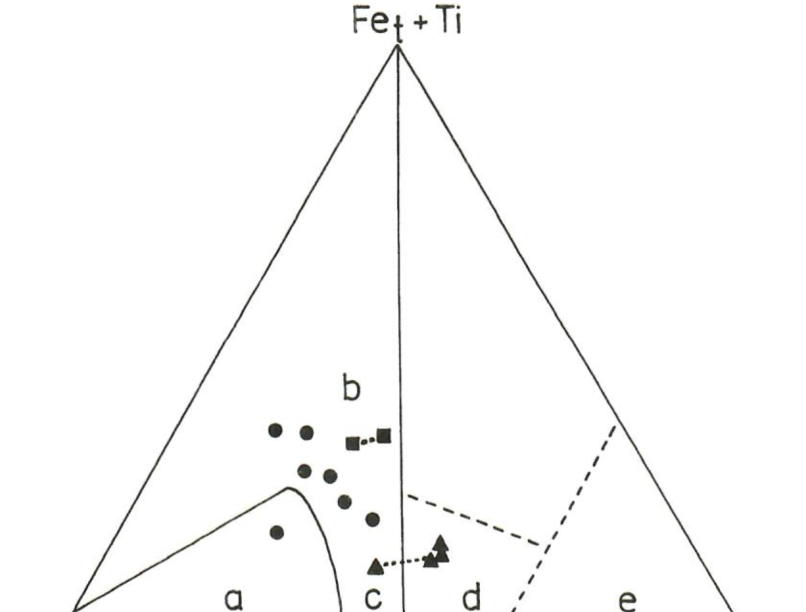

Fig. 5. Amphibolites of the Chýnov zone in terms of Al_2O_3, MgO and FeO_t+TiO_2 (wt %, according to JENSEN 1976). Triangles – highly mafic amphibolites, squares – amphibolites from the surroundings of Věžná, points – other amphibolites of the zone. a – calc-alkaline basalts, b – ferroan tholeiites, c – magnesian tholeiites, d – basaltic komatiites, e – ultramafic komatiites.

Obr. 5. Amfibolity chýnovské zóny v diagramu Al_2O_3-MgO-(FeO_t+TiO_2) (váh %, podle JENSEN 1976). Trojúhelníky – silně mafické amfibolity, čtverečky – amfibolity z okolí Věžné, body – ostatní amfibolity zóny. a – alkalicko-vápenaté basalty, b – tholeiity Fe, c – tholeiity Mg, d – basaltové komatiity, e – ultramafické komatiity.

recorded in the East Pacific Rise (EPR, NIELSEN 1988). This trend is controlled by modal changes running from olivine basalts (the TiO_2 – low end of the line in Fig. 6) over plagioclase-olivine-clinopyroxene basalts to plagioclase basalts (BASS et al. 1973) and is consistent with the model of simple fractional crystallization (NIELSEN 1988). The slope of the TiO_2-MgO correlation line in Fig. 5 suggests that the content of clinopyroxene in rocks acted as the main controlling factor (compare HOECK and KOLLER 1989). Considered as a whole, the scatter of points in Fig. 6 is considerable, but it decreases significantly if amphibolites of only smaller areas are considered (Fig. 7).

In Fig. 6 also points of the samples from the Pacov hill (N of the town of Chýnov) and those from the surroundings of the Věžná village (eastern section of the Chýnov zone) are separately connected by tie-lines. All the three low, intermediate and high-MgO trends of volcanogenic suites follow similar pathways. In spite of paucity of points in two suites they have the same slopes in Fig. 6 and, consequently, also the same petrologic significance. They probably were controlled predominantly by the shallow fractionation of diversely magnesian parents. Points at the low end of the variational lines at the highest MgO values are generally assumed to be consistent with primitive (parental) magmas of the series, because they are believed to have undergone the smallest amounts of crystallization since separation from the mantle. To get the presumed parental mag-

