Acta Mus. Moraviae, Sci. geol.
82(1997):63–72

HIGH-AL AMPHIBOLITES OF THE BOHEMIAN-MORAVIAN HEIGHTS

VYSOCE HLINITÉ AMFIBOLITY ČESKOMORAVSKÉ VRCHOVINY

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Abstract

Němec, D., 1997: High-Al amphibolites of the Bohemian-Moravian Heights. *Acta Mus. Moraviae, Sci. geol.*, 82:63–72.

In the Bohemian-Moravian Heights high-Al amphibolites having 21–22 wt % Al_2O_3 were observed in four amphibolite complexes (at Kozlov, Račice and Rožná in the Strážek subdivision of the Moldanubian Complex, and at Kasany in the southernmost part of the Svratka Complex). Their occurrences evidently are only solitary and of small extension. Their high Al_2O_3 level is either due to their elevated content of basic plagioclase, whose share in the rock exceeds 50 %, or due to the extremely high basicity of the constituting plagioclase (anorthite) in rocks with otherwise current petrography. Before regional metamorphism the rocks were leucogabbros and high-Ca gabbros. This view is also supported by the fact that similar basic types rich in basic plagioclase are common within the family of plutonic rocks, but exceptional within the family of volcanic rocks, and by the geochemical signature of the rocks. The metaleucogabbros represent an additional type among the pre-metamorphic gabbroic protoliths which, in the Moldanubian Complex of the Bohemian-Moravian Heights, also include Mg and Fe metagabbros.

Key words: Leucogabbros, amphibolites, genesis, Moldanubian Complex, western Moravia.

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Introduction

Amphibolites are petrographically monotonous, representing simple, mostly only bimineral, assemblages. This is due to an extraordinarily broad chemical variability of amphiboles, so that variable original mineral assemblages, which include plagioclase, clinopyroxene, olivine and magnetite, yield, after regional metamorphism, only amphibole as a product. The variability of the original protoliths of amphibolites can be disclosed only when various approaches are applied which mostly base on the chemical composition of the rocks. In the Moldanubian Complex of the Bohemian-Moravian Heights (Českomoravská vrchovina) the protoliths comprise various types of basaltic and gabbroic rocks (Němec 1994, 1996, in print a, b). There, also, peculiar high-Al amphibolites were detected. They are characterised by Al_2O_3 contents which range from 21 to 22 wt % (Fig. 1). The goal of the present paper is to characterise them and to decipher their genesis. The bulk rock analyses used were mostly performed by H. Červená at the former Geoindustria Laboratory in Jihlava.

Petrographic characterisation of the localities

Rožná. The occurrence of the high-Al amphibolite lies within the amphibolite zone which runs the length of about four kilometers between the Rožná and the Rodkov villages. The zone probably represents a metamorphosed ophiolite complex in that it includes rare serpentinite bodies and amphibolites which have the chemistry of gabbros, rarely also that of basalts (Fig. 2). The low-Al amphibolites which predominate in the locality are small to medium grained. Their hornblende is light coloured. Biotite is subordinate. Plagioclase is a basic andesine. Titanite is an accessory.

The high-Al amphibolite does not differ megascopically from other amphibolites of the zone. The grainsize of hornblende is medium (1–2 mm). Plagioclase is finer (tenths mm), forming, however, accumulations whose dimensions correspond to the amphibole crystals. The rock consists only of amphibole and plagioclase. Amphibole is brown-green and very slightly pleochroic. Plagioclase is anorthite (90–100% An).

Kasany at Ujčov. The locality is about 2 km north of the town of Nedvědice, in the southernmost projection of the Svratka Complex, near the boundary with the Moravian Complex. Most of the fragments occurring there belong to the low-Al amphibolite. The grainsize of the amphibolite are tenths mm. The grey-brown hornblende strongly predominates in it over basic andesine. Garnet is a scarce irregular constituent.

The high-Al amphibolite is rare. Its grainsize is coarser (1 mm). Light constituents prevail in it. Hornblende is very light green-brown. Plagioclase is of two kinds. Most of it is finely polysynthetically twinned, often sericitized and basic (67–80% An). A clear untwinned, probably younger, plagioclase is scarcer. Garnet is rare and titanite very rare.

