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Mafic K- and Mg-Rich Magmatic Rocks from the Western Mühlviertel (Austria) Area and the Adjacent Part of the Šumava Mountains (Czech Republic)

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9 Text-Figures, 1 Table

Österreichische Karte 1:50.000
Blatt 2 Kuschwarda
Blatt 3 Wallern
Blatt 13 Engelhartszell
Blatt 14 Rohrbach in OÖ

Upper Austria
Bohemian Massif
Moldanubian Zone
Granitoid
Durbachite
Dyke
Glimmerite
Granulite

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K- und Mg-reiche mafische Magmatite aus dem westlichen Mühlviertel (Österreich) und dem angrenzenden Teil der Šumava-Berge (Tschechische Republik)

Zusammenfassung

Mafische, K- und Mg-reiche Granitoide mit der Bezeichnung Durbachite (equivalent dem Rastenberg-Granit-Typ in Österreich) sind typische variszische Intrusiva im moldanubischen Block. Ein großer und mehrere kleinere Körper typischer Durbachite (SiO_2 um 60–65 %) finden sich im tschechischen Grenzgebiet nördlich des Vltava-Tales und werden als die „Knížecí Stolec“-Intrusionen bezeichnet. Auf beiden Seiten der österreichisch-tschechischen Grenze wurden bisher unbekannte, extrem mafische Varietäten von Durbachiten gefunden. Die Vorkommen liegen N der Ortschaft Schwarzenberg am Böhmerwald und entsprechen Pyroxen-Phlogopit-Melasyeniten (<50 % SiO_2) und Amphibol-Phlogopit-Melasyeniten (50–55 % SiO_2). Beide Varietäten weisen Phenokristen von K-Feldspat (Kfs, ca. 3x1 cm) in einer Matrix von Oligoklas, Phlogopit (Mg/(Mg+Fe)-ratio [xMg] = 0,58–0,67), und Aktinolith (xMg = 0,67–0,80), seltener auch Diopsid (xMg = 0,74-0,78) auf. Ihre chemische Zusammensetzung entspricht: 47-61 Gew.% SiO_2, 5,5–8,5 Gew.% FeO_{tot}, 4,0–13,7 Gew.% MgO, 2,3–6,7 Gew.% CaO, 1,0-2,0 Gew.% Na_2O und 4,7–7,7 Gew.% K_2O, 200–700 ppm Cr, 70–260 ppm Ni, 300–450 ppm Rb, 280–500 ppm Sr und 250–600 ppm Zr.

Zahlreiche ultramafische Gänge mit einem Gehalt an mafischen Mineralphasen >90 % finden sich im Endo- beziehungsweise im Exo-Kontakt der Prachatice- und Křišťanov- Granulitkörper. Diese Ganggesteine werden hier als „Glimmerite“ bezeichnet und sind mittel- bis feinkörnig. Sie bestehen vor allem aus Phlogopit (xMg = 0,65–0,80) und Aktinolith (xMg = 0,75–0,85). Cummingtonit (xMg = 0,70–0,75) oder Diopsid (xMg = 0,81–0,83) treten nur gelegentlich auf. Stengeliger Apatit und kleine Zirkone sind gängige Akzessorien. Die typische Zusammensetzung der Glimmerite liegt im Bereich von 45–54 Gew.% SiO_2, 8–11 Gew.% Al_2O_3, 0,3–1,3 Gew.% Na_2O, 11–17 Gew.% MgO, 3,3–5,5 Gew.% K_2O, 1,2–2,4 Gew.% P_2O_5, 500–1000 ppm Cr und 200–600 ppm Ni. Sie ist damit reichlich ungewöhnlich und unterscheidet sich von den benachbarten Durbachiten deutlich.

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Abstract

Mafic K-Mg-rich granitoids termed durbachites (the Rastenberg type in Austria) are one of the typical Variscan magmatic rocks of the Moldanubian Zone. One large and several small bodies of typical durbachite (SiO_2 around 60–65 %) appear in the Czech territory to the north of the Vltava valley and are well known (the "Knížecí Stolec" intrusion). Several smaller bodies of extreme basic and mafic varieties of durbachite were newly found on both the Czech and Austrian side of the state border, N of the town of Schwarzenberg am Böhmerwald: pyroxene-phlogopite melasyenite (<50 % SiO_2) and amphibole-phlogopite melasyenite (50–55 % SiO_2). Both varieties contain phenocrysts of K-feldspar (Kfs, about 3x1 cm) in a matrix of oligoclase, phlogopite (xMg = 0.58–0.67), and actinolite (xMg = 0.67–0.80), occasionally also diopside (xMg = 0.74–0.78). Their chemistry is particularly interesting: 47–61 wt % SiO_2, 5.5–8.5 wt % FeO_{tot}, 4.0–13.7 wt % MgO, 2.3–6.7 wt % CaO, 1.0–2.0 wt % Na_2O and 4.7–7.7 wt % K_2O, 200–700 ppm Cr, 70–260 ppm Ni, 300–450 ppm Rb, 280–500 ppm Sr, 250–600 ppm Zr.

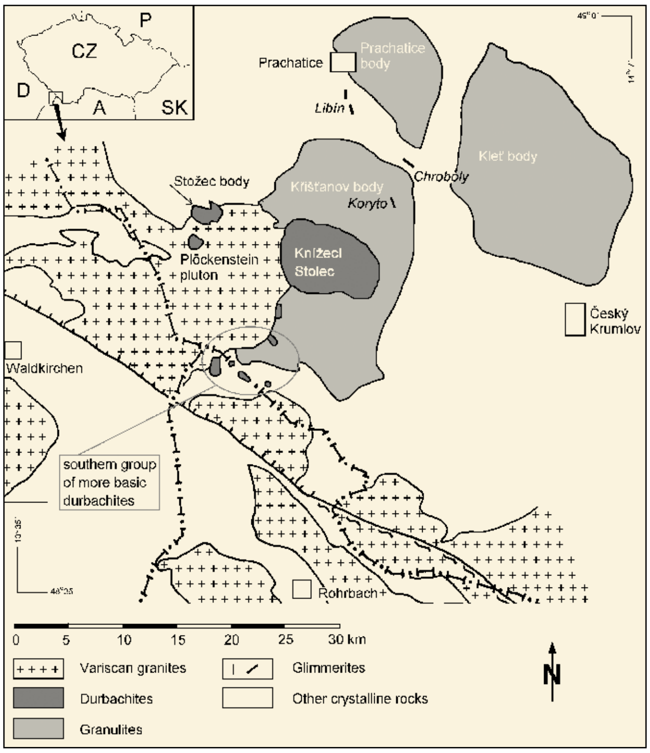
Several ultramafic dykes with a content of mafic minerals >90 % appear in the endo- and exocontact of the Prachatice and Křišťanov granulite bodies. The dyke rocks, termed here as glimmerites, are medium- to fine-grained, composed mainly of phlogopite (xMg = 0.65–0.80) and actinolite (xMg = 0.75–0.85). Cummingtonite (xMg = 0.70–0.75) or diopside (xMg = 0.81–0.83) appear only locally. Long columnar apatite and small grains of zircon are common. The typical chemical composition of 45–54 wt % SiO_2, 8–11 Al_2O_3, 0.3–1.3 wt % Na_2O, 11–17 wt % MgO, 3.3–5.5 wt % K_2O, 1.2–2.4 wt % P_2O_5, 500–1000 ppm Cr, 200–600 ppm Ni is rather unusual and differs from neighbouring durbachites.

