GEOCHEMISTRY OF METABASITES AND GABBROIC ROCKS FROM THE TEPLÁ-DOMAŽLICE ZONE

U. Schüssler[1], Z. Vejnar[2], M. Okrusch[1], S. Rose[3] and E. Seidel[4]

[1] *Mineralogisches Institut, Universität Würzburg, Am Hubland, D-8700 Würzburg, F. R. G.*
[2] *Geological Survey, Prague, Czechoslovakia*
[3] *Institut für Angewandte Mineralogie, Universität Regensburg, Kumpfmühlerstrasse 2, D-8400 Regensburg, F. R. G.*
[4] *Mineralogisch-Petrographisches Institut, Universität Köln, Zülpicher Strasse 49, D-5000 Köln, F. R. G.*

Abstract

Various amphibolites, metagabbros and eclogitic relics of the Mariánské Lázně complex, and amphibolites from the Černá Hora Massif exhibit an uniform geochemical character which compares well with modern mid-ocean ridge basalts. Geochemically these metabasites are similar to the amphibolites of the Mýto area and to schistose, partly striped amphibolites of the neighbouring Tirschenreuth—Mähring Zone and the Erbendorf—Vohenstrauss Zone (Bavaria).

Greenschists and amphibolites from the Domažlice metamorphic complex show an alkaline-basaltic tendency conforming to modern within-plate basalts or basalts from anomalous mid-ocean ridge segments. In their chemical character, these metabasites compare well with the flaseramphibolites of the Erbendorf—Vohenstrauss Zone. Fine-grained amphibolites in the Warzenrieth area and (gabbro-) amphibolites in the Blätterberg—Hoher Bogen area show normal MORB character. The metamorphosed gabbroic rocks in the southern part of the Neukirchen—Kdyně (meta-) igneous complex are subalkaline — tholeiitic and exhibit a magmatic differentiation trend. They differ from the neighbouring amphibolites by generally lower contents of incompatible elements.

Introduction

The pre-site studies of the German Continental Deep Drilling Project KTB led to a new paleotectonic concept for the western part of the Bohemian Massif, strongly influenced by plate tectonic models. The essential point of the new concept is a collision and thrusting of the Moldanubian onto parts of the Saxothuringian. Subsequent to the collision both units were partly overthrusted by a nappe complex, relics of which are the Münchberg nappe pile, the Erbendorf—Vohenstrauss Zone with the Erbendorf Greenschist Zone at its base and, possibly, the Teplá—Domažlice Zone (Weber and Vollbrecht 1986). Moldanubian and Saxothuringian were welded by a last low-pressure metamorphism 330 to 320 Ma ago. In contrast, the last metamorphic event in the crystalline nappes of the Münchberg pile and the western part of the Erbendorf—Vohenstrauss Zone is of medium-pressure type and took place in the Early Devonian around 380 Ma ago (e.g. Blümel 1983, Schüssler et al. 1986, Teufel 1988, Kreuzer et al. 1989). The Erbendorf—Vohenstrauss Zone and the Erbendorf Greenschist Zone partly suffered a thermal influence by the late Hercynian granite intrusions 324 and 310 Ma ago (e.g. Köhler and Müller-Sohnius 1976, Wendt et al. 1986). The most conspicuous metamorphic event in the Teplá—Domažlice Zone was also of medium-pressure type (Vejnar 1972, 1977, Blümel 1983) and, judging from extensive K-Ar dating, took place in Devonian times. However, a later thermal influence around 320 Ma is obvious (Kreuzer et al. this volume).

In all three units metabasites form important constituents which provoke a geochemical comparison. Our joint Czechoslovakian-German working group started new geochemical investigations on metabasites and gabbroic rocks of the Teplá—Domažlice Zone in order to enable a comparison with recent geochemical data on the metabasites from the other two allochthonous units (Schüssler 1987, Schüssler et al. 1989, Okrusch et al. in press). Furthermore, the geochemical characteristics of the various amphibolite complexes in the Teplá—Domažlice Zone and the relationship between the amphibolites and the gabbroic rocks in the Neukirchen—Kdyně (meta-) igneous complex will be evaluated.

Geology and sample characteristics

Metabasites of the Mariánské Lázně complex

Within the Bohemian Massif the Mariánské Lázně complex represents one of the largest metabasite accumulations (Kastl and Tonika 1984). It is bordered by kyanite/sillimanite bearing paragneisses of the Teplá anticlinorium in the southeast and by Variscan granite intrusions in the northwest. The dominating metabasites are intercalated by serpentinites, paragneisses, marbles, calcsilicate rocks and orthogneisses.

According to Kastl and Tonika (1984), the various types of metabasites exhibit a zonal distribution: The outer flanks of the complex are formed by garnet-free amphibolites and by sphene-bearing garnet amphibolites, whereas rutile-bearing garnet amphibolites, eclogite amphibolites and eclogites are concentrated in the center. Kastl and Tonika (1984) interpreted this arrangement by an increase of P-T conditions from the margins to the core of the complex during the (single-stage?) metamorphism. However, judging from the situation in the Münchberg complex and from other eclogite occurences in different parts of the Variscides a two-stage metamorphism should be considered: Mineral assemblages of the earlier high-pressure event were overprinted by a medium-pressure, amphibolite-facies metamorphism. This view is corroborated by textural evidence observed in thin sections of our samples (see below). The Mariánské Lázně complex furthermore contains lenses of gabbros and gabbronorites which, according to Kastl and Tonika (1984), were "apparently formed at the end of the metamorphic cycle".

Samples of the following metabasite types were investigated:

Schistose amphibolites (samples 69, 70) are medium to fine grained. They contain greyish-green hornblendes of an older generation which are surrounded by younger aggregates of smaller, lath-shaped hornblendes of the same colour. Plagioclase is partly altered to sericite or saussurite. Opaques are overgrown by sphene. Samples 66 and 67 are transitional to garnet-bearing hornblende-gneisses with high amounts of quartz and plagioclase. Some of the schistose amphibolites (sample 58) may contain intercalations rich in biotite which is partly replaced by chlorite.

Garnet- and rutile-bearing flaseramphibolites (samples 59, 60, 61, 65, 68) strongly resemble the flaseramphibolites of the Erbendorf—Vohenstrauss Zone in their textural appearance and mineralogy (but not in their trace element chemistry, see below!). The medium grained rocks consist of xenoblastic plagioclase and greyish-green, hypidioblastic hornblende. Garnet is widely replaced by finegrained aggregates of hornblende, plagioclase and epidote. Rutile is the predominant titanium mineral; other accessories are sphene, apatite and opaques. Later alteration processes led to the formation of sericite and saussurite in plagioclase as well as to partial replacement of hornblende by chlorite and epidote and of ilmenite by leucoxene.