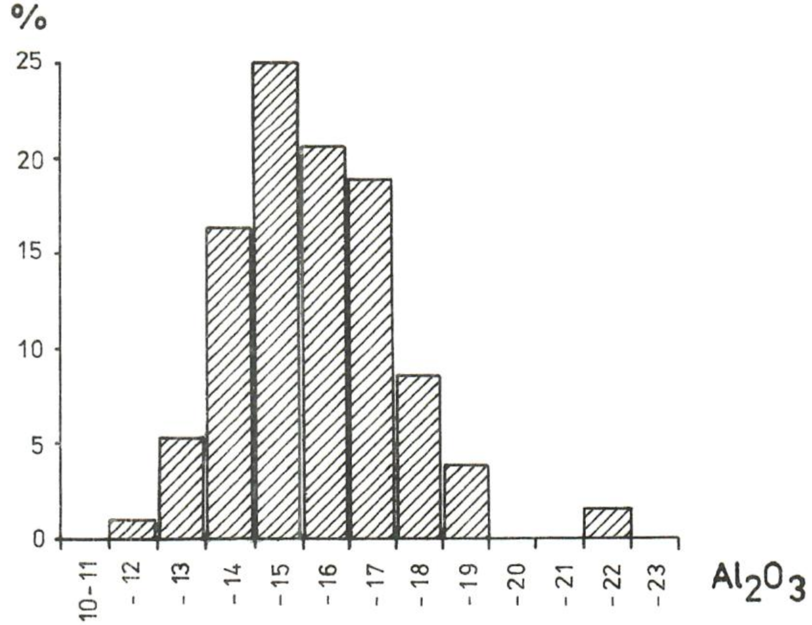


Fig. 1. Distribution of Al_2O_3 contents (wt %) in 210 amphibolite samples from the Moldanubian Complex of the Bohemian-Moravian Heights.

Obr. 1. Distribuce obsahů Al_2O_3 (váh. %) ve 210 vzorcích amfibolitů z moldanubika Českomoravské vrchoviny.

Kozlov at Křižanov. The occurrence lies on the boundary of the Variegated and Gföhl Gneiss Groups. Fragments of amphibolite are scattered in fields near the Křižanov railway station, being part of a long amphibolite zone which runs in the NE–SW direction. There, also, the medium-grained low-Al amphibolite largely prevails, being composed of dirty green hornblende, plagioclase (53–55% An), minor clinopyroxene, and accessory titanite and opaques. Dark coloured constituents predominate over plagioclase.

The high-Al amphibolite is rare. It exhibits inequigranular texture and large grain-size (2 mm). It consists of dirty green hornblende, minor biotite and basic (89% An) plagioclase which is the dominant constituent of the rock. Titanite and relatively abundant apatite are accessories.

Račice. The high-Al amphibolite was identified in an amphibolite zone which runs between the Račice and the Dlouhá villages in the Strážek subdivision of the Moldanubian Complex, on the boundary between the Variegated and Monotonous