Introduction

In the framework of a new geological investigation in the "Dreiländereck"-area of the western Mühlviertel and adjacent southern Bohemia, two distinct types of mafic K- and Mg-rich granitoids were distinguished and defined petrographically, mineralogically and chemically.

Durbachites (the "Rastenberg-type" granitoids) were found for the first time in the northwestern Mühlviertel. A group of small bodies situated between Schwarzenberg am Böhmerwald (Austria) and Nová Pec (Czech Republic) differs from similar rocks situated more to the north (e.g. Knížecí Stolec/Fürstenstuhl pluton) being more magnesian and less silicic.

The mafic, mica-rich dyke rocks from the area between the towns of Prachatice and Volary have been known for a very long time. These rocks have been used in sacral architecture already in the 15th century and the oldest scientific mentions are from the middle of the 19th century (Helmhacker, 1873). But the only modern textural and partially chemical (major element) description has been done by Hejtman (1975). We publish the first whole-rock, trace-element data and chemical composition of rock-forming and accessory minerals.

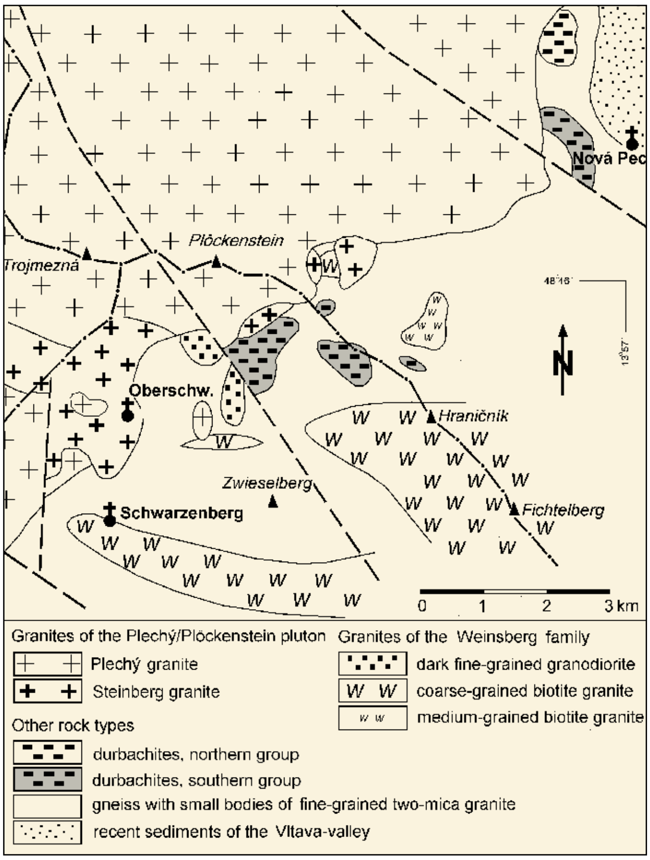


Text-Fig. 1.
Geological sketch map of study area.