The eclogitic rocks in investigated (samples 62, 63, 64) exhibit relics of the high-pressure assemblage garnet—omphacite—rutile, but display textural evidence for strong post-eclogitic overprint. Part of the garnet and most of the omphacite are replaced by extremely fine-grained, symplectitic aggregates (plagioclase + ?pyroxene/hornblende). Their formation may be correlated to a decompression after the eclogite-facies metamorphism. A renewed metamorphic overprint under medium-pressure, amphibolite-facies conditions is documented by the formation of coarser olive-green to brown hornblende and plagioclase which may be intimately intergrown. Sample 62 was furtheron affected by a latestage retrogressive alteration with formation of epidote, chlorite and sericite.

Metagabbros (sample 57) are characterized by relics of clinopyroxene which are overgrown by porphyroblasts of yellow hornblende, intensively dusted by opaques. In their vicinity flakes of reddish-brown biotite and larger opaque graines occur Retrograde influences led to the formation of pale-green to colourless ?actinolitic amphibole and to sericitization of the coarse-grained plagioclase.

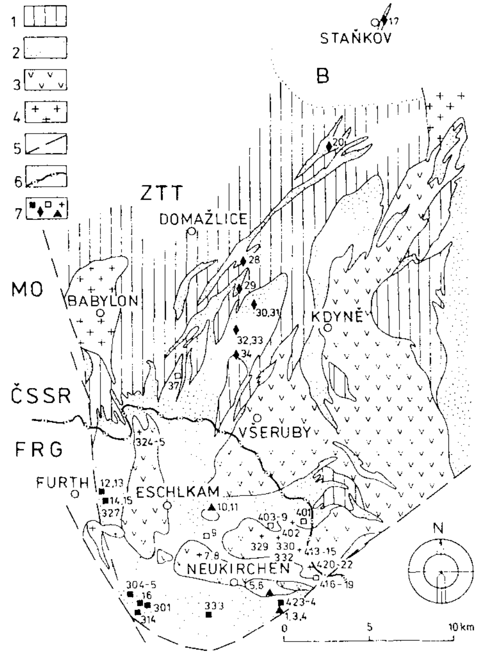
Amphibolites in Moldanubian gneisses near Mýto west of Tachov

In the Mýto area several small bodies of amphibolite are intercalated within the Moldanubian sillimanite gneisses west of the Bohemian Quartz Lode. They may represent a continuation of the amphibolites in the Tirschenreuth—Mähring Zone (Bavaria) which forms a transition between the Moldanubian and the Saxothuringian realms. In order to corroborate this assumption by geochemical constraints, samples 41 and 43 were analyzed from the occurrence near Mýto. The medium- to fine-grained amphibolites consist of pale olive-green to greyish-green (Y, Z) hornblende (partly altered to chlorite), of plagioclase, subordinate biotite and accessory sphene, apatite and opaques. A characteristic of the Mýto amphibolites is the high amount of calcsilicate intercalations. They consist of clinopyroxene and sericitized plagioclase; some layers contain additional garnet and carbonate. This feature is at variance to the amphibolites of the Teplá—Domažlice Zone, but also the Tirschenreuth—Mähring Zone. In gneisses associated with the amphibolites in the Mýto outcrop, the assemblage biotite—microcline—sillimanite—corundum—plagioclase is recognized. This assemblage conforms to the temperatures of about 750° C (at pressures of 3 to 4.5 kbar) estimated by Wagener—Lohse and Blümel (1986) for the highest grade of low-pressure type metamorphism in the Tirschenreuth—Mähring Zone.

Amphibolites of the Černá Hora massif near Hostouň

The amphibolite bodies are intercalated with micaschists and paragneisses of the Teplá—Domažlice Zone. The complex is intruded by later Hercynian granites and, at its western border, delineated by the Bohemian Quartz Lode. Judging from the isograd pattern mapped by Vejnar (1972) the grade of medium-pressure metamorphism increases from east to west. The Černá Hora metabasites are associated with metapelites of the staurolite and the kyanite zone.

The investigated amphibolite samples (38, 46 to 55) are very fine- to (rarely) medium-grained. Some of them exhibit a well developed schistosity. A fine banding, caused by a variation in

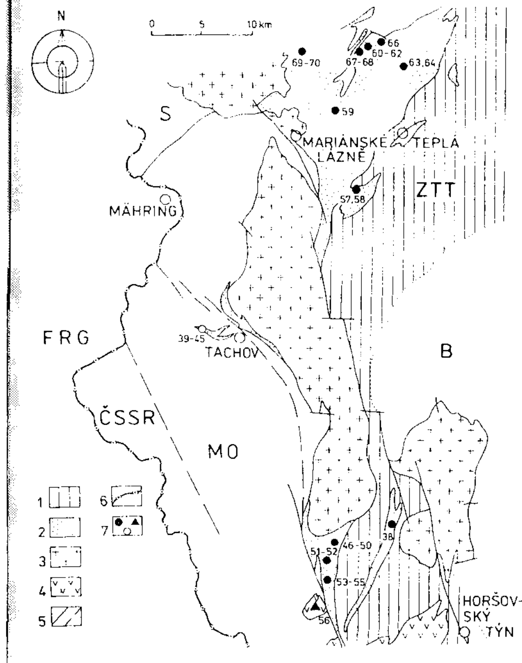


1. Geological situation in the southern part of the Teplá—Domažlice zone, based on the geological maps of Bavaria 1 : 500 000 (Bayerisches Geologisches Landesamt, München), ČSFR 1 : 25 000 (Geological survey Prague) and on the compilation of Troll and Weiss (1988), with sample localities. 1 — metapelitic rocks of the Teplá—Domažlice zone; 2 — metabasic rocks; 3 — gabbroic and dioritic rocks of the Neukirchen—Kdyně (meta-) igneous complex; 4 — granites; 5 — faults; 6 — FRG/ČSFR frontier; 7 — sample sites: filled squares — (gabbro-) amphibolites of the Blätterberg—Hoher Bogen area. Open squares — amphibolites of the Warzenrieth area. Rhombs — greenschists and amphibolites from the southeastern part of the Domažlice metamorphic complex. Crosses — gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex. Triangles — metapelitic rocks discussed by Kreuzer et al., this volume. MO — Moldanubien. ZTT — Teplá—Domažlice zone. B — Barrandian.

the hornblende/plagioclase ratio or by intercalation of clinopyroxene-rich layers is observed in some of the samples. Usually the hornblendes are pale-green to pale-bluishgreen (Z). Poikiloblastic garnet may be present as additional phase. Retrograde alteration is indicated by saussuritization of plagioclase and by infiltration of monomineralic carbonate veins.