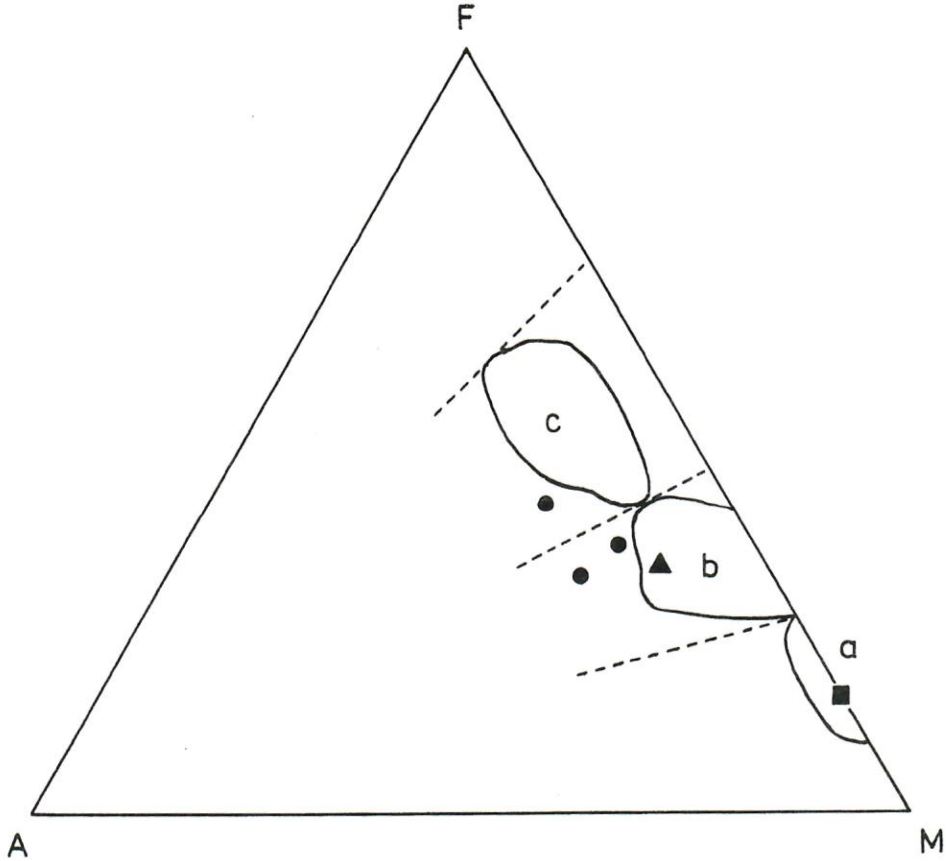


Fig. 2. AFM diagram showing samples of serpentinite (square), high-Al amphibolite (triangle) and low-Al amphibolites (points) from the Rožná amphibolite complex. The encircled areas give fields of ultrabasites (a), gabbros (b) and basalts (c) of the Oman ophibolite complex (according to Alleman and Peters 1972).

Obr. 2. Diagram AFM se vzorky serpentinitu (čtverec), vysoce hlinitého amfibolitu (trojúhelník) a basaltů (body) z rožnského amfibolitového komplexu. V kroužcích jsou pole ultrabasitů (a), gaber (b) a basaltů (c) ofiolitového komplexu Omanu (podle Allemana a Peterse 1972).

Groups. The sample has small to medium grainsize. Its mode is as follows (vol. %): 40 hornblende, 58 plagioclase (about 50% An), 2 titanite. The hornblende is strongly pleochroic (light brown – dark green). Other amphibolite types of the locality were not examined. Klápová (1977) reports from Račice a pyroxene amphibolite with (vol. %) 46 hornblende, 9 pyroxene, 44 plagioclase, 0.4 titanite, 0.9 opaques.

Bulk rock chemistry

Rožná. All the samples examined from the locality possess gabbroid chemistry which corresponds simultaneously to that typical of gabbros of the ophiolite complexes. As seen in Fig. 2, all samples but one plot into, or near, the field of gabbros, while only one corresponds chemically to basalts. All the samples have high mg numbers and low TiO_2 and P_2O_5 contents (Table 1) which are all features typical of amphibolites associated with serpentinites. Their contents of alkalies are higher than usual in gabbros of the ophiolite complexes. The amphibolites probably were enriched by alkalies during regional metamorphism, which took place in higher zones of the almandine amphibolite facies. The influx of alkalies is particularly conspicuous in an about two meters large amphibolite pod imbedded in gneiss, whose K_2O content (3.16 wt %) is unusually high. Similar enrichment of metabasites by highly mobile elements is common in strongly metamorphosed terranes (Bodinier et al. 1986, Cabanis et al. 1983, Koller 1985). In contrast, the mg numbers of metabasites mostly does not change after regional metamorphism (Büsch et al. 1979).

The high-Al amphibolite differs chemically from all the other amphibolite samples of the locality by its higher Al_2O_3 and CaO contents. As the share of plagioclase in all samples is approximately similar, this difference is evidently due to raised basicity of the plagioclase in the high-Al amphibolite (Table 1).

Kasany. The low-Al amphibolites of the locality correspond chemically to the usual type of the Molanubian metavolcanic amphibolites (Table 1). Considered as magmatic rocks, their chemistry is gabbroid or gabbrodioritic. Their main difference from other amphibolites consists in their relatively high P_2O_5 contents attaining up to 0.59 wt %, which is the highest content ever recorded in the amphibolites of the Bohemian-Moravian Heights (compare Fig. 3 in Němec 1996). The Zr content, too, is abnormally high (Fig. 3). This is in accord with the high P_2O_5 content of the rock (compare Fig. 2 in Němec 1994), as the two elements show a geochemical coherence (Gill and

Table 1. Some chemical and normative (CIPW) data on high-Al amphiboles and associated rocks, western Moravia.