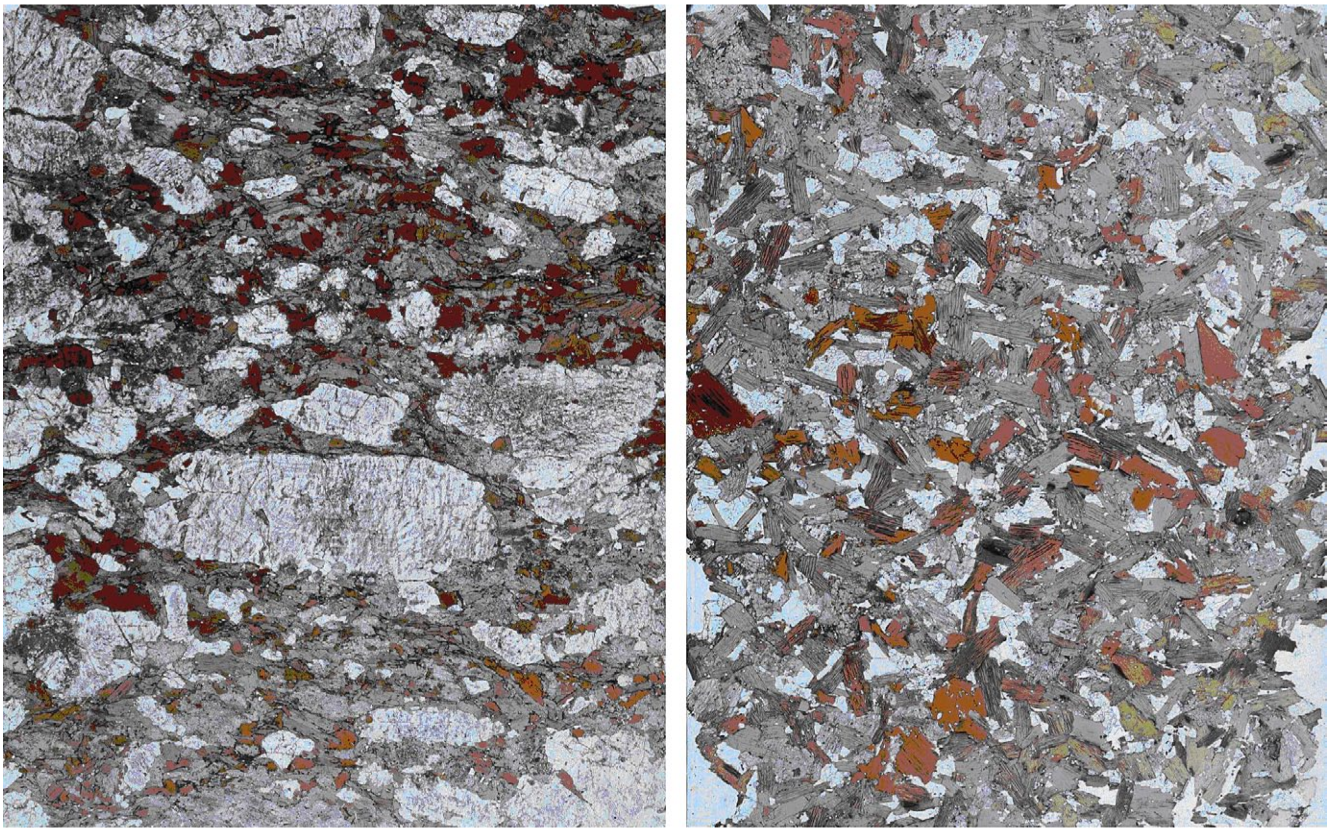
Geology

The studied area is situated in the Austrian and Czech part of the "Dreiländereck" (Trojmezí), approximately between the Vltava (Moldau) valley to the NE and the Mühl fault zone to the SW. Geologically, it is a part of the Moldanubian Zone of the Bohemian Massif, formed by amphibolite-facies metamorphic rocks which were intruded by several types of Variscan granitoids including K- and Mg-rich melasyenites (durbachites), porphyritic biotite granites (Weinsberg-type), fine grained, locally deformed biotite to two-mica granites, and coarse-grained, locally porphyritic two-mica granites of the Plechý/Plöckenstein pluton (Breiter et al., 2007). Further to the north, north of the Vltava valley, the melasyenite (durbachite) pluton of Knížecí Stolec (Fürstenstuhl) and the granulite massifs of Prachatice and Křišťanov crop out (Text-Fig. 1).

Geological maps at different scales exist on the territories of all three states: 1 : 200.000 in Austria (Krenmayr & Schnabel, 2006), 1 : 50.000 in the Czech Republic (Miksa &



Text-Fig. 2.
Detail map of the southern group of durbachite bodies.



Text-Fig. 3.
Textures of studied rocks: Left: durbachite from Brunnau (sample 4342): Large phenocrysts of K-feldspar (light) are slightly aligned. Groundmass is composed of oligoclase, actinolite (both gray), and phlogopite (red-brown). Right: glimmerite from Libín (sample 4343): Crystals and aggregates of actinolite (light) are surrounded with laths of strongly pleochroic phlogopite (dark brown to red-brown). (Transmitted light, area of both images about 2 x 2.5 cm).

Opletal, 1995) and 1:25.000 in Germany (Ott, 1992), but their accuracy namely in the mountainous area along the Austrian-Czech border is still not fully sufficient.

In the frame of small scale mapping and petrological investigation in 2005–2006 we found in the northwesternmost corner of Austria, N of the village of Oberschwarzenberg, several new small bodies of melanocrate amphibole-biotite syenite, some of them crossing the border to the Czech territory (Text-Fig. 2).

The largest body (about 1.0 km^2) is situated in a forested area around the “Adalbert-Stifter-Quelle”. The porphyritic syenite is composed of up to 3 x 1 cm large crystals of K-feldspar and with fine- to medium-grained amphibole-phlogopite-plagioclase matrix (Text-Fig. 3). Other outcrops of similar porphyritic durbachites (about 0.5 km^2) were found in the area of “Brunnau” and around the border-stone No. I/10. Small durbachite bodies (about 100 m diameter) with only small crystals of K-feldspar (less than 5 mm in diameter) were found on the western slope of the hills “Zwieselberg” and “Studniční hora” in Bohemia. All bodies are internally homogeneous. Contacts with wallrocks (gneiss) are not exposed. Xenoliths and enclaves were not found.

Up to now, all known durbachite intrusions, situated on the Bohemian territory near Stožec, Nová Pec and the Knížecí Stolec pluton, are medium-grained and distinctly porphyritic, macroscopically resembling the body from “Adalbert-Stifter-Quelle”. All these bodies were also sampled to estimate the regional heterogeneity of durbachites.

The mica-rich ultramafic rocks form a swarm of mainly NW-SE trending dykes in the western endo- and exocontact of the Prachatice granulite body in the vicinity of the town of Prachatice. Hejtman (1975) localised here about 30 dykes and small bodies, at least 20 of them are crosscutting the granulite.

We revised dyke rocks from 4 well exposed localities, three of them situated in gneiss, SW of the gneiss-granulite contact:

- blocky outcrop NW of the summit of hill Libín, area 20–30 m diameter,
- abandoned quarry SE of the summit of hill Libín, small NW–SE trending dyke,
- abandoned quarry SW of the village of Chroboly, NW–SE trending dyke, 5–7 m thick, max. 200 m long,

In the fourth locality, in an abandoned quarry SE of the village of Koryto, a N–S trending dyke up to 10 m thick and about 200 m long intruded the biotite granulitic gneiss of the Křišťanov granulite body.

All studied dyke rocks are homogeneous, equigranular, fine- to medium-grained. Coarse-grained up to pegmatitic domains (tens of cm diameter) are only slightly enriched in plagioclase and were found scarcely. The rocks are composed of phlogopite (up to 70 vol.%), actinolite (20–40 vol.%), plagioclase (normally about 2 vol.%, enriched only in pegmatitic domains <10 vol.%) and apatite. Quartz and/or cummingtonite (less than 5 vol.%) appear only locally. Zircon is the most common accessory.

Based on the fact that these phlogopite rich ultramafic dyke rocks are unusual in the international rock classification and do not fit with normal ultramafic rocks like hornblendites or with lamprophyric rocks (mafic to ultramafic) we therefore use the old term “glimmerite” for all phlogopite-rich ultramafic dykes (Le Maitre, 2002).