Metabasites of the Domažlice metamorphic complex and gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex

The southern part of the Teplá—Domažlice Zone is formed by a metamorphic complex consisting of SW—NE trending metabasite bodies intercalated with metapelites. The grade of regional metamorphism increases from NE to SW, as indicated by a succession of isograds in the metapelites: biotite, garnet, staurolite and kyanite (Vejnar 1972). The transition from greenschist to amphibolite facies occurs between the biotite and the garnet isograd.



2. Geological situation in the northern- and central parts of the Teplá—Domažlice zone based on the geological maps of ČSFR 1 : 200 000 and 1 : 25 000 (Geological Survey Prague), with sample localities. Symbols as in fig. 1. Sample sites: Filled circles — metabasites of the Mariánské Lázně complex and Černá Hora massif. Open circles — amphibolites of the Mýto area. Triangle — diorite of the Mutěnín stock.

The Domažlice metamorphic complex contains several large intrusions of varying composition, the Neukirchen—Kdyně (meta-) igneous complex. It is interpreted by Vejnar (1986) as a Skaergaard-type layered intrusion of Late Cadomian (Cambrian) age which can be subdivided into three stratiform units. The lower, gabbroic zone forms a sequence of olivine gabbros, olivine gabbronorites, anorthosites and olivine ferrodiorites. In the middle zone two-pyroxene diorites predominate, whereas the upper zone consists of quartz diorites. A younger intrusive phase is represented by tonalites, trondhjemites and granodiorites. Around the igneous intrusions the crystalline schists of the Domažlice metamorphic complex suffered a strong thermal overprint, leading to a contact aureole up to 4 km wide. Moreover, contact-metamorphosed xenolites of the country rocks are frequently observed in the intrusives.

In the northern part of the Neukirchen—Kdyně (meta-) igneous complex, Vejnar (1986) describes local metamorphic recrystallization, mostly accompanied by the formation of secondary amphiboles. This metamorphic overprint was much more intensive in the southern part of the complex where all transitions between gabbroic relics and fine-grained amphibolites can be observed (Fischer 1930 and own observations, see below). The increase of metamorphic recrystallization in the gabbroic rocks from NE to SW fits well into the isograd pattern mapped by Vejnar (1972) in the Domažlice metamorphic complex, attributed to the medium-pressure event about 380 Ma ago (Kreuzer et al. 1989 and this volume). This could lead to the assumption that the metamorphic overprint of the gabbroic rocks took place during this event. However, the thermal influence of the igneous intrusions on the Domažlice metamorphics as observed by Vejnar (1986) contradicts this interpretation. Further detailed investigations are necessary to solve this enigma.

Samples of the following rock types were investigated:

The greenschists of the Domažlice metamorphic complex (sample 17, 28) are very fine-grained, often schistose and sometimes folded. They consists of pale-green chlorite (clinochlore), bluish-green (Z) amphibole, epidote, albite and subordinary quartz. Leucoxene and opaques may be present in considerable amounts. Carbonate is either dispersed in the rock or concentrated in layers or veins.

The amphibolites of the Domažlice metamorphic complex (20, 29 to 34) are medium- to fine-grained. They consist predominantly of hornblende and plagioclase and contain frequently biotite (partly chloritized), sometimes also thin layers rich in epidote. Accessory minerals are opaques and sphene. The complex history of the rocks is documented in a multiple zonation of the amphiboles (for details see Vejnar 1977). In some of the investigated samples, a retrograde overprint is shown by a decomposition of hornblende into chlorite and epidote and by a sericitization of plagioclase.

Gabbroic relics in the southern part of the Neukirchen—Kdyně (meta-) igneous complex (samples 8, 9; 324, 325, 329, 330, 332, 413—415, 420—422) are characterized by a medium- to coarse-grained, granular texture formed by disorientated tabular plagioclases and xenomorphic pyroxenes. In some of the samples large flakes of primary biotite can be observed. Accessories are large grains of opaques and long prisms of apatite. In all gabbroic rocks investigated a metamorphic overprint is clearly documented, leading to different degrees of amphibolitization. The pyroxenes are partly or totally replaced by different types of amphibole which occur either as large xenoblasts dusted by opaques or as fine-grained, granoblastic to fibroblastic aggregates. Judging from their different colours the amphiboles must be highly variable in composition. In one of the samples porphyroblasts of yellow hornblende are partly replaced by tartan-like aggregates of biotite. During the metamorphic overprint, the igneous plagioclases were gradually recrystallized to finer-grained, granoblastic aggregates.

Amphibolites of the Warzenrieth area are medium- to fine-grained and exhibit a more or less developed schistosity. Main constituents are yellow, rarely olive-green (Z) hornblende, plagioclase, and sometimes clinopyroxene; sphene, opaques, zircon and apatite are present in subordinate amounts. Epidote occurs as an alteration product. Judging from textural evidence at least some of the fine-grained amphibolites can be derived from gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex. However, some of the amphibolites bodies in the Eschlkam—Warzenrieth area may form extensions of the Domažlice metamorphic complex.

The (gabbroic-) amphibolites of the Blätterberg—Hoher Bogen area form a distinct petrographic group which is characterized by a flaser texture with poorly developed schistosity. The hornblende/plagioclase ratio is extremely variable ranging from hornblendites to leuco-amphibolites. The grayish- to bluishgeen, rarely yellow hornblendes are intensively dusted by opaques. They form large xenoblasts which underwent post-crystalline deformation. Plagioclase mostly forms fine-grained, granoblastic aggregates together with minor quartz and hornblende (mortar structure). Relics of igneous pyroxenes are missing. Accessories are sphene, apatite and opaques. The rocks are penetrated by alteration zones consisting of strongly sericitized plagioclase and pale-green hornblende.