Locality	Type	Sample No	Al_2O_3 wt %	CaO wt %	TiO_2 wt %	P_2O_5 wt %	An norm.	fels[1]	fem[2]	mg
Rožná	high-Al	1	21.07	14.98	0.34	0.13	99	60.0	37.7	76
	low-Al	2[3]	14.01	10.35	0.95	0.10	56	50.6	46.0	71
	low-Al	3	15.49	9.30	0.96	0.10	64	58.2	39.5	73
	low-Al	4	17.25	10.73	1.12	0.12	57	61.7	36.2	62
Kasany	high-Al	2	21.59	13.02	0.38	0.06	81	67.2	29.3	66
	low-Al	1	14.03	9.00	2.44	0.59	41	54.8	41.6	47
	low-Al	3	12.83	9.96	2.60	0.36	42	49.6	47.7	52
Kozlov	high-Al		21.75	12.77	1.16	0.48	82	69.5	25.6	57
Račice	high-Al		21.50	12.21	0.86	0.10	70	70.8	28.2	48

[1] fels = an+ab+or+ne
[2] fem = di+hy+ol+il+mt
[3] according to Klápová (1977)

Bridgwater 1979), due to their similar behaviour during differentiation processes of basic magmas.

The high-Al amphibolite differs from the low-Al amphibolites not only with the Al_2O_3 content, but also with the strikingly low TiO_2 and P_2O_5 contents (Table 1). High Al_2O_3 and CaO contents of the rock result in high share of basic plagioclase so that the rock is chemically gabbroid.

Kozlov. The high-Al amphibolite of the locality is rich in basic plagioclase, which makes the chemistry of the rock leucogabbroid. Compared with the global average of gabbros (LeMaitre 1976) the rock exhibits a relatively high P_2O_5 content. The K_2O content is also enhanced, evidently due to the presence of minor biotite in the rock. Similar elevated K_2O contents of amphibolites are usually ascribed to an input during regional metamorphism (Büsch et al. 1979).

Račice. The high-Al amphibolite is chemically similar, except for Al_2O_3, to the current Moldanubian amphibolites of the Bohemian-Moravian Heights. Its high content of basic plagioclase results in its considerable Al_2O_3 content and in its leucogabbroid chemistry.

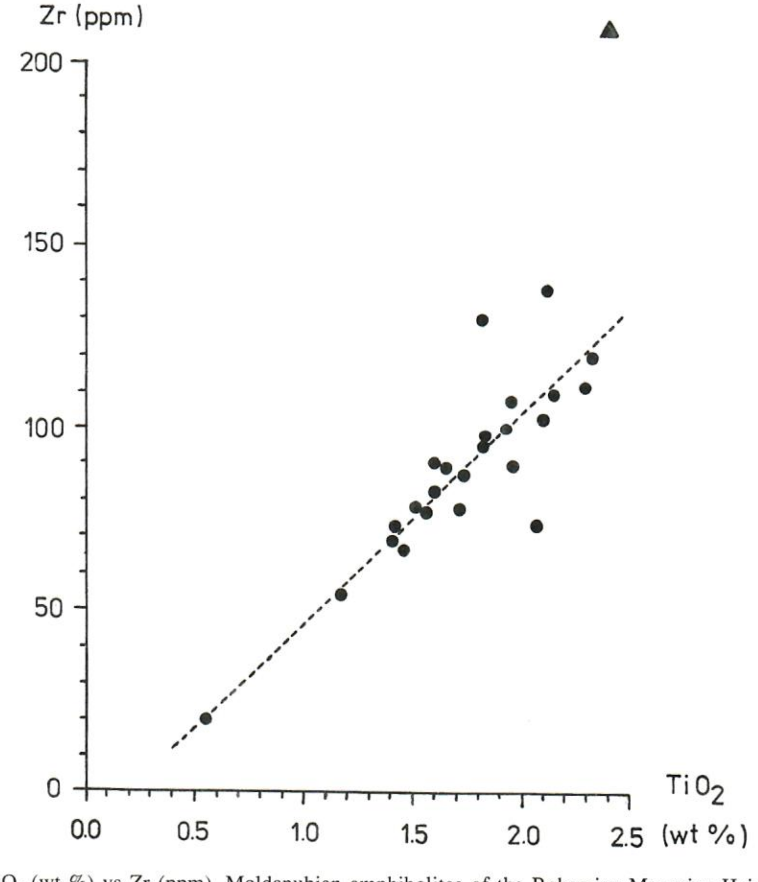


Fig. 3. TiO_2 (wt %) vs Zr (ppm), Moldanubian amphibolites of the Bohemian-Moravian Heights (dots). Triangle – the Kasany low-Al amphibolite.