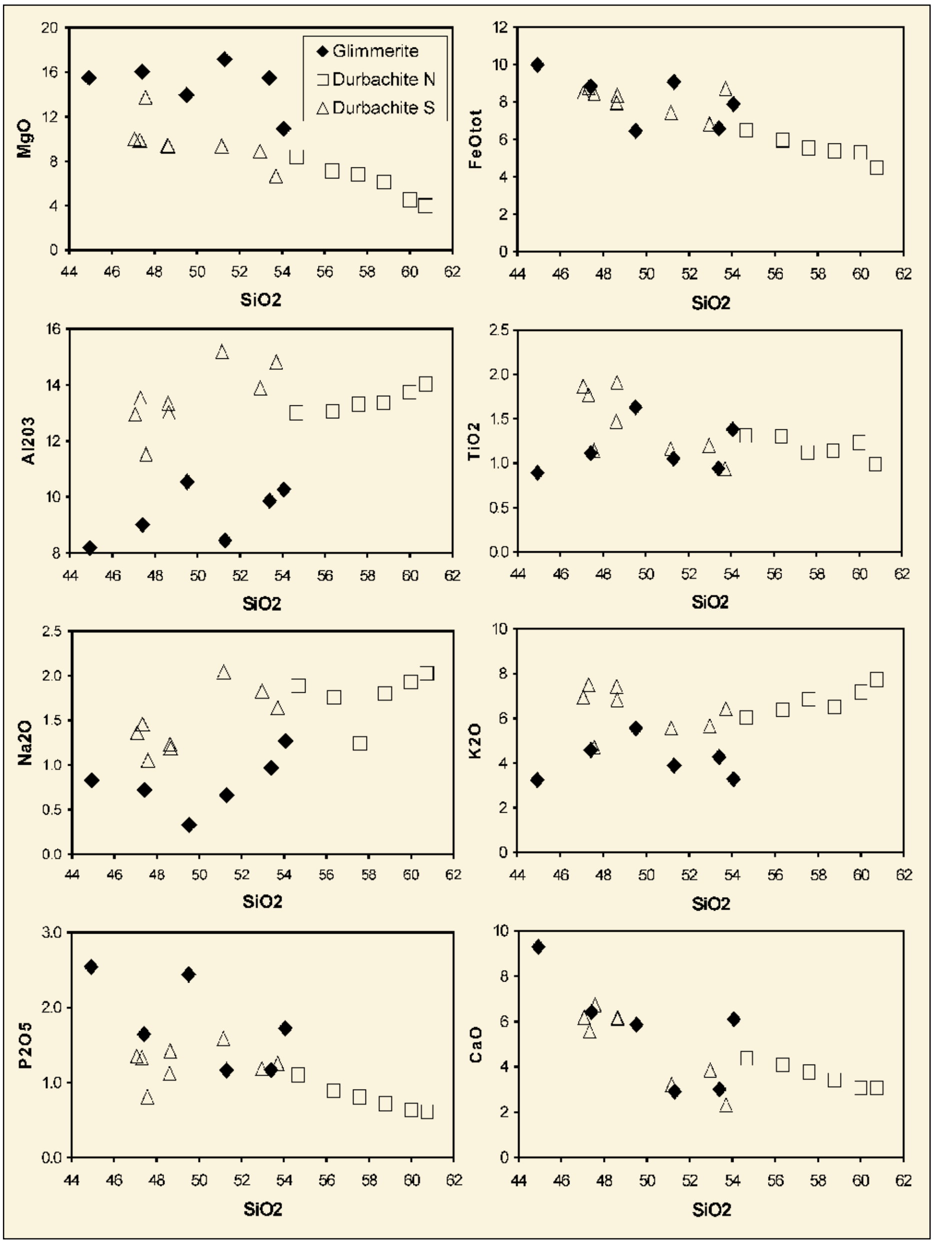
Whole-Rock Chemical Composition

Both durbachites and glimmerites group to specific classes of magnesium- and potassium-rich mafic magmatic rocks.

Despite overall chemical and mineralogical similarities of durbachitic rocks through the Variscan Europe, heterogeneity of studied rocks from a relatively small area is conspicuous. Contents of SiO_2 variegated from 47 to 61 wt % and allow dividing studied durbachites into two groups (Table 1, Text-Fig. 4). The more acid group of samples (54–61 wt % SiO_2) comprises the known bodies in the northern part of the area around the village of Stožec and the Knížecí Stolec (Fürstenstuhl) pluton. On the contrary, all the newly found small durbachite bodies near the Austrian-Czech border are remarkably silica-poorer with only 47–54 wt % SiO_2. Appropriate magnesium contents variegated among 4–8 wt % and 8–10 wt % MgO respectively. Contents of potassium are similar in both durbachite groups: mostly between 6–8 wt % K_2O. The K- and Mg-contents are well correlated negatively in the more acid durbachites (decrease of amphibole coupled with increase of Kfs), but no correlation appears in the more mafic group which is poor in Kfs, where the larger part of potassium is bound in phlogopite.

With increasing acidity, contents of Ca decreased from 7 to 2 wt % CaO and simultaneously Na increased from 1 to about 2 wt % Na_2O. This is recorded by an increase of the Ab-component in plagioclase and simultaneous decrease of content of Ca-bearing amphibole.

Content of iron decreased from 9 to 4 wt % FeO, titanium from 2 to 1 wt % TiO_2, phosphorus from 1.5 to 0.5 wt % P_2O_5, Ni decreased from 200 to 50 ppm, Cr from 600 to 200 ppm. On the other hand, Zr increased from 200 to 500 ppm. Contents of Al, Sr and Ba (up to 2000 ppm) variegated without any distinct trend. Rubidium variegated only slightly between 300 and 350 ppm without correlation to potassium (Text-Fig. 5). Thus, the K-most enriched samples show the highest K/Rb-ratio. Studied durbachites are relatively poor in radioactive elements containing 5–10 (up to 15) ppm U and 5–30 (up to 45) ppm Th.



Text-Fig. 4.
Harker diagram of studied rocks: Glimmerites and the northern and the southern groups of durbachites.