Table 1 Metabasites of the Mariánské Lázně complex

Probe	57	59	60	61	62	63	64	65	66	67	68	69	70
SiO_2	48.2	48.4	48.5	47.2	49.6	49.8	50.9	53.2	59.1	64.3	47.4	48.3	47.8
TiO_2	0.91	1.91	0.82	0.98	1.06	1.84	1.54	1.87	0.72	0.64	1.50	1.30	1.33
Al_2O_3	18.7	15.3	16.6	17.6	16.1	13.5	14.0	15.8	14.7	15.0	13.8	14.7	15.1
Fe_2O_3	0.99	1.27	1.94	2.27	2.53	2.49	1.84	1.87	2.27	1.32	3.67	1.57	0.95
FeO	6.91	9.38	5.76	6.24	7.16	10.7	9.72	7.44	5.09	5.07	10.2	8.60	9.17
MnO	0.13	0.17	0.12	0.13	0.17	0.24	0.19	0.16	0.16	0.14	0.25	0.18	0.17
MgO	9.57	7.45	8.93	8.66	7.31	7.37	7.36	4.59	5.00	2.26	6.88	7.26	6.98
CaO	10.1	9.67	12.1	11.7	9.78	10.2	9.07	5.73	6.03	5.72	11.2	12.3	12.7
Na_2O	2.71	2.86	2.75	2.97	3.55	2.96	3.39	4.13	2.84	2.97	1.74	2.86	2.92
K_2O	0.30	0.70	0.18	0.23	0.41	0.02	0.02	1.11	0.98	0.62	0.52	0.25	0.28
P_2O_5	0.12	0.20	0.08	0.09	0.11	0.13	0.08	0.18	0.09	0.19	0.15	0.26	0.24
CO_2	0.21	0.05	0.05	0.05	0.37	0.06	0.06	0.68	0.33	0.05	0.10	0.15	0.15
S	0.16	0.05	0.02	0.02	0.02	0.04	0.09	0.12	0.08	0.13	0.02	0.02	0.03
H_2O	0.7	2.1	1.60	1.6	1.8	0.3	2.6	2.6	2.1	1.0	2	1.7	1.6
Summe	99,71	99.46	99.38	99.72	99.95	99.63	100.84	99.48	99.49	99.31	99.41	99.45	99.47
V	125	264	171	194	226	394	359	237	129	111	392	299	293
Cr	280	326	671	273	288	108	178	78	201	<20	134	241	259
Ni	183	37	116	145	151	39	61	<20	77	<20	55	106	108
Rb	7	18	3	<2	11	<2	<2	30	31	15	11	9	7
Sr	321	203	256	253	211	71	63	159	176	506	142	294	267
Y	18	32	22	25	25	52	41	31	29	24	32	41	37
Zr	88	111	39	49	62	100	97	135	72	66	73	89	76
Nb	9	13	5	<3	5	5	6	14	7	8	8	6	8
Ba	137	315	79	61	135	96	47	332	448	369	168	75	73
Ce	<10	18	<10	<10	<10	<10	25	<10	25	<10	<10	34	20

Table 2 Amphibolites of the Černá Hora massif and the Mýto area (M)

Probe	38	46	47	48	49	50	51	52	54	55	41 (M)	43 (M)
SiO_2	49.1	48.7	47.8	46.8	49.5	49.9	47.3	47.1	42.8	47.1	48.1	46.7
TiO_2	2.24	1.46	1.62	1.14	1.58	1.78	1.46	1.41	1.29	1.28	1.67	1.19
Al_2O_3	12.9	14.5	15.1	14.0	14.1	14.8	16.4	16.0	13.2	13.9	16.1	16.4
Fe_2O_3	0.98	1.45	1.21	1.52	2.04	2.25	1.28	1.41	1.6	1.30	2.09	1.21
FeO	12.2	8.86	9.73	8.45	8.97	8.36	8.04	8.30	8.73	9.14	8.68	8.98
MnO	0.24	0.17	0.19	0.17	0.18	0.17	0.17	0.18	0.18	0.18	0.16	0.17
MgO	6.75	8.15	8.39	11.9	8.91	6.69	5.37	5.76	5.45	9.48	6.65	6.71
CaO	11.1	11.5	12.3	11.9	11.7	10.6	14.0	14.2	17.9	12.8	9.50	12.1
Na_2O	1.94	2.65	2.25	1.16	1.61	3.01	2.59	2.29	2.58	1.58	3.89	3.13
K_2O	0.09	0.29	0.14	0.28	0.18	0.23	0.07	0.11	0.09	0.09	0.40	0.38
P_2O_5	0.21	0.15	0.20	0.12	0.19	0.25	0.16	0.17	0.41	0.14	0.18	0.09
CO_2	0.11	0.06	0.08	0.14	0.05	0.05	0.71	0.54	4.29	0.20	0.38	0.80
S	0.18	0.04	0.02	0.02	0.02	0.02	0.34	0.40	0.32	0.17	0.16	0.11
H_2O	1.5	1.6	1.6	2.3	1.7	1.3	1.6	1.4	1.1	2.1	1.3	1.8
Summe	99.52	99.58	100.61	99.88	100.73	99.34	99.49	99.27	99.94	99.46	99.26	99.77
V	450	290	298	239	298	296	278	275	235	265	294	227
Cr	114	508	463	708	525	349	382	353	253	301	319	370
Ni	32	188	147	333	206	121	102	114	93	171	12	141
Rb	<2	5	<2	10	<2	3	<2	<2	<2	3	10	15
Sr	123	139	130	66	89	202	185	157	105	186	152	278
Y	46	38	39	31	41	37	27	35	37	26	27	18
Zr	137	91	107	73	109	125	103	103	94	84	120	92
Nb	6	9	9	8	10	11	7	10	9	6	9	7
Ba	318	122	125	60	154	152	138	154	43	69	94	42
Ce	<10	<10	<10	<10	14	<10	<10	<10	<10	<10	15	<10

Geochemistry

Analytical methods

The major elements Si, Ti, Al, Fe^{tot}, Mn, Ca, K, P and the trace elements V, Cr, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba, Ce were analyzed by standard XRF analysis using lithium tetraborate fusion disks and powder pellets respectively. Mg and Na were determined by standard AAS methods after decomposing the sample in HF—$HClO_4$. Fe(II) was determined by the vanadate method (Peters 1968), S by IR spectroscopy, CO_2 volumetrically, and H_2O by the Penfield method. Calibration was performed against international reference samples.

Metabasites of the Mariánské Lázně and the Černá Hora complexes (Table 1, 2)

Nearly all analyzed metabasites of the two complexes reveal a chemical composition which compares well with subalkaline ocean-floor tholeiites. The subalkaline charakter is well established by the variation diagrams $Na_2O + K_2O$ vs. SiO_2 (Fig. 3) and Zr/TiO_2 vs. Nb/Y (Fig. 4). The TiO_2 vs. FeO^{tot}/MgO diagram (Fig. 5) and the Jensen cation plot (Fig. 6) corroborate a tholeiitic and exclude a calcalkaline composition for the metabasites. The only notable exception, sample 67, is a leucocratic hornblende gneiss of questionable origin. In the diagram Ti vs. Zr (Fig. 7) nearly all analyzed samples plot within the field of mid-ocean ridge basalts. The flat trace-element patterns (Fig. 8) are also consistent with a MORB-composition.