Obr. 3. Korelační diagram TiO_2 (váh %) – Zr (ppm) v moldanubických amfibolitech Českomoravské vrchoviny (body). Trojúhelník – nízce hlinitý amfibolit od Kasan.

General chemical characteristics of the high-Al amphibolites. The SiO_2 contents of all the samples investigated range between 44–49 wt %. They are just Si-saturated (Kasany) or Si-deficient, being ol- and ne-normative (all the other localities). Their oxidation ratio of iron is relatively considerable. The rocks have similar Al_2O_3 and CaO contents, but diverse TiO_2 and P_2O_5 contents, mg numbers and normative An numbers. This probably has genetic reasons. Their high Al_2O_3 contents are either due to the extreme basicity of the constituting plagioclase of the rock which otherwise has usual mode (Rožná), or due to increased content of basic plagioclase (all the other samples). In the first case, the chemistry of the rock remains gabbroid, whereas in the second it becomes leucogabbroid. This is also demonstrated by Fig. 4.

Genesis

Among the high-Al amphibolites examined, two types can be distinguished according to their petrography and chemistry. The first type is represented only by the Rožná sample. Its grainsize, basicity of plagioclase and high share of normative femic constituents (Table 2) point to an original gabbro. Except for alkalies it corresponds chemically to some gabbros of the Ransko massif (Mísař 1974). Also some gabbros from the Nowa Ruda massif in Polish Sudets (Pin et al. 1988) and from the Mid-Atlantic Ridge (Thompson 1973) are very similar to it.

The three remaining samples analysed are less femic and correspond by their bulk rock chemistry to leucogabbros which appear subordinately in ophiolite complexes of Cuba (Kudělásek et al. 1984), Saxony (Rössler et al. 1986), the Alps (Koller 1985) and the Urals (Dobretsov and Aschepkov 1991). The plagioclase-rich varieties are common in the gabbro family (there, continuous transitions exist from gabbros to anorthosites), as their development requires differentiation which is favoured by plutonic crystallization. In ophiolite associations they mostly are of cumulative character. Nevertheless, plagioclase-rich types are locally also reported from the rocks of the basaltic family (Flower 1980, Höck and Koller 1989).

An important support for the appurtenance of the rocks to the original gabbros is provided by their geochemical signature, which departs markedly from that of the MORB-derived metavolcanics of the region (Fig. 5). Only the contents of the large-ion lithophile elements are similar, but it is due to an additional enrichment during regional metamorphism, accompanied with strong migmatisation of pelitic rocks which affected all metabasics of the region (Němec in print b).

On the other hand, the spidergram of the Kasany high-Al amphibolite corresponds to that of the low-Al West Moravian metagabbros (Fig. 5, Němec 1996) as well as to that of the Saxonian metagabbros, including those labelled as high-Al metagabbros (they contain 22.1 wt % Al_2O_3 on the average) by Rössler et al. (1986) (Fig. 6). Particularly a strong Zr and Ti depletion associated with high MgO and low FeO_{tot} contents are typical features of ophiolite gabbros in many regions of the world.

In the Kasany and Kozlov samples whose plagioclase displays large grainsizes, plagioclase perhaps could be a relict mineral. This possibility is corroborated by finds of relict gabbros in some West Moravian amphibolite complexes (Němec 1994, in print b). In the Rožná sample, whose plagioclase has fine grain, this possibility must be excluded.

In the Rožná locality the high-Al amphibolite is probably part of a metamorphosed ophiolite complex (Fig. 2). Its chemistry is so similar to the other metagabbros of the locality that they all could have been differentiation products of a common parental magma.

Table 2. Chemical analyses of high-Al amphibolites, western Moravia (wt %). Analysts: I. Zavadilová (No. 1), H. Červená (all other analyses).