Glimmerites contain 45–54 wt % SiO_2, which is similar to the more mafic group of durbachites, but their contents of Mg are substantially higher, mostly between 12–18 wt % MgO. In comparison with mafic durbachites, glimmerites are enriched in P, Co, Cr, Ni and V, and depleted in Al (8–11 wt % Al_2O_3), K (3–6 wt % K_2O), Na (less than 1 wt % Na_2O), Ti, Rb, Sr and Zr. Contents of Fe, Ca, Ba, REE, U and Th are in both rock groups similar.

Mineralogy

Potassium feldspar

Large crystals of Kfs (usually 2x0.5 cm, occasionally up to 4x1 cm) are typical for all durbachites. The Kfs is enriched in Ba in the range of 0.8–1.0 wt % of BaO, but some irregular domains may reach up to more than 10 wt % BaO (0.2 apfu Ba). Content of Na is generally lower than 1 wt % Na_2O (0.1 apfu Na) and content of phosphorus is usually under the detection limit of the microprobe.

In the mafic dyke rocks K-feldspar is usually completely absent, while all accessible potassium was embedded into the phlogopite.

	Glimmerite			Durbachite southern variety			Durbachite northern variety	
Locality	Libín	Chroboly	Nebahovy	Zwieselberg	Adalbert-Stifterquelle	Border stone “1/10“	Stožeček	Stožec
Geo.Coord. North	48°58´48´´	48°56´31´´	49°00´45´´	48°45´13´´	48°45´29´´	48°45´46´´	48°52´30´´	48°50´57´´
Geo.Coord. East	14°00´36´´	14°03´05´´	14°03´09´´	13°52´05´´	13°51´41´´	13°52´57´´	13°51´09´´	13°50´18´´
Sample No.	4343	4340	4339	4274	4143	4142	3986	3893
SiO2	49.52	51.30	54.07	47.32	48.62	53.71	54.67	60.00
TiO2	1.63	1.05	1.38	1.77	1.47	0.94	1.31	1.23
Al2O3	10.53	8.44	10.26	13.53	13.34	14.82	12.99	13.74
Fe2O3	1.08	0.71	0.74	1.52	1.11	1.50	1.34	1.28
FeO	5.48	8.43	7.22	7.40	6.96	7.36	5.27	4.15
FeOtot	6.45	9.07	7.89	8.77	7.96	8.71	6.48	5.30
MgO	13.96	17.13	10.93	9.88	9.44	6.64	8.40	4.53
MnO	0.10	0.14	0.12	0.15	0.14	0.09	0.11	0.10
CaO	5.86	2.91	6.10	5.58	6.14	2.33	4.37	3.07
Li2O	0.00	0.01	0.01	0.01	0.01	0.05	0.01	0.02
Na2O	0.33	0.66	1.27	1.46	1.23	1.64	1.89	1.93
K2O	5.55	3.89	3.28	7.50	7.43	6.42	6.04	7.17
P2O5	2.44	1.16	1.72	1.33	1.12	1.26	1.10	0.63
F	0.40	0.24	0.27	0.32	0.32	0.72	0.25	0.29
LOI	2.69	3.47	2.25	2.05	2.16	2.16	2.07	
H2O-	0.16	0.12	0.14	0.16	0.14	0.26	0.23	0.12
TOTAL	99.72	99.66	99.77	99.97	99.63	100.01	100.06	99.79
ASI	0.61	0.80	0.61	0.65	0.63	1.07	0.74	0.83
Mg/(Mg+Fe)	0.79	0.77	0.71	0.67	0.68	0.58	0.70	0.60
Cr	775	974	461	505	513	344	500	221
Ni	323	558	184	127	146	75	122	68
Cu	30	73	32	37	36	9	23	23
Zn	95	113	93	123	114	191	97	95
Ba	2026	1220	1574	2272	2515	532	1647	
Be	2	3	2	4	2	2	5	
Co	41	66	45	35	39	17	25	
Cs	29	19	11	15	15	39	28	
Ga	17	14	19	25	23	33	24	
Hf	5	7	7	20	19	10	15	
Nb	29	15	13	37	34	46	34	29
Rb	325	237	270	376	365	516	420	348
Sn	9	3	2	1	1	4	7	
Sr	180	171	204	502	540	130	354	
Ta	2	1	1	2	2	3	2	
Th	14	18	3	10	11	6	19	43
U	13	9	7	10	9	11	15	12
V	187	185	159	186	168	117	136	
W	5	3	4	1	1	2	1	
Zr	169	247	293	674	603	308	540	600
Y	44	29	48	40	36	85	40	30
La	53.9	33.9	33.9	65.3	58.3	25.7	49.5	
Ce	133	82	92	155	147	69	129	
Pr	18.4	11.3	13.6	21.2	18.9	9.3	17.0	
Nd	85.4	51.8	63.6	94.7	96.1	45.8	79.6	
Sm	20.0	13.4	17.6	21.6	19.6	12.0	17.7	
Eu	2.39	1.60	1.50	3.02	3.37	0.97	2.21	
Gd	12.9	8.6	12.3	12.7	10.9	11.1	10.4	
Tb	1.66	1.01	1.84	1.56	1.56	2.58	1.44	
Dy	9.1	5.6	9.1	7.5	6.8	14.2	7.1	
Ho	1.41	0.91	1.53	1.24	1.20	2.62	1.28	
Er	3.72	2.52	4.16	3.39	3.06	6.81	4.05	
Tm	0.52	0.39	0.61	0.50	0.43	0.84	0.67	
Yb	3.06	2.26	3.45	3.26	2.67	4.74	3.54	
Lu	0.37	0.30	0.49	0.42	0.40	0.65	0.52	

Table 1.
Whole-rock composition of typical samples. Major elements analysed by wet chemistry (in wt %, Czech Geological Survey Praha), Cr, Ni, Cu, and Zn by XRF (in ppm, Czech Geological Survey Praha), other trace elements by ICP-MS (in ppm, ACME Vancouver).

Plagioclase

Subhedral plagioclase of An30–50 (andesine) is an important component of the matrix in all durbachite samples (about 10 vol.% of the rock). Content of K is low – about 0.1 wt % K_2O in the southern and about 0.5 wt % K_2O in the northern durbachite group. Contents of Ba and P are negligible.

In glimmerites, anhedral plagioclase grains are highly unevenly distributed (about 2 vol.%, in pegmatoid nests up to 10 vol.%). Besides older zoned grains with An20–50, also late albite was found.