Table 3 Greenschists and amphibolites from the southeastern part of the Domažlice metamorphic complex

Probe	17	20	28	29	30	31	32	33	34
SiO_2	44.9	46,2	48.3	46.6	48.5	48.3	46.2	48.4	46.9
TiO_2	2.47	1.71	3.53	2.41	3.30	2.85	1.79	2.15	2.49
Al_2O_3	15.7	17.0	14.3	14.3	14.1	14.1	16.8	16.5	15.6
Fe_2O_3	2.88	2.17	2.26	0.87	2.08	2.19	1.88	1.67	2.31
FeO	8.47	6.77	9.99	11.4	10.7	10.5	8.12	7.12	10.6
MnO	0.13	0.13	0.18	0.16	0.24	0.20	0.14	0.13	0.31
MgO	6.63	7.08	4.97	8.22	4.22	4.06	9.09	5.89	5.09
CaO	8.25	8.58	8.83	8.17	7.53	7.80	9.26	10.7	10.2
Na_2O	3.73	4.21	3.55	2.61	4.10	3.38	3.02	3.87	3.25
K_2O	0.58	0.47	0.66	1.02	1.55	2.07	0.79	0.70	0.92
P_2O_5	0.41	0.27	0.40	0.42	1.49	1.41	0.32	0.34	0.28
CO_2	1.56	1.83	0.31	0.05	0.11	0.59	0.09	0.18	0.11
S	0.06	0.02	0.02	0.05	0.05	0.05	0.07	0.05	0.05
H_2O	4.3	3.7	2.1	3.2	1.7	2.0	2.6	1.6	1.5
Summe	100.07	100.14	99.38	99.43	99.67	99.50	100.17	99.30	99.61
V	284	184	514	265	269	204	200	269	337
Cr	67	212	53	210	<20	<20	166	199	206
Ni	44	162	18	157	<20	<20	165	26	26
Rb	4	10	8	12	17	21	12	10	10
Sr	566	837	356	355	332	706	497	507	136
Y	38	27	40	30	58	67	29	31	37
Zr	223	160	219	216	351	371	188	186	173
Nb	25	18	25	21	33	36	17	18	24
Ba	273	218	304	347	451	501	233	255	431
Ce	49	30	34	48	76	90	38	33	47

Table 4 Gabbroic rocks of the Neukirchen—Kdyně (meta-)igneous complex

Probe	324	325	329	330	332	402	413	414	415	420	421	422
SiO_2	49.8	47.7	49.9	48.6	50.4	45.7	50.5	48.8	49.4	51.3	47.7	45.6
TiO_2	0.34	1.18	1.14	1.03	0.36	7.82	1.92	1,81	1,70	0.93	0.29	1.03
Al_2O_3	18.0	17.3	17.8	15.2	20.9	13.8	15.7	17.4	17.9	16.9	18.2	16.8
FeO tot.	6.69	8.46	11.5	10.8	5.31	13.0	11.9	10.9	10.5	6.70	5.42	12.2
MnO	0.12	0.15	0.20	0.20	0.10	0.18	0.22	0.17	0.18	0.13	0.10	0.10
MgO	10.3	9.86	6.99	9.12	7.15	6.89	6.76	8.12	7.35	7.06	11.3	10.8
CaO	8.59	8.79	8.48	10.1	10.3	9.64	8.79	10.1	9.68	12.8	14.2	10.3
Na_2O	2.45	2.75	3.50	2.71	3.36	2.26	3.30	3.00	3.20	2.63	1.24	1.52
K_2O	0.40	0.26	0.14	0.19	0.21	0.22	0.16	0.14	0.17	0.14	0.11	0.10
P_2O_5	0.06	0.05	0.03	0.03	0.04	0.03	0.22	0.12	0.12	0.10	0.02	0.02
Summe	96.75	96.50	99.68	97.98	98.13	99.54	99.47	100.56	100.20	98.69	98.58	98.37
V	49	120	135	224	74	610	245	216	193	368	155	319
Cr	135	129	70	204	113	89	123	86	100	442	302	752
Ni	180	146	45	23	46	<20	23	27	26	<20	36	177
Cu	21	31	15	16	26	9	18	24	19	20	29	76
Zn	61	71	97	75	42	97	103	80	81	48	42	82
Rb	13	7	<2	5	6	5	3	3	4	4	5	<2
Sr	175	189	258	199	280	183	254	239	253	222	178	108
Y	12	16	10	14	9	18	24	21	20	17	8	13
Zr	46	45	49	42	14	51	68	66	50	35	16	20
Nb	5	4	5	5	4	12	8	5	5	5	<3	4
Ba	97	80	175	140	72	301	177	126	144	118	51	79
Ce	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10

Amphibolites of the Mýto area (Table 2)

The two analyzed amphibolite samples from the Moldanubian of the Mýto area conform to a subalkaline ocean-floor tholeiitic (MORB) composition (Fig. 3—8).

Greenschists and amphibolites in the southeastern part of the Domažlice metamorphic complex (Table 3)

The metabasites of this area exhibit a composition transitional between tholeiites and alkaline basalts. In the relevant discrimination diagrams the data points plot either into the alkaline field (Fig. 3) or scatter around the border line between alkaline and subalkaline compositions (Fig. 4). A calcalkaline character can be excluded (Fig. 5, 6). Conformably these metabasites are similar to modern withinplate basalts in their chemical composition (Fig. 7). The trace-element patterns (Fig. 8) are enriched in incompatible elements, a feature typical of modern within-plate basalts or of basalts from anomalous mid-ocean ridge segments (E-MORB). In contrast, sample 37 from the occurence Zadni Skála near Filipova Hora conforms to a normal MORB character.

Gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex

In their geochemical character the gabbroic rocks are subalkaline (Fig. 3, 4) and conform to a tholeiitic trend (Fig. 5). A certain degree of magmatic differentiation is indicated by the relatively wide range of FeO^{tot}/MgO ratios and a conformable variation in some of the trace elements (Fig. 5, 7). The Mg-rich gabbroic rocks are distinctly depleted in the incompatible trace elements P, Zr, Ti and Y (Fig. 8) and are higher in Cr.