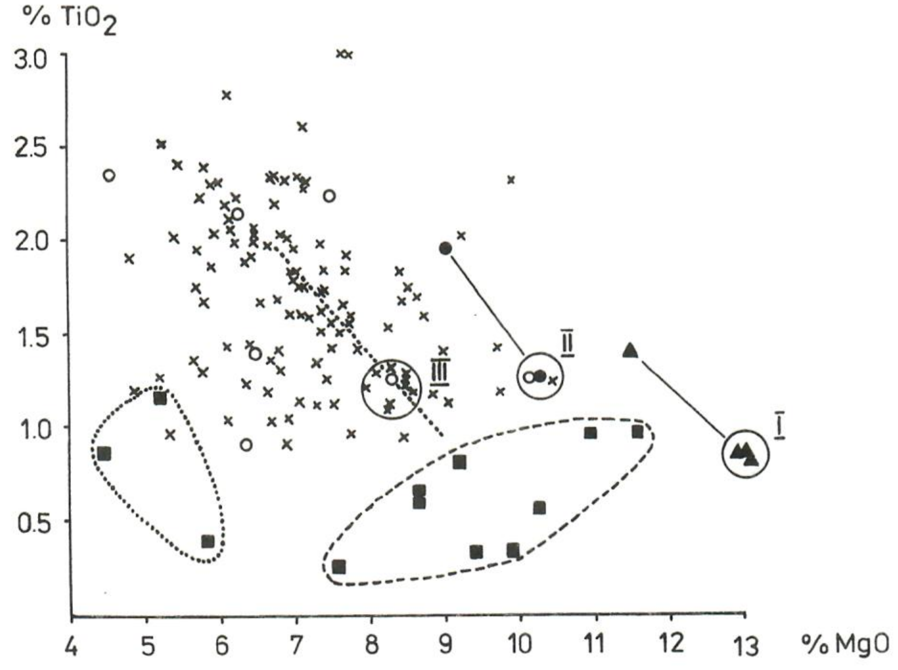

Fig. 6. MgO and TiO_2 contents (wt %) of highly mafic amphibolites (triangles), of amphibolites from the surroundings of Věžná (dots), of other amphibolites of the Chýnov zone (circles) and of all other Moldanubian amphibolites of the Bohemian-Moravian Heights (crosses). Fields of magnesian metagabbros and metaleucogabbros are enclosed by broken and dotted lines, respectively. Samples within circles were used to compute primitive magmas of the pertinent series.

Obr. 6. Obsahy MgO a TiO_2 (váh. %) silně mafických amfibolitů (trojúhelníky), amfibolitů z okolí Věžné (body), ostatních amfibolitů chýnovské zóny (kroužky) a ostatních moldanubických amfibolitů Českomoravské vrchoviny (křížky). Pole metagaber Mg je ohraničeno čárkovanou linií, pole metaleukogaber tečkovanou linií. Vzorky uvnitř kroužků byly použity pro výpočet primitivních magmat v jednotlivých sériích.

mas, data of the samples enclosed by the circles in Fig. 6 were averaged and entered into Table 5 (all the No I metabasites displayed marked H_2O and CO_2 contents, thus, also mean data of analyses corrected for these components are given in the Table). It has been shown (NĚMEC in print b) that regional metamorphism of the Moldanubian amphibolites affected their Na_2O and K_2O contents, but other major components remained essentially unchanged. The obtained presumed parental magmas can be commented as follows:

Table 5. Supposed parental magmas of individual series and comparable MORBs.
Tab. 5. Předpokládaná parentální magmata jednotlivých serií a MORB obdobného složení.

Series Serie	Ia	Ib	1	II	2	III	3
Number of averaged samples	3	3		2		8	
SiO_2	46.10	48.56	49.64	44.93	47.0	48.23	50.15
TiO_2	0.83	0.87	0.59	1.25	1.1	1.24	1.45
Al_2O_3	13.00	13.69	14.34	14.73	17.0	15.47	15.26
Fe_2O_3	1.71	1.80	–	3.30	–	2.36	–
FeO	7.64	8.05	8.58+	8.42	10.0+	7.52	9.96+
MnO	0.06	0.06	–	0.08	–	0.14	0.19
MgO	13.05	13.75	13.83	10.24	9.8	8.30	8.37
CaO	10.94	11.52	11.10	13.34	11.0	11.53	12.36
Na_2O	1.06	1.12	1.65	1.95	2.7	2.61	2.62
K_2O	0.45	0.47	–	0.40	0.05	0.53	0.07
P_2O_5	0.10	0.11	–	0.21	–	0.13	0.11
CO_2	1.11	–	–	–	–	–	–
H_2O^+	3.60	–	–	1.20	–	1.60	–
H_2O^-	0.15	–	–	0.13	–	0.19	–
Total	99.80	100.18	99.73	100.18	98.65	99.85	100.54
FeO_t	9.18	9.67	8.58	11.52	10.0	9.60	9.96
mg	0.72	0.72	0.74	0.62	0.64	0.60	0.60

Samples: Ia Parental magma, No I series
Ib Parental magma, No I series (corrected for CO_2 and H_2O)
1 28 % melt extracted from a MORB pyrolite at 8–12 kbar (according to FALLOON and GREEN 1988)
II Parental magma, No II series
2 Primitive MORB (ELTHON 1989)
III Parental magma, No III series
3 East Pacific Rise basalt (TIGHE et al. 1988)

Vzorky: Ia Parentální magma, ser. I
Ib Parentální magma, ser. I (korigováno na CO_2 a H_2O)
1 28 % tavenina extrahované z pyrolitu MORB při 8–12 kbar (podle FALLOON a GREEN 1988)
II Parentální magma, ser. II
2 Primitivní MORB (ELTHON 1989)
III Parentální magma, ser. III
3 Basalt Východopacifického hřbetu (TIGHE et al. 1988)
+ Total Fe as FeO
+ Celkové Fe jako Feo

The type No I parental magma. A melt of chemical composition comparable to the highly mafic amphibolites was produced experimentally by FALLON and GREEN (1988) through a 28 % melting of a MORB pyrolite at 8–12 kbar. However, no rocks of similar chemistry are reported in lists of primary MORBs given by FLOWER (1991), BATIZA (1991) and NATLAND (1991). Thus, the high MgO content and a relatively low alumina content of the No I type rather point to an olivine+clinopyroxene-enriched accumulative magma. Similar origin was proven e.g. by FRANCIS (1985) for a rock originally held for picrite. In our case such an explanation is corroborated by the occurrence of olivine-bearing tremolite-actionolite intercalations in several amphibolite bodies of the study area (MACHART 1984), which continuously pass into their hosts.