Phlogopite

Phlogopite is the most abundant mineral in both described rocks. It forms individualised subhedral flakes several mm in diameter, light do dark brown in crossed polars. It is younger than associated amphibole.

Phlogopite from durbachites is relatively rich in iron (xMg about 0.58–0.67), while the one from dyke rocks is iron-poor (xMg about 0.70–0.85, Text-Fig. 6). It is generally fluorine-poor (about 1 wt % F in durbachites, less than 0.5 wt % F in glimmerites).

Manganese is more enriched in mica from durbachites (about 0.2 wt % MnO), while Ba and Na are more enriched in phlogopite from glimmerites (0.2–0.5 wt % BaO and 0.2–0.4 wt % Na_2O).

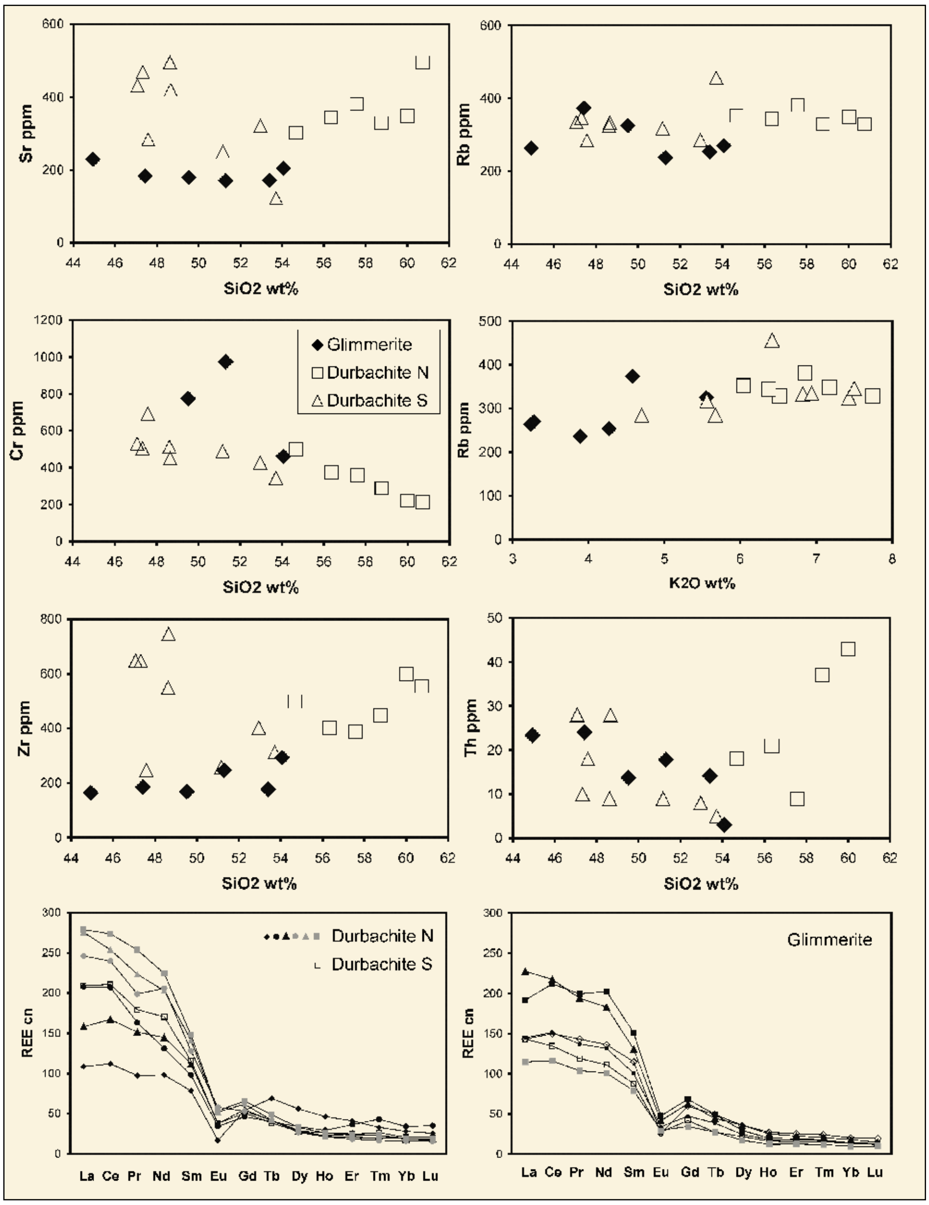
Content of titanium is stable within the range of 2–3 wt % TiO_2 in all samples. Among trace element, Li and Zn reached 100–300 ppm respectively 140–240 ppm in glimmerite and 200–900 ppm respectively 220–430 ppm in durbachite. Rb reached 500–900 ppm, Cs 30–80 ppm, V 250–350 ppm, Be 1–2 ppm and Sr less than 10 ppm in both rocks types (Text-Fig. 7).

Actinolite (sensu Leake et al., 2003)

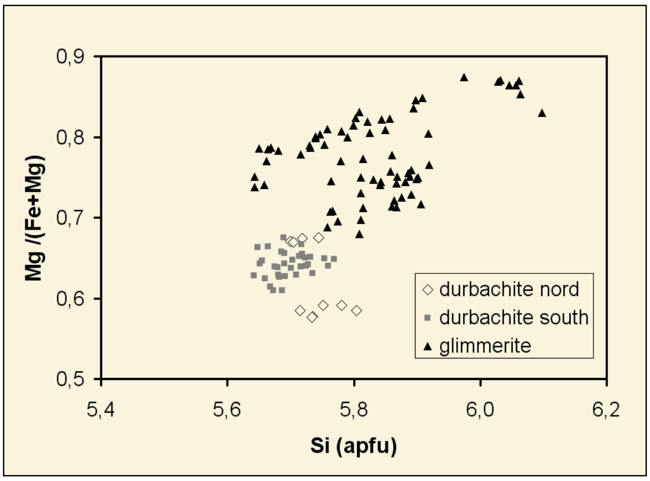
Ca-bearing amphibole is an abundant mineral in all studied rocks (Text-Fig. 8). It forms mostly subhedral columnar grains, light green in transmitted light. It is the oldest among all major minerals. According to the chemical composition (7.3–8.0 apfu Si, xMg 0.7–0.9), it should be termed as actinolite. Only negligible amounts of grains come up to magnesiohornblende (Text-Fig. 9). The xMg increases from actinolite in the northern group of durbachites (0.65–0.75), through the southern group of durbachites (0.75–0.80) to glimmerites (0.75–0.90), like in phlogopite. Contents of Al, Ti and K are low and independent of rock type (0.2–0.6 apfu Al, 0.01–0.04 apfu Ti, 0.01–0.05 apfu K). Na is slightly enriched in actinolite from glimmerites (0.10–0.25 apfu) when compared with those from durbachites (<0.10 apfu).