Table 5 Amphibolites of the Warzenrieth area

Probe	7	8	9	37	401	403	404	405	406	407	408	409	416	417	418	419
SiO_2	49.6	49.5	45.6	47.3	51.7	45.6	45.3	45.6	48.8	53.4	45.1	46.6	52.0	51.0	50.8	50.9
TiO_2	0.32	0.31	1.24	1.39	2.16	2.82	3.17	3.31	2.96	2.34	2.81	2.08	1.70	1.79	1.92	1.65
Al_2O_3	17.3	20.4	16.3	17.5	13.2	12.6	13.9	12.4	11.3	12.9	12.2	10.5	14.4	14.3	13.4	13.5
Fe_2O_3	0.46	0.81	0.32	1.17	—	—	—	—	—	—	—	—	—	—	—	—
FeO	4.83	5.10	8.95	6.04	12.1*	15.1*	15.5*	16.1*	13.0*	12.1*	15.4*	13.5*	11.8*	11.9*	13.4*	12.7*
MnO	0.10	0.11	0.19	0.12	0.21	0.21	0.26	0.25	0.22	0.21	0.24	0.18	0.19	0.19	0.21	0.21
MgO	10.1	8.00	9.03	7.57	6.07	9.21	9.35	8.35	8.92	6.34	9.89	6.99	7.07	6.68	7.02	7.93
CaO	12.5	10.2	14.0	12.6	8.97	10.8	8.94	10.3	13.6	9.44	11.5	1.26	9.13	9.91	9.18	9.14
Na_2O	2.34	3.08	1.24	2.45	2.56	1.87	2.36	1.82	1.42	2.45	1.71	0.10	2.77	2.77	2.56	2.18
K_2O	0.06	0.11	0.17	0.12	0.55	0.10	0.10	0.14	0.10	0.24	0.12	0.44	0.31	0.60	0.57	0.29
P_2O_5	0.03	0.03	0.03	0.13	0.19	0.03	0.03	0.03	0.02	0.02	0.02	—	0.21	0.18	0.17	0.14
CO_2	0.07	0.11	0.10	0.70	—	—	—	—	—	—	—	—	—	—	—	—
S	0.12	0.30	0.32	0.06	—	—	—	—	—	—	—	—	—	—	—	—
H_2O	1.8	2.2	1.8	2.2	—	—	—	—	—	—	—		—	—	—	—
Summe	**99.60**	**100.26**	**99.50**	**99.50**	**97.71**	**98.24**	**98.81**	**98.30**	**100.24**	**99.44**	**98.99**	**98.45**	**99.58**	**99.32**	**99.23**	**98.64**
V	147	96	336	284	441	590	620	650	650	520	600	347	346	337	388	329
Cr	963	315	422	491	116	152	164	144	165	112	150	72	142	89	101	144
Ni	140	77	128	113	36	34	42	29	<20	22	33	<20	31	<20	22	33
Cu	—	—	—	—	36	42	12	27	18	20	40	30	25	29	32	33
Zn	—	—	—	—	141	104	105	122	99	92	110	121	135	108	107	84
Rb	<2	<2	5	<2	16	<2	4	3	<2	4	3	4	6	13	14	6
Sr	21	433	132	157	106	89	101	114	97	121	83	99	99	122	84	64
Y	16	11	24	35	50	16	9	19	25	18	16	52	40	39	45	38
Zr	25	31	27	101	144	22	21	22	23	26	26	119	109	120	115	112
Nb	4	4	4	6	5	4	5	6	4	7	5	7	9	12	8	8
Ba	<20	69	179	9100	158	143	165	151	99	169	149	261	162	162	146	100
Ce	<10	<10	<10	<10	13	<10	<10	<10	<10	<10	<10	<10	<10	21	14	<10

Table 6 (Gabbro-)amphibolites of the Blätterberg—Hoher Bogen area

Probe	12	13	14	15	16	301	304	305	314	327	333	423	424
SiO_2	48.9	49.3	48.3	46.8	46.8	45.5	47.6	41.5	47.4	45.8	45.4	41.5	53.1
TiO_2	2.11	1.96	1.97	3.31	1.72	2.14	1.34	3.70	2.00	2.43	1.80	2.96	0.52
Al_2O_3	14.2	13.6	13.2	11.7	13.4	13.6	14.6	11.2	14.2	12.0	14.2	13.7	25.0
Fe_2O_3	1.43	0.70	1.68	2.02	3.78	—	—	—	—	—	—	—	—
FeO	11.2	11.4	11.8	15.1	10.1	13.9*	11.4*	21.3*	12.4*	16.6*	12.2*	17.8*	2.68*
MnO	0.21	0.23	0.23	0.27	0.23	0.22	0.21	0.23	0.21	0.26	0.20	0.27	0.05
MgO	5.87	5.78	7.11	5.25	8.22	8.61	8.46	7.45	7.17	7.73	9.62	7.68	1.36
CaO	10.6	11.1	10.3	10.2	11.3	11.9	11.8	10.7	11.3	10.2	12.1	12.0	10.3
Na_2O	3.23	3.14	2.74	2.32	2.69	2.15	2.17	1.88	2.81	2.44	1.84	2.00	5.22
K_2O	0.16	0.23	0.23	0.18	0.03	0.10	0.10	0.11	0.11	0.22	0.10	0.24	0.10
P_2O_5	0.17	0.18	0.21	0.34	0.14	0.19	0.12	0.15	0.18	0.40	0.19	0.29	0.23
CO_2	0.03	0.10	0.10	0.05	0.08	—	—	—	—	—	—	—	—
S	0.17	0.20	0.20	0.23	0.07	—	—	—	—	—	—	—	—
H_2O	1.4	1.4	1.7	1.4	1.8	—	—	—	—	—	—	—	—
Summe	**99.71**	**99.32**	**99.77**	**99.17**	**100.36**	**98.21**	**97.70**	**98.22**	**97.78**	**98.08**	**97.55**	**98.44**	**98.46**
V	454	408	421	609	396	229	306	1500	215	530	338	580	44
Cr	83	74	164	61	172	238	297	112	220	114	374	104	<20
Ni	46	44	52	21	47	55	66	56	38	28	113	<20	<20
Cu	—	—	—	—	—	85	37	32	62	35	28	11	18
Zn	—	—	—	—	—	3	137	133	111	152	82	149	26
Rb	4	9	19	7	<2	75	<2	8	<2	11	<2	8	<2
Sr	165	175	114	109	125	42	85	68	168	75	103	133	882
Y	46	47	47	65	40	85	31	41	45	59	37	52	13
Zr	112	99	105	215	69	9	68	93	111	124	91	75	10
Nb	8	6	8	11	7	43	7	8	8	8	8	7	6
Ba	185	170	107	186	88	<10	119	204	219	67	41	100	63
Ce	<10	<10	22	23	<10		<10	<10	<10	20	<10	<10	<10