	Rožná, No 1	Kasany, No 2	Kozlov	Račice
SiO_2	43.76	48.93	44.24	47.17
TiO_2	0.34	0.38	1.16	0.86
Al_2O_3	21.07	21.59	21.75	21.50
Fe_2O_3	1.50	1.54	2.34	3.26
FeO	4.26	4.01	4.91	5.47
MnO	0.05	0.09	0.06	0.14
MgO	9.87	5.86	5.21	4.45
CaO	14.98	13.02	12.77	12.21
Na_2O	1.52	1.36	1.51	2.85
K_2O	0.54	0.97	1.76	1.27
P_2O_5	0.13	0.06	0.48	0.10
H_2O^+	1.69	1.63	2.71	1.47
H_2O^-	0.16	0.24	0.33	0.14
Total	99.87	99.68	99.23	100.89
FeO_{tot}	5.61	5.40	7.02	8.40
mg	0.75	0.66	0.57	0.49
CIPW norm				
or	3.3	5.8	10.6	7.5
ab	1.6	11.5	10.5	17.8
an	48.9	49.9	47.3	42.1
ne	6.2	–	1.1	3.4
di	19.2	11.2	9.9	13.6
hy	–	15.1	–	–
ol	15.8	–	9.9	8.1
ap	0.3	0.2	1.1	0.3
il	0.6	0.8	2.3	1.7
mt	2.1	2.2	3.5	4.8
Q	–	1.2	–	–
ab+an	50.5	61.4	57.8	59.9
An (norm.)	97	81	82	70

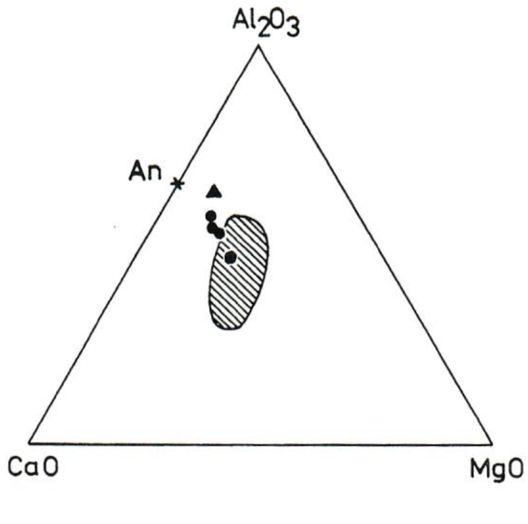


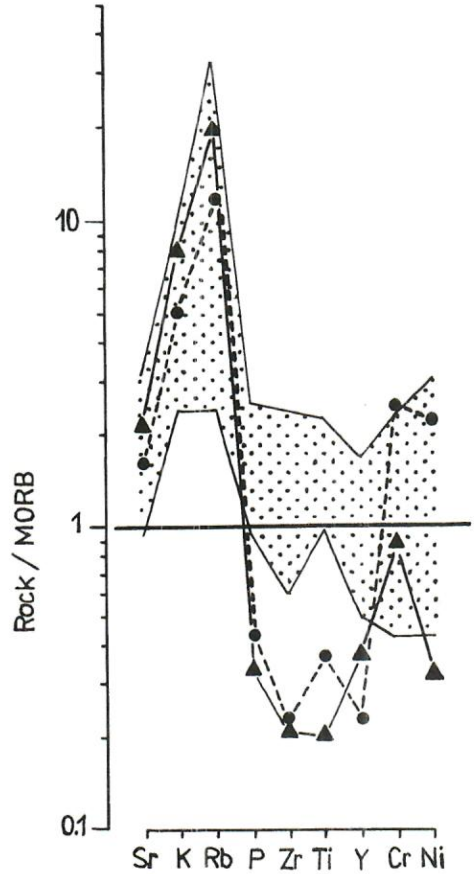
Fig. 4. High-Al amphibolites of Western Moravia (points) in terms of CaO, MgO and Al_2O_3 (wt %). Ruled area – field of Cuban ophiolite gabbros (according to Kudělásek et al. 1984, the dot within it – the Rožná high-Al amphibolite). Triangle – Cuban leucogabbro containing 75 % plagioclase. An – anorthite.

Obr. 4. Vysoce hlinité amfibolity západní Moravy v diagramu CaO-MgO-Al_2O_3 (váh %). Čárkovaně je vyznačeno pole kubánských gaber ofiolitové formace (podle Kuděláska et al. 1984, bod uprostřed něho značí vysoce hlinitý amfibolit od Rožné). Trojúhelník – kubánské leukogabro s 75 % plagioklasu. An – anortit.

In the Rožná and Kasany localities that were examined in greater details, it seems that the occurrences of the high-Al amphibolites within the amphibolite complexes are only very limited.