Cummingtonite

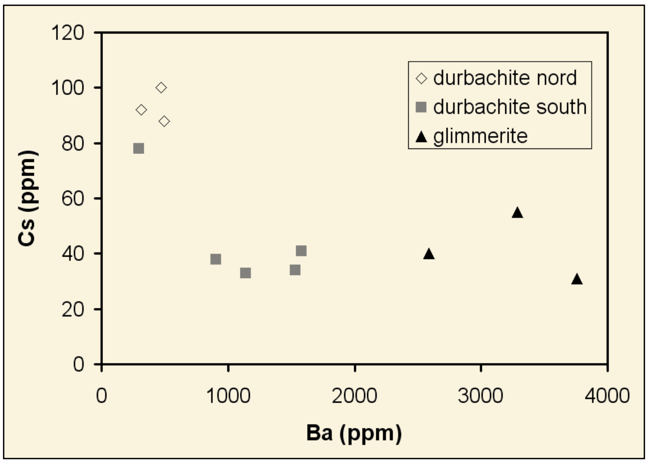
The Ca-poor amphibole cummingtonite was found only in some glimmerite samples. It forms individual anhedral to euhedral grains (up to 0.5 mm in diameter) and inclusions in actinolite (up to 50 µm). Vice versa, larger cummingtonite grains contain inclusions of actinolite up to 500x200 µm (Text-Fig. 8). Texturally, cummingtonite seems to be a primary magmatic mineral in equilibrium with actinolite (Text-Fig. 8). It is rich in Si (>7.95 apfu) and poor in Al (<0.1 apfu) and Ca (<0.2 apfu). Relative enrichment of Mg is the lowest of all associated Mg and Fe-bearing minerals (xMg mostly 0.70–0.75).



Text-Fig. 5.
Distribution of some trace elements in studied rocks (glimmerite and from both subtypes of durbachite).



Text-Fig. 6.
Chemical composition of phlogopite in atoms per formula unit (EMPA – electron microprobe analyser).



Text-Fig. 7.
Contents of Ba and Cs discriminate phlogopite from glimmerite and from both subtypes of durbachite (Chemical analysis of monomineralic phlogopite concentrate, analysed with AAS in the laboratory of CGS Praha).

Diopside

Clinopyroxene appears in small amounts in some samples from the southern durbachite group, in glimmerites only as exceptional individual grains. It is chemically homogeneous with only a very small chemical variation. Content of calcium reached 0.87–0.95 apfu, the xMg is among 74–78 in durbachite and 81–83 in glimmerite. Contents of alumina and sodium are low (0.01–0.03 apfu Al, 0.01–0.02 apfu Na).

Apatite

Apatite is a common mineral in both types of the studied rock. Its content is well negatively correlated with the SiO_2-content in the rock: 1.5–2 vol.% in the northern group of durbachites, 2–3 vol % in the southern group of durbachites and 3–5 vol. % in glimmerites. Apatite forms short prismatic to needle-like crystals, often embedded in mica or amphibole. Apatite is chemically homogeneous, poor in iron and manganese (max. 0.2 wt % FeO and 0.05 wt % MnO). Cerium reached 0.2 wt % Ce_2O_3, while contents of Na, Y, U and Th are negligible. The content of fluorine variegated between 2.2–2.8 wt % (0.6–0.7 apfu) and the content of chlorine is below the detection limit of the microprobe. Thus, the fluorapatite-component only slightly exceeded the hydroxyl-apatite-component.

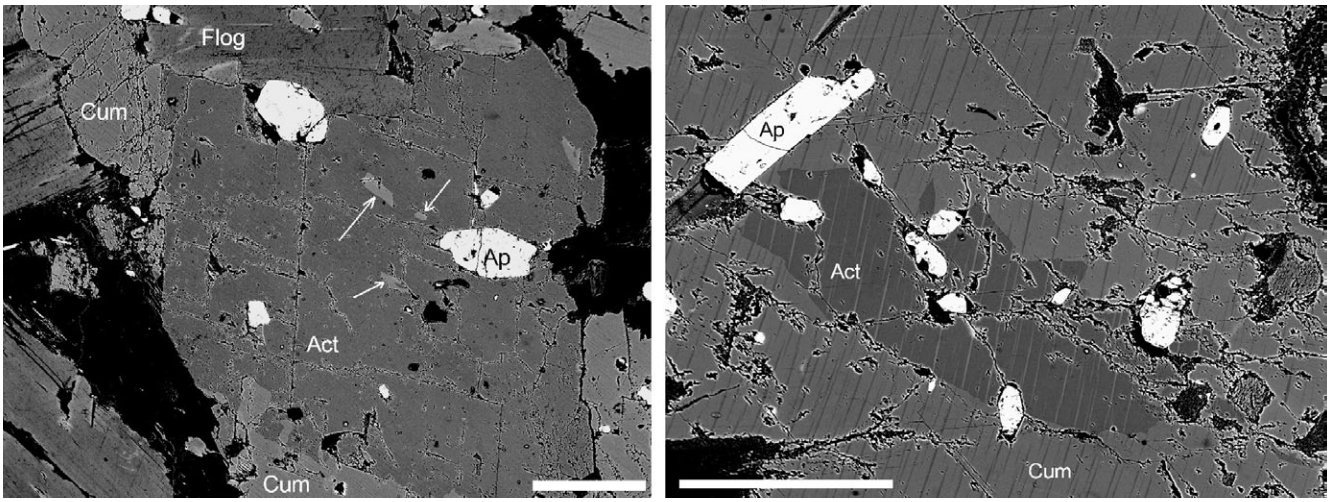
Zircon

Zircon forms in both rock types small, prismatic homogeneous crystals without any type of zonation. Zircon from both rocks is chemically poor and primitive in respect to fractionation. Contents of U and Th are usually less than 0.5 wt % UO_2 and ThO_2, the content of the xenotime component is negligible with maximally 0.005 apfu. The content of HfO_2 reaches in durbachites about 1.5 wt %, in glimmerites about 1.1 wt %, which corresponds to the atomic Zr/Hf-ratio 65–85 and 90–100 respectively.