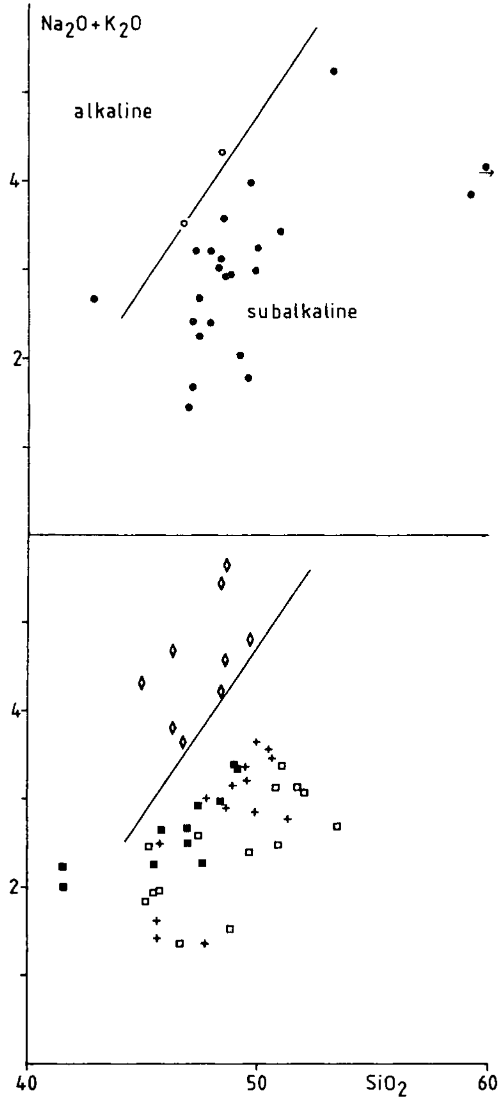
* FeO_{tot}

Amphibolites of the Warzenrieth area

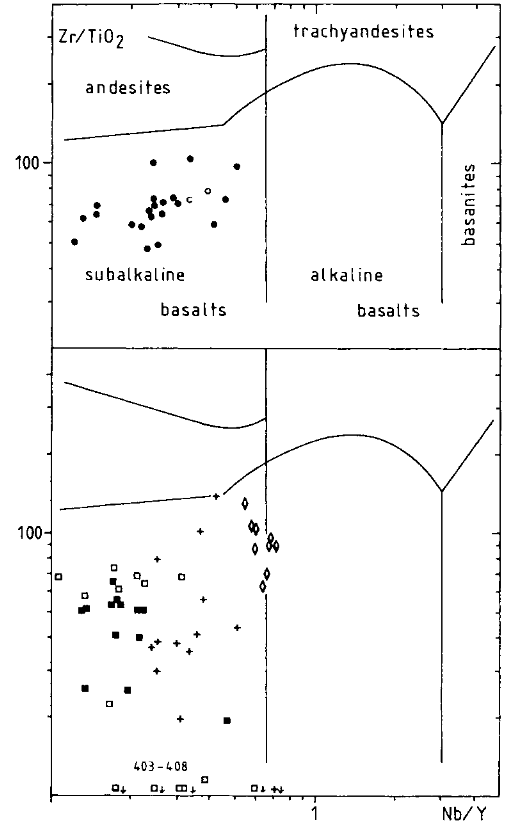
The chemical composition of the fine-grained amphibolites is subalkaline — tholeiitic (Fig. 3, 4), however, with a wide compositional range. Samples 401 and 416 to 419 exhibit a normal MORB-like character (Fig. 7, 8). Compared to the gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex they are slighly enriched in incompatible elements (Fig. 8). The samples 403 to 409 are distinguished by their unusually high Ti/Zr (Fig. 7) and Ti/P ratios. Secondary alteration processes may have affected the chemical composition of these samples.

(Gabbro-) amphibolites of the Blätterberg—Hoher Bogen area

Although these metabasites form a distinct petrographical group, they are geochemically similar to the normal MORB-type amphibolites of the samples 401 and 416 to 419 from the Warzenrieth area. The (gabbro-) amphibolites, too, are slighly enriched in incompatible elements which is at variance to the gabbroic rocks (Fig. 4, 7, 8) of the Neukirchen—Kdyně (meta-) igneous complex.



3. Discrimination between subalkaline and alkaline basalts (Irvine and Baragar 1971). Filled circles — metabasites of the Mariánské Lázně complex and Černá Hora massif; open circles — amphibolites of the Mýto area; rhombs — greenschists and amphibolites of the southeastern part of the Domažlice metamorphic complex; open squares — amphibolites of the Warzenrieth area; filled squares — (gabbro-) amphibolites of the Blätterberg—Hoher Bogen area; crosses — gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex.

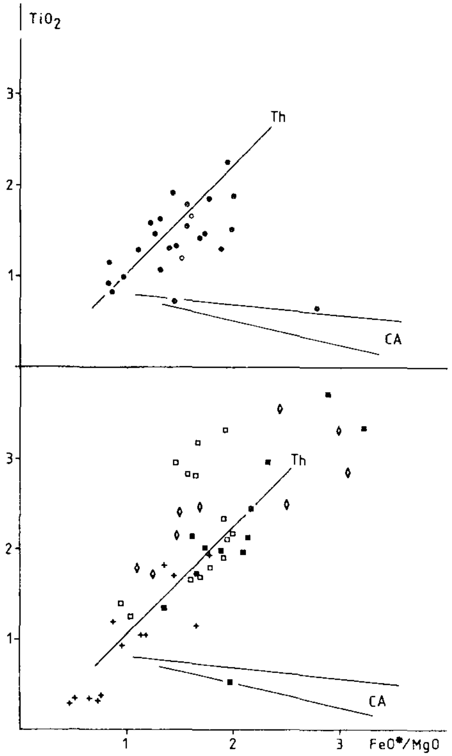


4. Discrimination between subalkaline and alkaline series (Floyd and Winchester 1978). Symbols as in fig. 3.

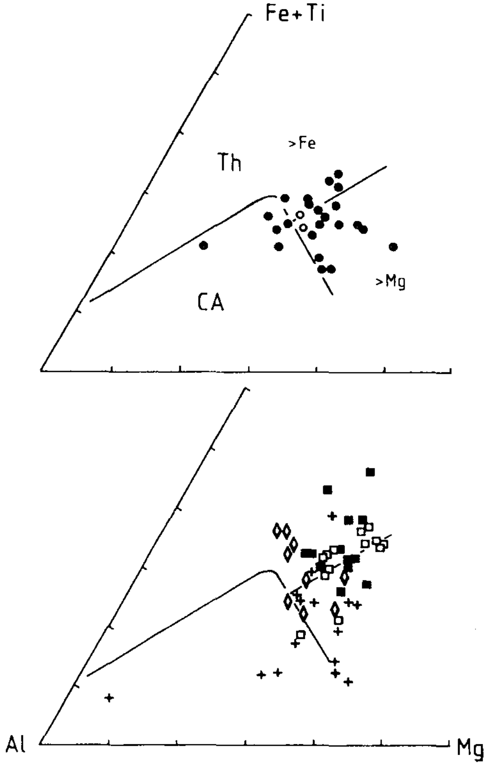
Conclusions

Despite of their variable petrographical character, the metabasites in the northern part of the Teplá—Domažlice Zone, i.e. from the Mariánské Lázně and the Černá Hora complex exhibit a uniform geochemical character which compares well with modern mid-ocean ridge basalts (N-MORB). The same holds true for the amphibolites of the Mýto area which may form the extension of the Tirschenreuth—Mähring Zone (Bavaria), the transition between the Moldanubian and the Saxothuringian realsm. Striking geochemical similarities exist to the schistose, partly striped amphibolites of the Tirschenreuth—Mähring and the Erbendorf—Vohenstrauss Zone (Bavaria).