The type No II parental magma. There is not a generally accepted definition of what is a primitive magma, nonetheless basalts with more than 9.5 wt % MgO usually are termed so (ELTHON 1991). Our type II amphibolite falls within this MgO range. Chemistry of primitive parental MORBs is rather variable presumably due to different degrees of partial melting and slight variation of the mantle source. In spite of it, it was not possible to find a sample among them that would approach closely enough to the type No II amphibolites (Table 5). However, it must be pointed out that the number of points which define the No II differentiation series is too low to consider the trend to be reliable.

The type No III parental magma. In view of its MgO content this type apparently represents an already considerably evolved basaltic melt. MORBs which display similar chemical compositions are rather common. The sample listed for comparison in Table 2 derived from the EPR (TIEGHE et al. 1988).

Conclusions

In the Chýnov zone which is part of the Moldanubian Varied series highly mafic amphibolites that are almost entirely composed of amphibole occur forming layers in marbles. Their chemistry is gabbroic. Their geological setting as well as the association of rocks suggest an originally volcanogenic rock of a volcanosedimentary complex. In spite of their chemical composition which corresponds to basaltic komatiites they cannot be classified so, because they show relationships to the tholeiite suite. This can be inferred from their association with metatholeiites and, which is more important, from the lack in the study area of other rocks of the komatiite suite, particularly of peridotite

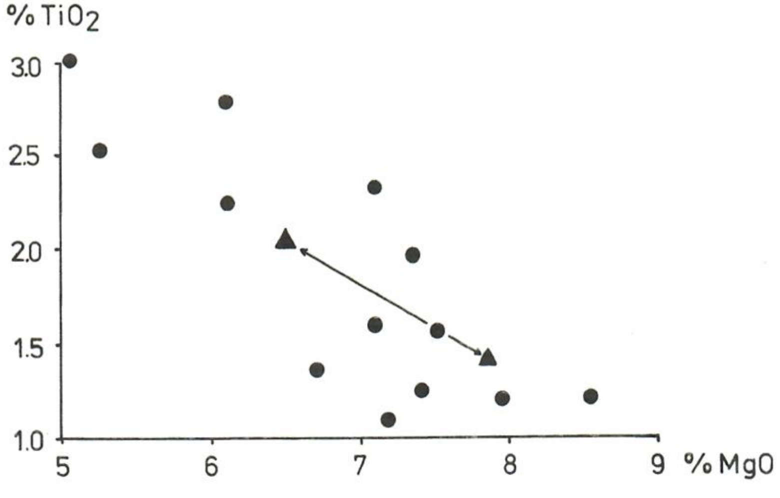

Fig. 7. MgO and TiO_2 contents (wt %) in metavolcanics of the amphibolite-rich belt between Měřín and Křižanov (dots), the Strážek subdivision of the Moldanubian Zone. Triangles – amphibolites from Břevnice (near the town of Havlíčkův Brod).

Obr. 7. Obsahy MgO a TiO_2 (váh. %) metavulkanitů pásma bohatého amfibolity mezi Měřínem a Křižanovem (body) ve strážecké větvi moldanubika. Trojúhelníky – amfibolity od Břevnice (u Havlíčkova Brodu).

metakomatiites that are the parental magma of all other members of the komatiite suite. However, the content of femic constituents in the highly mafic amphibolites evidently had to be higher in the original igneous rock than in primitive MORBs. Hence, they supposingly were originally olivine- and clinopyroxene-enriched accumulative magmas. Most of the Moldanubian amphibolites of the Bohemian-Moravian Heights originally were MORBs, whose parental magma was not primitive, but already markedly evolved.

SOUHRN

V chýnovské zóně, která náleží pestré sérii moldanubika, se v mramorech vyskytují i silně mafické amfibolity tvořené často prakticky jen amfibolem. Jejich chemismus je gabroidní. Jejich geologická pozice nasvědčuje, že šlo původně o vulkanickou vyvřelinu, která byla součástí vulkanosedimentárního komplexu. Přesto, že jejich chemismus odpovídá basaltovým komatiitům, jejich asociace s metatholeiity, jejich chemické vztahy k nim a naopak chybění ostatních členů komatiitové série v oblasti ukazují, že náleží do série tholeiitů. Obsah mafických složek byl však v nich vyšší než v primitivních basaltech středooceánských hřbetů (MORB), takže je nutno předpokládat, že šlo patrně původně o kumulativní magmata nabohacená olivinem a klinopyroxenem. Velká většina ostatních amfibolitů moldanubika Českomoravské vrchoviny náleží metavulkanitům typu MORB, jejichž mateřská primitivní magmata byla již částečně vyvinuta.

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