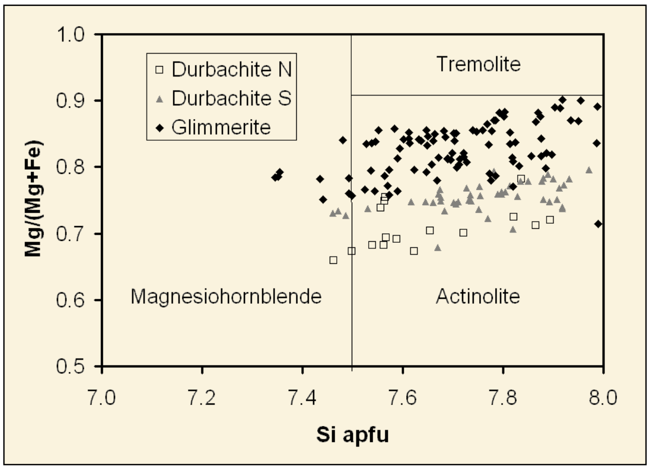
Discussion

Correct Terminology of Mafic Feldspar-Poor Rocks

According to internationally accepted rules of terminology of magmatic rocks, all rocks containing more than 10 vol. % of quartz+feldspars, should be termed according



Text-Fig. 8.
Microphotographs (BSE – backscatter electron) of co-existing amphiboles. Left: cummingtonite inclusions in actinolite (depicted by arrows). Right: actinolite inclusion in cummingtonite. Note nearly identical orientation of the exsolution lamellas. Flog – phlogopite, Ap – apatite, Act – actinolite, Cum – cummingtonite. Scale bars 200 µm.



Text-Fig. 9.
Chemical composition of Ca-bearing amphiboles from both subtypes of durbachite and from glimmerite. Classification fields according to LEAKE (2003).

to their quartz/alkalifeldspar/plagioclase ratio (LE MAITRE, 2002). Rocks with less than 10 vol.% of quartz+feldspars should be termed according to the major mafic mineral. All the described mafic dyke rocks contain mica (phlogopite) as the major rock-forming mineral. Among light minerals, the relatively most common is plagioclase, quartz is usually present in accessory amount, and Kfs completely absent in the majority of samples. Light minerals are unevenly distributed and their total amount in studied samples should be estimated to only 5–10 vol.%, though in some rock portions maybe somewhat higher. HEJTMAN (1975) published 29 modal analyses of dyke rocks. According to international terminology, 11 samples among them termed as biotitite, 8 samples as quartz diorite, 6 samples as syenite, 1 sample as gabbro, 1 sample as hornblendite and 2 samples as granite.

In our opinion, all investigated rocks form from chemical, mineralogical and genetic points of view one group and therefore puristic use of different names for rocks differing only in 1–2 vol.% of quartz and/or plagioclase is confusing. Thus, we use the name glimmerite for all studied mafic dyke rocks from the Prachatice area.

Two Co-Existing Amphiboles

Descriptions of rocks with two coexisting amphiboles are rare. MARTIN (2007) in his comprehensive work mentioned only one case of a published occurrence of an actinolite-cummingtonite pair: from quartz diorite, Koyama pluton, Japan (YAMAGUCHI 1985).

In our studied sample from Chroboly (Text-Fig. 5), both amphiboles seem to be primary magmatic phases crystallised in or near equilibrium. Both amphiboles contain admixed lamellae of the same crystallographic orientation: cummingtonite contains lamellae of actinolite, and actinolite contains lamellae of cummingtonite. This may represent a late low-temperature tendency of both minerals to come close to an ideal chemical composition.

Relation Between “Common” Durbachites, “Basic” Durbachites and Glimmerites

“Common” porphyritic durbachites with 55–60 wt % SiO_2 and 4–9 wt % MgO form several moderately large (50–500 km^2) plutons through the whole Moldanubian Zone: Třebíč pluton in Moravia, Čertovo Břemeno massif in the frame of the Central Bohemian pluton, Knížecí Stolec pluton in southern Bohemia, Rastenberg pluton in Austria, and several smaller bodies. More basic (<55 wt % SiO_2) and more magnesium-rich (>10 wt % MgO) varieties occur mostly as fine-grained non-porphyritic enclaves or dyke rocks cutting the common facies. The “Dreiländereck” area is the first area, where the chemically more basic variety of durbachite forms medium-grained distinctly porphyritic rocks, macroscopically only hardly distinguishable from the classic, more acid durbachites. In addition, in the studied area, bodies of both durbachite types are geographically clearly segregated. The “common” durbachites form one large pluton (Knížecí Stolec) and several small bodies (500 m diameter) in its SW vicinity between the villages of Nová Pec and Stožec on the northern slope of the Šumava/Böhmerwald mountain-ridge. The “basic” durbachites form an independent group of small bodies (max. 500 m diameter) on the southern slope of the Šumava/Böhmerwald Mts.

Spatial segregation of both chemical types of durbachites into the northern (“common”) and southern (“basic”) durbachite group implies their origin from different sources.

Comparing the chemical evolutionary trends of major and trace elements in both types of durbachites with that of glimmerite, some similarity between the basic durbachites and the glimmerites is visible. Nevertheless, with the same SiO_2-content, durbachites are richer in crustal elements (K, Na, Al, Rb, and Sr). At the same time, glimmerites are richer in Mg, P, Co, Cr, Ni, and V. Glimmerites do not represent the extreme basic durbachite variety, nor the hypothetic “basic” component of a magma mixing process (sensu HOLUB, 1997) producing “common” durbachites.

Glimmerites should be discussed as an independent magma type coming from an extremely depleted mantle source, or undergoing very unusual fractionation producing strong enrichment in Mg, P, Co, Cr, Ni, V etc. and depletion in Si, Al, and alkalies. Spatial associations of glimmerites with formerly deep seated and after this extremely rapid exhumed granulite bodies may indicate fractionation from a deep crustal source in conditions of strong decompression (VRÁNA, 1992; KOTKOVÁ, 2007).

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