In contrast, much more complicated relationships were recorded in the southern part of the Teplá—Domažlice Zone. Greenschists and amphibolites in the southeastern part of the Domažlice metamorphic complex exhibit a geochemical character with alkaline-basaltic tendency, conforming to modern within-plate basalts or basalts from anomalous midocean ridge segments (E-MORB). Geochemically these metabasites compare well with the flaseramphibolites of the Erbendorf—Vohenstrauss Zone. Amphibolite bodies of alkaline-basaltic character may also be



5. Tholeiitic (Th) and calcalkaline (CA) trends after Miyashiro (1975). Symbols as in fig. 3.

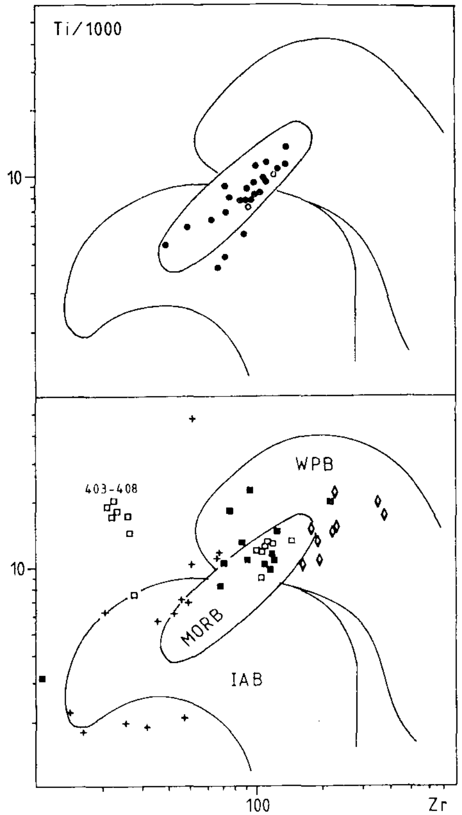


6. Tholeiitic (Th) and calcalkaline series in the Jensen (1976) cation plot. Symbols as in fig. 3.

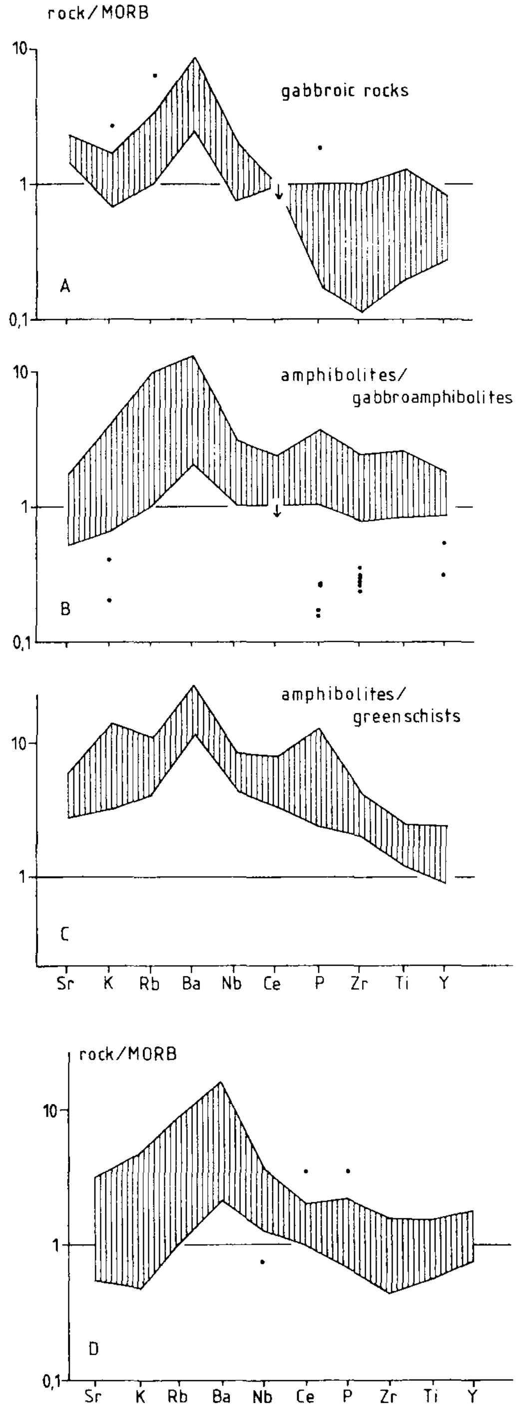
present in the large amphibolite area around Eschlkam (Bavaria) from which no samples have been analyzed so far. On the other hand, the amphibolite 37 of Zadní skála (ČSFR) exhibits a normal MORB character like part of the fine-grained amphibolites in the Warzenrieth area (Bavaria). Consequently, an interfingering of both types may be suspected in the area north of Eschlkam—Warzenrieth. Further investigations on both sides of the political border are necessary.

The gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex were subjected to a metamorphic overprint and show different stages of amphibolitization. In their chemical composition, these rocks are subalkaline—tholeiitic and conform to a magmatic differentiation trend. Similar petrographical and geochemical features were observed in the metagabbros of the Erbendorf—Vohenstrauss Zone (Voll 1960, Schüssler 1987).

The (gabbro-) amphibolites of the Blätterberg—Hoher Bogen area show a normal MORB character similar to the finegrained amphibolites of the Warzenrieth area. Slight geochemical differences to the babbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex can be recognized. This may indicate different gabbroic intrusions in the southern part of the Neukirchen—Kdyně complex.



7. Comparison of the investigated metabasites with modem basalts from different tectonic setting (Pearce 1982). Symbols as in fig. 3.



8. Variation of MORB-normalized trace element contents in the different metabasite types (normalization after Pearce 1982). A — gabbroic rocks of the Neukirchen—Kdyně (meta-) igneous complex; B — amphibolites of the Warzenrieth area and (gabbro-) amphibolites of the Blätterberg—Hoher Bogen area. Samples 403—408 (dots) sometimes differ clearly from the other amphibolites; C — greenschists and amphibolites from the southeastern part of the Domažlice metamorphic complex; D — metabasites from the northern- and central parts of the Teplá—Domažlice zone.

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