Conclusions

High-Al amphibolites were identified within four amphibolite complexes (at Rožná, Kozlov and Račice in the Strážek subdivision of the Moldanubian Complex and at



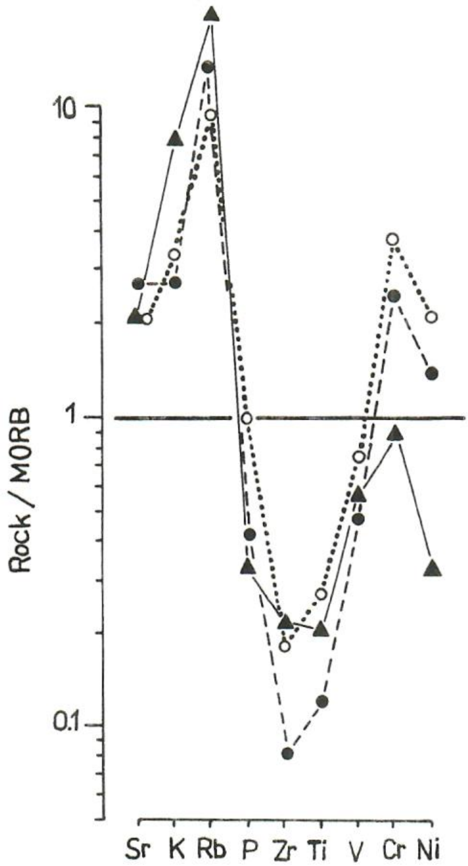


Fig. 5. MORB-normalized multi-element diagrams of MORB-derived Moldanubian amphibolites of the Bohemian-Moravian Heights (dotted field, 26 samples), of the Mg metagabbro from Naloučany, Western Moravia (dots) and of the metaleucogabbro from Kasany (triangles). The normalizing values from Pearce (1982).

Obr. 5. Mnohoprvkové diagramy normalizované na MORB moldanubických amfibolitů Českomoravské vrchoviny vzniklé z MORB (tečkované pole, 26 vzorků), metagabra Mg od Naloučan, západní Morava (body) a metaleukogabra od Kasan (trojúhelníky). Normalizační hodnoty od Pearce (1982).

Fig. 6. MORB-normalized multi-element diagrams of the metaleucogabbro of Kasany (triangles), of average pre-Variscan metagabbro (circles) and average high-Al metagabbro from the ophiolite series of middle Saxony (dots, according to Rössler et al. 1986).

Obr. 6. Mnohoprvkové diagamy normalizované na MORB leukogabra od Kasan (trojúhelníky), průměrného metagabra (kroužky) a průměrného vysoce hlinitého metagabra (body) ofiolitových serií středního Saska (podle Rösslera et al. 1986).

Kasany in the Svratka Complex). Their Al_2O_3 contents range between 21 and 22 wt %. Their occurrences seem to be only exceptional and spatially very limited. Their enhanced Al_2O_3 contents are either due to their raised content of basic plagioclase, whose share in the rocks exceeds 50 vol. %, or due to extreme basicity of the constituting plagioclase (anorthite) of the rock with otherwise usual modal composition. The rocks were originally leucogabbros and high-Ca gabbros, as is also endorsed by their geochemical signature. The leucogabbros represent a further type of gabbroic protolith identified in the amphibolites of the Bohemian-Moravian Heights, in addition to the already previously described Fe- and Mg-metagabbros.

SOUHRN

Vysoce hlinité amfibolity byly identifikovány uvnitř čtyř amfibolitových komplexů (u Rožné, Kozlova a Račic ve strážeckém moldanubiku a u Kasan ve svrateckém krystaliniku). Jejich obsah Al_2O_3 je v rozsahu 21–22 váh. %. Jejich výskyty jsou patrně jen výjimečné a prostorově velmi omezené. Jejich vysoké obsahy Al_2O_3 byly způsobeny buď zvýšeným obsahem bazického plagioklasu, jehož podíl v hornině přesahuje 50 %, nebo extrémní bazicitou plagioklasu (anortit) při jinak běžném modálním složení amfibolitu. Pravděpodobně šlo původně o leukogabra a vysoko vápenatá gabra. Nasvědčuje tomu i geochemická signatura těchto hornin. Leukogabra představují další typ gabroidních protolitů zjištěných v amfibolitech Českomoravské vrchoviny, v nichž byla identifikována ještě metagabra Fe a Mg.

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